THE COMPARATIVE PALAEOPATHOLOGY OF MALES AND FEMALES IN ENGLISH MEDIEVAL SKELETAL SAMPLES IN ITS SOCIAL CONTEXT

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Abstract

The aim of this study was to determine whether there is evidence to suggest that males and females in medieval England experienced differences in health and mortality, which could be objectively demonstrated from their skeletal remains. Palaeodemographic and palaeopathological data pertaining to a total sample of 1,056 adult males and 674 adult females were compared statistically. The material was derived from seven cemeteries, spanning the period from *c.*1066-1540. A method for sexing subadults using tooth measurements was also developed. This enabled the comparative analysis to be extended to include a further 83 (47 'male', 36 'female') individuals aged between *c.*5-18 years.

Sex differences in mortality, general health status, activity related pathology and dental disease were identified. However, the differences were often subtle, with age and site differences tending to transcend disparities between the sexes, perhaps suggesting that factors other than sex had a greater bearing on health and mortality. Females displayed an inclination toward an earlier age at death, but no statistical association between sex and age at death was demonstrated. The collective analysis of four stress indicators (stature, enamel hypoplasia, cribra orbitalia and non-specific infection) suggested that males were inclined to experience a poorer level of general health. This was primarily interpreted as evidence to support the theory that males have a greater biological sensitivity to environmental stress. Males displayed a higher prevalence of fractures, particularly those caused through violence; a greater prevalence of Schmorl's nodes; and a tendency toward a higher prevalence of osteoarthritis in the appendicular skeleton. Sex differences in the anatomical distribution of fractures and joint disease were also detected. Females displayed a proclivity towards poorer dental health. Interpretations for the observed patterns are discussed, and the limitations of the method are evaluated.

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The Comparative Palaeopathology of Males and Females in English Medieval Skeletal Samples in its Social Context

1. Introduction

Studies of skeletal assemblages often assume that differences in health and mortality exist between males and females. However, these potential differences have yet to be explored systematically, and the possible reasons for them examined (Grauer 1991; Roberts and Manchester 1995:80, 200-201; Roberts *et al.* 1998). The purpose of this investigation was to compare the demography, and the pattern and prevalence of pathology in males and females from a series of English medieval cemeteries, and to consider the possible interpretations for any sex differences or similarities identified. The chief methodological approach entailed the statistical analysis of existing skeletal data. Medical, historical and archaeological evidence was used to assist the process of interpretation. A further objective was to develop a method of subadult sex determination using tooth measurements (Duncan 1998), so that the comparative analysis could be extended to include material aged under *c.*18 years. Previous observations relating to this topic have so far been confined to adult skeletons due to difficulties in sexing immature remains, thereby precluding a significant demographic cohort from investigation.

The project concentrated on the English Middle Ages (*c.*AD 1066-1540) because the period has clearly recognisable archaeological boundaries, defined by the Norman Conquest and the Reformation, and the social context is relatively accessible for the purposes of interpretation. There is also a substantial archive of well-documented skeletal assemblages dating to the period (Anderson 1994). The statistical exploration of existing cemetery data was adopted as the primary method of analysis in order to provide a systematic, rigorous and objective comparative study (Cohen and Holliday 1982:3-7; Waldron 1994). A biocultural approach was required for the process of interpretation because health and mortality may be influenced by both sex and gender (Grauer *et al.* 1998; Roberts and Manchester 1995:4,196-197). To clarify, 'sex' is defined here as the biological difference between males and females, whereas 'gender' is defined as the cultural construct of sex. Only sex can be identified in skeletal remains, but the skeleton may react to a variety of environmental factors, including those which are gender-specific, and so skeletal material may provide a window through which aspects of gender may be inferred (Larsen 1998).

Historical research points toward a medieval gender system in which women were generally subordinate to men, in both the public and private spheres, and some of its chief manifestations can be summarised as follows (Bennett 1987; 1988; Bloch 1991; Goldberg 1986; 1990; 1992; 1997; Hadley 1999; Hanawalt 1977; 1986; Kowaleski 1986; Lees 1994; Shahar 1983):

Women were barred from holding all public office, whether in municipal government or manorial court, and this severely restricted their political power. Unlike men, women tended to be defined by their marital status, which dictated their civil rights and their working lives. Married women were considered secondary to their husbands, in what was largely a household economy. Their pattern of work was orientated to accommodate the demands of the family and this limited their occupational horizons. Women commonly undertook waged labour in addition to unpaid work within the home, the family business, or on the land. However, they were largely employed in work which was perceived to be low status and low skilled (though it could be argued that there is an element of circular argument in this perception), such as petty trade, piece-work crafts and the service industries; and their wage rates were lower than those of men, even when undertaking comparable tasks. Women were also financially disadvantaged by customs of inheritance, and were largely denied access to education. By contrast, men not only controlled political and economic affairs, their working lives were more continuous because they were less likely to be interrupted by marriage and family. This opened a wider range of opportunities to them. They were more likely to benefit from apprenticeships, and enjoyed scope for advancement through trade guild membership; institutions which granted only limited entry to women and sometimes acted to restrict their employment. Men had greater access to professions that were considered prestigious, and were more able to engage in occupations that required capital as they were able to accumulate and control a greater proportion of financial wealth.

Women's subordination in the secular world was supported by a misogynistic religious culture (Dalarun 1992; Fiero *et al.*1989:58-73; Morgan 1985:7-8; Shahar 1983:22-28). The medieval Church justified its belief that woman was morally, physiologically and intellectually inferior to man largely on the basis of her secondary place in the story of Creation and her role in Original Sin (Gen.3:1-24). Adam was created in God's own image whereas Eve was merely formed from Adam's rib. Through her seduction of Adam, Eve was responsible for the fall of humankind from God's grace, and so woman's subjugation to man was deserved as the fruit of her carnal sin. Women were forbidden to officiate in Church, and the qualities of subservience, reticence and chastity were encouraged. Viewed as the redeemer of Eve, the Virgin Mary was exalted as the model of female perfection, yet the dual status of virgin and mother was unattainable for earthly women.

From this overview, it might be surmised that women's subordination would have served to the detriment of their health. This is often the case in modern societies which practice such inequality according to gender, a situation that also tends to be synonymous with inferior nutrition, a lack of access to medical treatment, poverty and relentless labour (Johansson 1984; Leatherman 1998; Manchester 1983:9; Ortner 1998; Stinson 1985). Though not always stated explicitly, this agenda tends to permeate the interpretation of skeletal data (Grauer 1991; Manchester 1983:9; Mays 1998:42; Molleson 1989; 1993:181).

However, there is also historical evidence to suggest that the apparent oppression of women may not have been so extreme in reality (Goldberg 1986; 1990; 1992; 1997; Hadley 1999; Hanawalt 1977; 1986; Lees 1994; Shahar 1983). Despite their lack of public rights, women did gain power and status by force of personality. Unmarried women, and widows in particular, were able to exercise a considerable degree of autonomy. They acted as heads of household, controlled their own financial affairs and traded independently. Women played a vital role in the rural and urban economy, participating in a broad range of occupations. In the countryside, they laboured in the fields, particularly during planting and harvesting, and were often responsible for tending to the animals. Women learned crafts in family workshops, specialised in certain trades, trained apprentices and occasionally organised their own guilds. Their lower wage rates may even have worked to their advantage, particularly during times of recession when employers preferred to hire women for this reason. When labour was scarce, such as in the post-plague period, women may even have been able to command pay rates that were equal to those of men. Similarly, the elevated status of men was probably not universal in practice. Status was strongly associated with social class. The lower classes were most disadvantaged, especially those tied under a feudal regime, although it could be argued that lower class women were even more greatly oppressed than their male counterparts. Nevertheless, many men would have encountered social and economic hardship, and like women, most received no formal education. There was often no strict sexual division of labour, with both sexes participating in a variety of toil for the common good. Coroner's evidence also suggests that men tended to undertake heavier and more dangerous tasks, which exposed them to a greater risk of injury (Hanawalt 1977; 1986). This alternative portrayal of medieval life echoes the controversial position taken by Power, that 'medieval society was neither one of superiority nor inferiority, but one of rough and ready equality' (Power 1928, in Bennett 1988:270).

These cultural generalisations should also be seen in the context of a basic biological framework, as variations in male and female physiology may have a different impact on health status. For example, in the absence of modern medicine, the process of childbearing can pose a significant threat to female morbidity and mortality (Biller 1986; Ortner 1998; Rawcliffe 1995:194-215). Conversely, there is a fairly pervasive hypothesis that males have an inherently lower resistance to environmental stress (Armelagos 1998; Goodman *et al.* 1984; Huss-Ashmore *et al.* 1982; Johanssen 1984; Mays 1998:157; Ortner 1998; Stini 1985; Stinson 1985). It is thought that females are endowed with a superior immune reactivity, which may have evolved as a mechanism to support pregnancy and initiate the offspring's immunological capacity.

It should be emphasised that the aim of this project was not an attempt to use skeletal data to determine the accuracy of the above generalised representations of medieval life. Indeed, this would clearly be beyond the confines of skeletal interpretation. However, it was anticipated that the comparative palaeopathological approach might go some way toward elucidating the relationship between sex and health status in a social context.

The data were derived from seven cemeteries: the rural assemblage recovered from the church and churchyard at the deserted medieval village of Wharram Percy in North Yorkshire; the Abingdon Vineyard lay cemetery, which served the medieval market town of Abingdon and its surrounding rural manors; the urban lay cemetery of St Nicholas Shambles in the City of London; the largely monastic assemblage from the Blackfriars friary at Ipswich; the Jewish burial ground at Jewbury in the city of York; and the cemeteries of the church and priory of St Andrew at Fishergate, also in York. Further details about these sites are presented in the following chapter, together with the criteria that were used to select them. The data upon which the analysis was based detailed the original laboratory findings pertaining to each individual in the sample, as opposed to published summary statistics.

A cumulative total of 2,625 articulated skeletons were recovered from the cemeteries. The analysis was based on those that had been sexed, totalling 1,813 individuals. Of these, conventional sexing methods had been used to classify 1,056 adults as male, and 674 adults as female. Tooth measurements were used to place sex assignations on 83 subadults, drawn from the cemeteries of Abingdon Vineyard and St Andrew, Fishergate, of which 47 were classified as male, and 36 as female. The method of subadult sex determination is discussed in chapter 3.

Given the large volume of data to be explored during the subsequent investigation of demography and pathology, a database was designed for storage and analytical purposes, and this is described in chapter 4.

The demographic structure of the cemetery samples are examined in chapter 5. This includes a discussion on the cemetery sex ratios, with particular reference to explanations proposed for the numerical predominance of males, and a comparison of male and female age at death. The subsequent chapters are organised according to the aspects of pathology that were targeted for analysis, selected on the basis of three criteria. Firstly, each had been routinely recorded in the majority of assemblages, using a protocol that was relatively comparable. Secondly, the pathological indicators were fairly prevalent, as rare conditions would contribute little to a comparative epidemiological study. Thirdly, the limited range of indicators pinpointed for analysis should be chosen to collectively facilitate a balanced perspective on male and female health and activity patterns (Larsen 1998). To provide a comparative measure of the general health of males and females, four indicators of skeletal stress were examined: stature, anaemia, enamel hypoplasia and infectious disease. This analysis is discussed in chapter 6, which is prefaced by an introduction to the concept of 'biological stress'. Chapter 7 investigates trauma by comparing the prevalence and distribution of fractures among males and females. This is followed by an analysis of joint disease in chapter 8, which focuses on the prevalence and distribution of osteoarthritis in the appendicular skeleton and the articular processes of the vertebral column, osteophytosis, and Schmorl's nodes. Dental pathology is examined in chapter 9 using three common conditions as criteria on which to compare the sexes: caries, abscesses and ante-mortem tooth loss. The concluding chapter synthesises the overall findings and interpretations, discusses the limitations of the project, and suggests directions for future research.

The structure of the majority of chapters follow a similar format, each comprising an introduction, method, and discussion of results. This format was adopted because the research methodology was specifically tailored to each aspect of pathology or demography under investigation, so it enabled the various stages of the research process to be integrated. Each introduction states the objectives and hypotheses to be tested, and describes the aetiology and pathogenesis of the skeletal indicators, as this formed much of the reasoning behind the interpretation. Each method describes the procedures that were used to record and classify the data, followed by the techniques of statistical analysis applied. The male and female data were normally compared with respect to each cemetery, the pooled site data, between cemeteries, and according to age category. Within each chapter, the results are summarised and discussed concurrently in order to avoid repetition. Due to the abundance of numerical data, most of the results are detailed at the end of the relevant chapter, rather than being integrated in the text. However, these form an integral component of the thesis and should be considered in conjunction with the text.

2. Material

2.1 Selection Criteria

It was foreseen that ideally, the study should be based on cemeteries which fulfilled as many of the following criteria as possible:

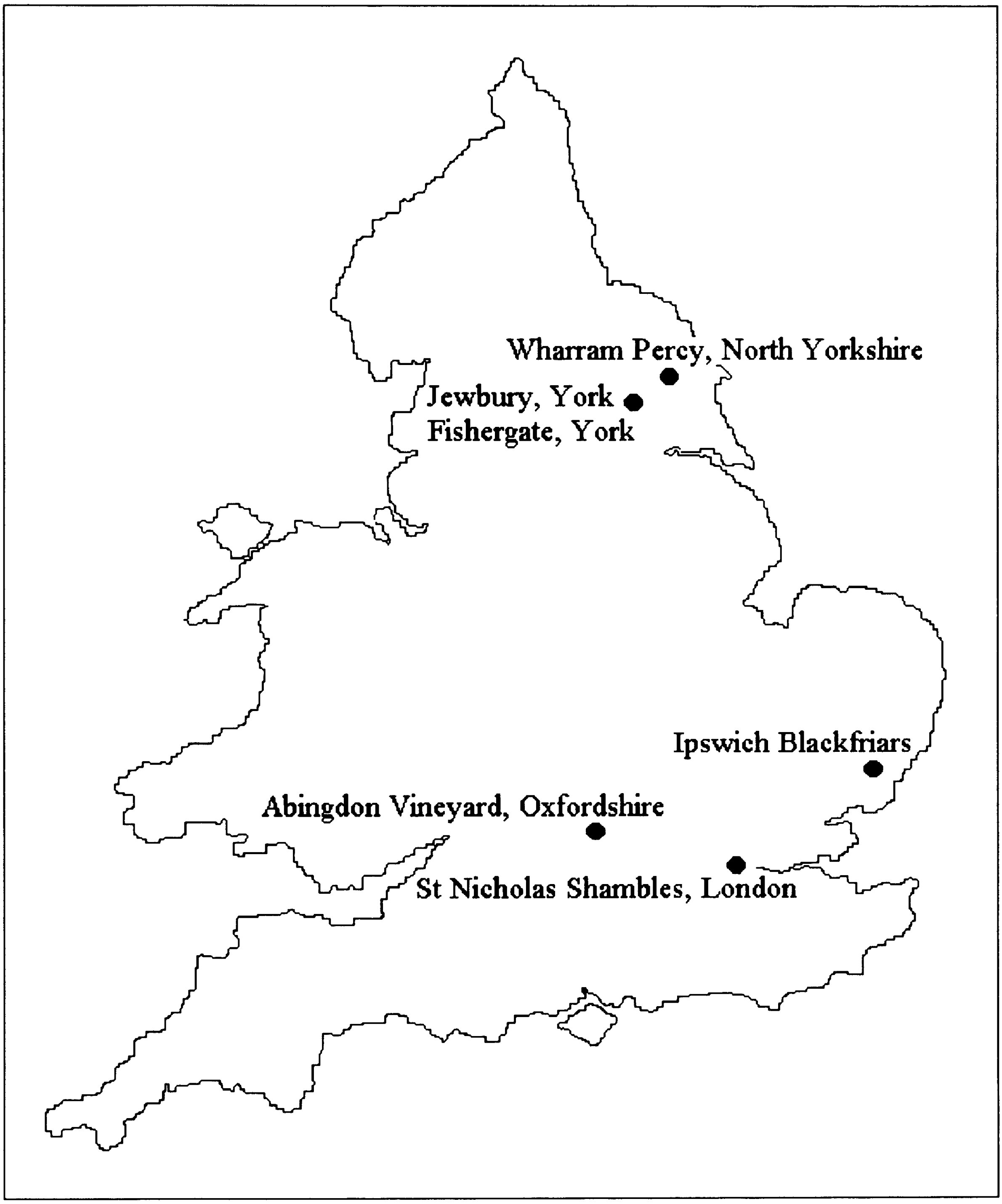
1. *Since the primary approach of the study was epidemiological, the sample size should be large, arbitrarily defined as a minimum of 100 individuals* (Waldron 1989:71; Waldron 1994:24-25). This was essential in order to enable the valid comparison of not only male and female prevalence figures, but also to maintain an adequate sample size following any further subdivisions of the data which may be necessary, such as by age group. For the same reasons, the material should be well preserved.
2. *The sex ratio of the sample should be close to unity.* A substantial under-representation of either sex could inhibit the ability to compare male and female prevalence figures.
3. *The original data recording sheets that were used to systematically document the findings from the laboratory examination of each skeleton should be available for consultation.* This was imperative because given the large sample sizes required and the broad range of pathological indicators to be investigated, it would be unrealistic to examine all the material in person. By contrast, the data supplied in published skeletal reports generally provide insufficient detail on which to base comparative epidemiological analyses, even those which supply a catalogue of skeletons that summarise pathology on an individual basis. In particular, published reports do not normally itemise the skeletal elements present in a sample, and this is an essential requirement for the computation of the 'corrected prevalence' statistic (section 6.5.2; Waldron 1994:54-54). The raw data would also enhance the ability to correlate differences in cemetery recording protocol (Waldron 1994:90). There may be considerable variation in what is recorded by different researchers, a problem which is not aided by a lack of established operational definitions, and developments in recording methods (Larsen 1997:340). This potentially represented a major weakness in the project's methodology, and the problem has been addressed in chapter 4, and repeatedly throughout the subsequent pathology chapters, primarily in the method sections.

4. *The skeletal material should be available for examination.* Again this would enable the implementation of recording protocol to be compared, enhancing compatibility between data. Material was also required for the investigation into skeletal sex determination using tooth measurements.
5. *The site report should be published.* This might be particularly useful for providing information which could assist the process of interpretation, such as environmental evidence, historical references, or cemetery phasing.
6. *The excavation and analysis of the selected material should be fairly contemporary.* This was desirable to minimise the problem of changing techniques and changing trends in the skeletal characteristics which are recorded (Larsen 1997:340; Waldron 1994:31-34).
7. The location and accessibility of the material and data would also be a consideration for economic reasons associated with the process of data collection.

In order to identify the most appropriate assemblages on which to base the study, an inventory of excavated English medieval cemeteries was compiled. This comprised 67 sites, as summarised in appendix 1. The following sources were used to construct the list: the Ancient Monuments Laboratory 'Human Bones Database'; the inventory of collections stored at, or reported to, the Anthropology Library at The Natural History Museum; newsletters produced by the Palaeopathology Association (British Section) and the Osteoarchaeological Research Group; published site reports and references cited within them; and enquiries made to various archaeology units.

Unfortunately, few of the cemeteries listed in appendix 1 satisfied all the selection criteria. In particular, many of the samples were deemed too small for inclusion, and specialist examination of several large collections had not been completed at the time this project commenced. Furthermore, the sex ratios of the majority of samples were biased toward males. Nevertheless, seven assemblages were selected from the inventory: Abingdon Vineyard, the Fishergate church and priory assemblages, Ipswich Blackfriars, Jewbury, St Nicholas Shambles, and Wharram Percy; the locations of which are illustrated in figure 2.1. Each of the selected samples comprised more than 100 individuals, yielding a total of 2,625 articulated skeletons, of which 1,056 adults were classified as male, and 674 as female. Although males outnumbered females in all the

Figure 2.1 Location of the Cemeteries Selected for Study



collections, the proportion of females in each assemblage was considered to be sufficient for the purposes of analysis, at least by comparison to many of the other sites initially identified. Permission had kindly been given to use the original laboratory data, and access was granted to all the collections with the exception of Jewbury which had been reburied. The assemblages from Ipswich and Wharram Percy had been examined by the same investigator, using the same recording protocol, as had those from Fishergate. This was considered to be an advantage as it eased the number of recording protocols that had been applied across the cemeteries, and diminished the potential problem of inter-observer variation in their implementation. Excavation and examination of the selected cemeteries had taken place over a fairly contemporary period, and skeletal reports were available for most of them, if not site reports or other relevant sources of information. The chief characteristics of the assemblages are summarised in table 2.1. Further background notes on the respective cemeteries are provided below, including their historical context, circumstances of excavation, and evidence for burial practices with particular respect to gender.

2.2 The Cemetery of St Nicholas Shambles, City of London

The foundations of the medieval parish church of St Nicholas Shambles and its associated cemetery were excavated by the Department of Urban Archaeology of the Museum of London between 1975 and 1979. The excavations followed the demolition of the GPO Headquarters Building at the site, located at 81 Newgate Street in the City of London, now occupied by the British Telecom Centre. A total of 234 articulated skeletons (inc. 91 males and 74 females) were retrieved from the cemetery to the north and east of the church, between 1975 and 1977. The area of excavation was governed by modern boundaries, but it is thought that almost the entire cemetery area on the north and east sides of the church was incorporated to the excavation (Schofield 1988). There is no evidence to suggest that interments were ever placed to the south or west of the church (Dyson 1988).

The church of St Nicholas Shambles underwent several phases of development between its initial construction in the eleventh century to its final demolition in 1548-51. The burials are thought to derive from the early phase of the church's history, and have

Table 2.1 Chief Characteristics of the Cemeteries Selected for Study

Cemetery	*n* males	*n* females	Dates of Use	Urban/Rural	Monastic/Lay
St Nicholas Shambles	91	74	11th and 12th centuries	Urban (London)	Lay
Fishergate Period 4	47	33	mid-11th to end of 12th century	Urban (York)	Lay
Fishergate Period 6	176	53	1195 - 1538	Urban (York)	Monastic
Jewbury	161	150	mid-12th century/*c.*1230 - 1290	Urban (York)	Lay (Jewish)
Abingdon Vineyard	223	171	*c.*1300 - 1540	Market town/rural	Lay
Wharram Percy	212	129	11th - 16th centuries	Rural	Lay
Ipswich Blackfriars	146	64	1263 - 1538	Urban	Monastic

been dated archaeologically to the eleventh and twelfth centuries. During this period London was flourishing. The city gained its official status as England's capital in 1042, and continued to expand after the Norman Conquest as a thriving centre of administration, architectural advancement, religion, culture and commerce. Writing in 1173, William Fitz Stephen described London as 'the most noble city' of all the world (Clout 1991:39). The expansion was accompanied by massive population growth, largely fuelled by migration from the provinces and abroad. The number of inhabitants in 1086 has been estimated at around 10-15,000, which compares with a figure of 5-7,000 for York, the second city of England at that time (Butler 1982:4; Clout 1991:12,39; Unwin 1990). By the late twelfth century, London's population exceeded 30,000 (Clout 1991:12,39). As the name implies, the parish of St Nicholas Shambles was a district for butchery, situated in the west of the walled 'City', which formed the mercantile and industrial centre of London (Clout 1991:39-53; White 1988:54).

The cemetery of St Nicholas Shambles continued to be used until the church's closure in 1548-51, but later cemetery strata were probably removed through development on the site after the demolition of the church. Grave-cuts were rarely discernible, so it was not possible to establish stratigraphic relationships between burials for more precise dating. The burials did not appear to be ordered in distinct rows, neither were they arranged according to sex or age. No separate area was identified for the interment of children, although two clusters were detected which comprised neonates and infants buried with adults, and these were interpreted as being 'suggestive of the burial of children with their parents' (White 1988:48). The burials conformed to the Christian rite of east-west alignment, and all were extended inhumations, predominantly with the hands placed at the sides of the body.

Six burial types were identified (White 1985). The majority, 189 individuals, were simple interments, possibly placed within a coffin. Evidence for coffin use comprised the occasional find of nails or traces of wood in close proximity to some skeletons, although the cemetery report does qualify that the nails could have been intrusive deposits from underlying strata and the wood may have served some other purpose, such as grave markers. Some of the simple burials had floors of pebbles, and one of these, a female, had fragments of what was probably a linen shroud adhering to the skull. Schofield (1988:20) comments that 'Linen shrouds were a common feature of female burial in the medieval period, whereas men were sometimes buried in hair shirts woven from coarse two-ply yarn' (Crowfoot 1976). The five burial practices identified among the remaining 45 individuals included the use of stone pillows, presumably for inhumations without coffins; graves with chalk and mortar floors; stone and mortar cists; graves lined with dry-laid stone or tile, which may have been less prestigious imitations of stone sarcophagi; and one infant was encased in charcoal. Possible evidence for burial ritual included the placement of stones or pieces of Roman tile on three individuals, and a pebble had been placed in the mouth of four skeletons. All the burial customs identified within the cemetery of St Nicholas Shambles have parallels at other early medieval and late Saxon sites (Schofield 1988:19-26). There was no distinct age or sex distribution to the burial practices employed within the cemetery, but while acknowledging that the sample was small, Schofield (1988:26) does note 'the apparent reverence with which old women were often treated': three of the individuals furnished with a pebble in the mouth were elderly females, and fifteen of the twenty adults placed in pillow-graves were female. The excavated material was in a variable state of preservation, and the overall condition was described as being 'fair'. Only 36 skeletons were classed as complete, and half the individuals were described as being 'deficient in the head region' (White 1988:29). All the material was examined and recorded in the laboratory by a single investigator, W.J.White, on behalf of the Museum of London, and the findings from White's analysis have been published (White 1988).

2.3 The Cemeteries of the Church and Priory of St Andrew, Fishergate, York

In 1985-86, excavations were carried out by the York Archaeological Trust at the site of the former Redfearn National Glass Factory, 46-54 Fishergate, York, prior to redevelopment. The results of the investigation have been published as part of the Trust's series entitled 'The Archaeology of York' (Stroud and Kemp 1993). A total of 402 articulated skeletons were reported to have been retrieved from the site and examined in the laboratory (Stroud and Kemp 1993:130), although the data recording sheets for five individuals were absent from the archive and so omitted from the analyses conducted in this study. All the data used in this study were compiled following examination of the remains by one investigator, G.Stroud, on behalf of the York

Archaeological Trust. The remains were considered to be well preserved. Approximately half the skeletons were more than 80% complete, and only 10% of the sample were represented by less than one quarter of the skeleton. Further burials are thought to exist to the south and west of the excavated area.

The excavated sample was considered to be representative of two separate burial populations associated with different archaeologically identified occupational phases, denoted as 'Period 4' and 'Period 6'. The majority of burials could clearly be assigned to one of the two periods, and grave cuts enabled further stratigraphic sequencing within these phases, although Kemp (1993b:130) acknowledges that there was an element of uncertainty over the phase attributions in a small minority of cases. The skeletal data from the two periods were treated as separate assemblages for the purpose of the demographic and pathological analyses, and are often distinguished throughout the text by the abbreviations 'Fishergate 4' and 'Fishergate 6'.

One hundred-and-thirty individuals (inc. 47 males and 33 females) were attributed to Period 4, dating from the mid-eleventh to the end of the twelfth century. They were derived from a cemetery presumed to have been associated with the church of St Andrew, which is known to have existed on the site from historical evidence. Stroud (1993:251) suggests that 'in the absence of any documentation to the contrary, it seems reasonable to expect that burials here would be of lay members of the population of York at that time'. York retained its status as England's second city throughout these centuries, and like London, its population expanded, primarily through immigration. The city served as the 'capital of the North', acting as the chief administrative and judicial centre for the region, and was an important manufacturing centre and inland port. However, in the latter half of the Middle Ages, York's wealth and prosperity was surpassed by other cities, notably Bristol and Norwich (Butler 1982:5; Hall 1996:45).

The graves from Period 4 were aligned east-west. Males, females and subadults tended to be distributed randomly across the excavated area, though there was some clustering of subadults in the western part of the site. Eighteen young males displayed unhealed blade injuries, and some had been placed in double graves, indicating that they were interred concurrently. Kemp (1993a:127) speculates that these individuals may have died as a result of a single violent event, possibly representing casualties of a battle. All the inhumations were extended, although it is possible that there were preferences in arm position pertaining to sex as the majority of females had been placed with the arms upon the body whereas a more diverse range of arm positions were observed among males. The presence of clench bolts, iron nails and wood fragments in some graves provided evidence for the use of wooden coffins.

In 1195, St Andrew's church and the surrounding land was donated to the Gilbertine Order for the construction of a priory, also dedicated to St Andrew in 1202. The priory was continuously occupied, undergoing a series of structural modifications, until its suppression in 1538 on the orders of Henry VIII. Two hundred-and-sixty nine individuals (inc. 176 males and 53 females) were assigned to this phase, Period 6, recovered from the priory buildings and the churchyard to the east and south. All were aligned in an east-west direction. The burials are believed to include the monastic inhabitants as well as wealthy patrons from the secular community. The demographic distribution of the inhumations and variations in burial practice across the site indicated that a system of spatial zoning may have been in operation which related to social status (Knüsel *et al.* 1997; Stroud and Kemp 1993). Those buried in the eastern churchyard were almost exclusively male, the majority having been interred in a similar burial position with the arms placed upon the body. It is suggested that this may have been an area reserved for the resident canons. The burial ground to the south of the priory buildings contained a predominance of males, but also females and two-thirds of all subadults dated to Period 6. The strong male contingent implied the inclusion of individuals associated with the monastery in this part of the cemetery, possibly servants or lay brethren, and their families. One male had been buried with a lead alloy chalice and paten and another was buried with a paten; customs which indicate that these individuals were probably priests (Hall 1996:112-113; Rodwell 1981:155-156). The inhumations within the priory buildings have been interpreted as those of lay benefactors and canons of comparatively high distinction. Adult males, females and children were retrieved, some of whom had been interred in stone or tile-lined coffins, possibly indicative of 'high status' burials. One male had been deposited in a shallow grave with a lime lining. Four double graves were identified, the remains from which displayed skeletal traits suggestive of familial groupings.

2.4 The Jewish Burial Ground at Jewbury, York

The Jewbury burial ground was also located in York, situated just outside the medieval city walls in the north-eastern suburbs, on the bank of the River Foss. The cemetery served the Jewish community of medieval York, although it may have contained individuals brought from Lincoln as documentary evidence suggests that the burial ground was, at least initially, shared by the Lincoln Jewry prior to the purchase of their own site at an unknown date. The York Jewry was established in the 1170's, probably as an offshoot of that at Lincoln. The community was small, estimated to comprise 20-40 households, concentrated in the city centre around Jubbergate and Coney Street, where the synagogue was (Butler 1982:4,6; Hall 1996:59). In 1190 the community was almost wiped out by a horrific massacre and mass suicide at York castle, which was incited by a Christian mob with religious and financial motives (Butler 1982:4,6; Dobson 1974; Hall 1996:59; Mitchell and Leys 1967:158-162). However, the community revived to become the most prosperous Jewish community in England during the mid-thirteenth century. The date when the Jewbury cemetery was established has not been determined precisely, though it is estimated to have been founded some time between the mid twelfth century and *c.*1230 when it is mentioned in a land sale agreement (Dobson 1974). It remained in use until its abandonment in 1290, when Edward I expelled all Jews from England.

Approximately half the cemetery was excavated during 1982-83 by the York Archaeological Trust in advance of redevelopment, the findings from which have been published as part of the 'The Archaeology of York' series (Lilley *et al.* 1994). It represents the only large scale investigation of a medieval Jewish cemetery in England, out of the ten which are known to have existed. A total of 476 articulated skeletons (inc. 161 males and 150 females) were reported to have been recovered and examined in the laboratory, although the skeletal recording sheets for seven individuals were missing from the archive and so excluded from the analyses performed in this study. The material was described as being in a variable state of preservation, from 'very good to poor' (Lilley *et al.*1994:353). Half the sample were represented by more than 80% of the skeleton and more than three quarters were represented by at least half the skeleton. However, the anthropological examination of the remains was curtailed because when the site was confirmed as being that of the medieval Jewish cemetery, the Chief Rabbi requested the immediate reburial of the remains. Jewish traditions dictate that the dead should be treated with the utmost reverence and have the right to rest undisturbed. A team of researchers were employed under the direction of D.R. Brothwell and M.H.Williamson to record as much detail as possible under the time restrictions imposed, although the premature reburial limited the amount of information which could be recorded, as detailed in the following chapters.

On site, the layout of the graves indicated that the cemetery was highly organised. The graves were arranged in distinct but irregular rows, aligned in a north-east/south west direction. Contrary to many Christian cemeteries, the graves rarely intercut, which indicates that the Jewish belief that the body should not be disturbed after burial was observed. It would also indicate that grave markers were used, perhaps earth mounds or wooden posts. A few graves contained stones which may have served to denote the grave or act as packing material to secure wooden posts. The lack of intercutting prevented any chronological differentiation between most of the burials. The distribution of males and females was largely random, although there was a cluster of twenty males in the western region of the site which was interpreted as being a possible area reserved for the burial of rabbis or other prominent people. The majority of children were focused in the north-eastern area, indicating that the segregation of child burials was practised. Burial method was extremely uniform across the site, suggesting that the Jewish tradition for equality and simplicity in burial was upheld. Most of the inhumations were extended with the arms placed at the sides of the body and there was an almost total absence of grave goods. The majority had clearly been buried in wooden coffins as some graves contained wood fragments or iron coffin fittings, and most contained iron nails. This contrasts with the modern Jewish practice of avoiding metal nails in preference for wooden pegs. Shrouds may have been used, as seven individuals were in constricted positions which suggested that they were bound prior to burial, and antler toggles, possibly shroud fasteners, were found above the skulls of two skeletons.

2.5 Abingdon Vineyard Lay Cemetery

In 1988-89 excavations were carried out in the Oxfordshire town of Abingdon, in an area known as The Vineyard, adjacent to the Municipal Park. The excavations were conducted by the Oxford Archaeological Unit prior to the construction of offices for the Vale of White Horse District Council (Allen 1990). The site encompassed part of an extensive medieval lay cemetery. Its limits could not be determined, but it is estimated that about one third of the total cemetery area was excavated (Wakely pers. comm.), from which 590 articulated skeletons (inc. 223 males and 171 females) were recovered and examined in the laboratory. The majority of the assemblage was examined and recorded at the University of Leicester under the direction of J.Wakely, who was assisted by several postgraduate students. J.W.P. Hacking co-directed the research on behalf of the Oxford Archaeological Unit, and also examined a substantial component of the sample. The completed skeletal report is currently awaiting publication (Wakely and Hacking forthcoming).

During its use the cemetery was situated within the grounds of Abingdon Abbey. The Abbey operated the cemetery (Townsend 1910:40), but the possibility that it contained monastic burials has been excluded (Wakely pers. comm.). The cemetery served the secular community of Abingdon and its surrounding rural manors, and was the only site in the vicinity to hold the legal right to burial (Townsend 1910:66-67). Medieval Abingdon was a market town which developed around the Abbey, one of the richest in England until its destruction in 1538. The skeletons excavated from the cemetery have been dated archaeologically to a period spanning from *c.*1300 to 1540, when the land was sold following the Dissolution. There was much intercutting of burials and their stratigraphic sequence is currently being evaluated, so the skeletons can not yet be ascribed to any particular phase of cemetery use. The graves were aligned east-west and the majority were single inhumations, although group burials of up to six skeletons were also recovered. Most individuals had been placed in simple, unfurnished graves but a minority, thought to date among the earliest burials, had been placed within stone cists, or had stones placed on either side of the head, resembling 'earmuffs' (Allen 1990).

2.6 The Cemetery at the Deserted Medieval Village of Wharram Percy, North Yorkshire

This assemblage comprised 685 individuals (inc. 212 males and 172 females) recovered from the church and two sample areas of the churchyard at the deserted medieval village of Wharram Percy, situated on the Yorkshire Wolds, about 18 miles north-east of York. The chalk geology of the site led to exceptionally good skeletal preservation of what is one of the few large collections derived from a rural medieval community in England. Excavations of the church and churchyard were carried out between 1963 and 1978 (Mays *et al.* 1996) and formed part of an extensive, pioneering research programme at the village site which began in 1950 and continued for more than 40 years (Beresford and Hurst 1990). All the anthropological data used in this study was compiled following examination of the material by a single investigator, S. Mays, at the Ancient Monuments Laboratory, English Heritage. The findings from Mays analysis are to be published in a forthcoming report (Mays pers. comm.).

Although the date of the village origins has not been determined, the settlement probably evolved from a shifting group of scattered farms in the Saxon period. The construction of the parish church of St Martin (Bell and Beresford 1987) in the mid-twelfth century may signify the foundation of the parish of Wharram Percy. By the late fourteenth century the village had become established as a compact community of about 30 houses which had been deliberately planned along three frontages around a central wedge-shaped green, surrounded by a methodical distribution of crofts and open fields. The parish economy centred upon both arable and livestock farming, with access to markets at nearby Driffield and Malton, as well as the large urban centres of York, Beverley and Hull (Scarre 1988:246-247). The decline of the village took place during the fifteenth century. Sixteen inhabited dwellings were documented in 1458 but by the early sixteenth century, the village was totally depopulated.

The burials spanned the period from the eleventh to the sixteenth centuries. Those in the graveyard were laid out in regular rows, although there was a great deal of disturbance between earlier and later graves. The rise in ground level, particularly on the north side of the churchyard, indicated that the graveyard was used 'for at least four cycles of burial' (Beresford and Hurst 1990:65), although further details on burial phasing have not been located. The vast majority of the inhumations are believed to be those of ordinary peasants who resided in the parish (Mays 1996). However, chalices had been deposited with two skeletons, one of which was also buried with a paten, indicating the burial of priests; and there was evidence for the burial of men at arms, possibly relations to the lords of the manor, from grave slabs built into the walls of the church that were engraved with swords and foliated crosses (Beresford and Hurst 1990:64). A concentration of infants were noted in the north churchyard. The practice of burial in shrouds was indicated by the identification of shroud fragments in three graves in the churchyard (Bell and Beresford 1987).

2.7 The Medieval Burials from the Blackfriars Friary, School Street, Ipswich

Excavations conducted by the Suffolk Archaeological Unit between 1983 and 1985 produced 250 skeletons (inc. 146 males and 64 females) from the site of the Blackfriars friary, School Street, Ipswich. Like Wharram Percy, the laboratory examination of the entire skeletal collection was undertaken by S. Mays. Mays findings have been presented as part of a series of interim reports (16/91) produced by the Ancient Monuments Laboratory in advance of full publication. The burials were all retrieved from within the friary complex, principally the church nave, and it is thought that they represent both friars and wealthy lay benefactors. Fifteen named individuals are known to have been buried in the friary but these could not be associated with specific skeletons. The interments took place over a 275 year period, from when the friary was founded in 1263 to its suppression in 1538. The town of Ipswich became increasingly prosperous during this period, and by the early sixteenth century it had become the sixth richest in England (Bridgwater 1996:19,191-192; Sager 1990:14). Its wealth was largely founded on its role as an inland port and the region's highly successful wool industry, which spawned a large, affluent middle class of clothiers and merchants.

Despite much inter-cutting of graves within the cemetery, it was not possible to date the burials with any further precision. Females were located in all areas of the friary complex apart from the south range of the cloister and the chapter house, suggesting that friars and lay benefactors were not segregated except perhaps in these two areas. A statistically significant association was identified between arm position in burial and skeletal sex. A substantial proportion of males and females were buried with the arms placed at the sides of the body, whereas virtually all individuals buried with the arms placed across the chest were male. Fragments of wood and iron nails provided evidence for the use of coffins in 89 cases, although there was no association between sex or age and coffin use. Skeletal preservation at the site was highly variable, ranging from complete skeletons to soil silhouettes. Forty per cent of the skeletons were more than 80% complete, and almost 70% of the sample were represented by more than 60% of the skeleton. It is likely that the friary site was not excavated in its entirety and that there may be further burials in areas which were not investigated.

2.8 Discussion

As the above accounts indicate, the composition of the selected cemeteries differed in a number of important respects, such as whether they primarily served an urban or rural settlement, a monastic or lay community, or differed in time span or geographical region. The majority of studies which have compared pathology between the sexes have so far focused on single cemetery collections, but it was anticipated that the variety of cemeteries included in this project would not only enable the direct comparison of males and females within the respective assemblages, but also the comparison of males and females from a range of cemeteries that were presumed to have different compositional characteristics. It was envisaged that this might help to elucidate whether potential sex differences in pathology were generally applicable to all the samples, perhaps reflecting universal sex differences in health status, or whether the results might have been influenced by other parameters.

However, it should also be emphasised that a multitude of what are largely indeterminable factors influence the demographic and cultural composition of a cemetery; and similarly, any assemblage retrieved from it (Larsen 1997:334-335). The identity of the burials are normally unknown, and an excavated sample may not be representative of that which was interred. Waldron (1997:10-27) has divided the chief sources of bias which may be introduced to a skeletal assemblage into 'extrinsic' and 'intrinsic' factors. Extrinsic factors act to diminish sample size, and include culturally determined biases in the proportion of the total dead population which are buried in a particular cemetery; the proportion lost as a result of disturbance or decomposition; the proportion of the buried population which is discovered during excavation; and the proportion of those which are actually recovered. Intrinsic factors revolve around the fact that a cemetery assemblage represents a static, dead population sample, and does not reflect the dynamic characteristics of a living population. This is particularly evident in the age profile of the two population types, as cemetery samples reflect age at death rather than the age distribution of those living in a population. Most cemeteries also develop over a protracted time span, and so contain individuals that existed many years apart. This can be particularly detrimental to the analysis of pathology prevalence because it has the effect of smoothing out potential peaks in prevalence occurring over time, and the impact of such peaks on the mean prevalence cannot be determined. Therefore, although the series of cemeteries included in the study represented an opportunity to compare data from assemblages that were presumed to display distinct compositional characteristics, there are inherent limitations surrounding such comparisons, and it should be emphasised that the inferred compositional characteristics can only be applied in loose, general terms.

3. Subadult Sex Determination Using Tooth Measurements

3.1 Introduction

At present, there is no consensus on a reliable method for identifying the sex of subadult human remains (Mays 1998:38-42; Mittler and Sheridan 1992; Molleson *et al.* 1998; Saunders 1992; Schutkowski 1993; Stone *et al.* 1996). Adults are primarily diagnosed from secondary characters of the pelvis and skull or from the size of the limb bones (Bass 1987), but as these traits are not fully developed until late adolescence (*c.*18 years), they cannot be used to sex children. This inability to sex subadults imposes a limitation on any general study of sex related pathology, because it necessitates the exclusion of a significant component of the population under study.

The permanent dentition is known to form at adult size within the jaws of the immature skeleton and erupt in a predictable sequence between the ages of *c.*5-15 years (with the exception of the third molars), thus representing an adult trait in a child (Ubelaker 1978). Since previous studies have consistently documented sex differences in permanent tooth size (Bermúdez de Castro *et al.* 1993; Brace and Ryan 1980; Ditch and Rose 1972; El-Nofely and Tawfik 1995; Frayer and Wolpoff 1985; Garn, Cole and Van Alstine 1979; Garn, Cole, Wainwright and Guire 1977; Garn, Lewis and Kerewsky 1964; 1966; 1967; Garn, Lewis, Swindler and Kerewsky 1967; Goose 1967; Hanihara 1981; Hillson 1986:240-242; 1996:81-82; Langenscheidt 1983; Lunt 1969; Molleson *et al.* 1985; Moss 1978; Potter 1972; Rösing 1983; Sciulli *et al.* 1977; Scott and Parham 1979), the dentition may hold the potential to reveal the sex of children. However, the practical application of this theory has rarely been attempted (Beyer-Olsen and Alexanderson 1995; Duncan 1998; Molleson 1989; 1993).

The purpose of this chapter was to investigate the validity of this hypothesis in relation to material excavated from the cemeteries of Abingdon Vineyard and St Andrew, Fishergate (see chapter 2). The hypothesis was tested on these assemblages because the remains were accessible for examination. If sex assignments could be attributed to a sample of subadults, it would enable their inclusion into the wider project, extending the comparative analysis of male and female pathology to individuals under the age of *c.*18 years.

The research design encompassed:

1. A metrical examination of permanent teeth in a reference sample of adult skeletons from each cemetery, whose sex had previously been determined using conventional methods.
2. Univariate analysis of the data to ascertain whether any statistically significant differences existed between the dimensions of male and female permanent teeth, from either cemetery.
3. The application of discriminant function analysis to each reference sample, with the aim of identifying a combination of measurements which might effectively distinguish the sexes and facilitate their classification.
4. Application of the discriminant functions to predict the sex of subadults from the respective cemeteries which had formerly been classified as indeterminate.

3.2 Method

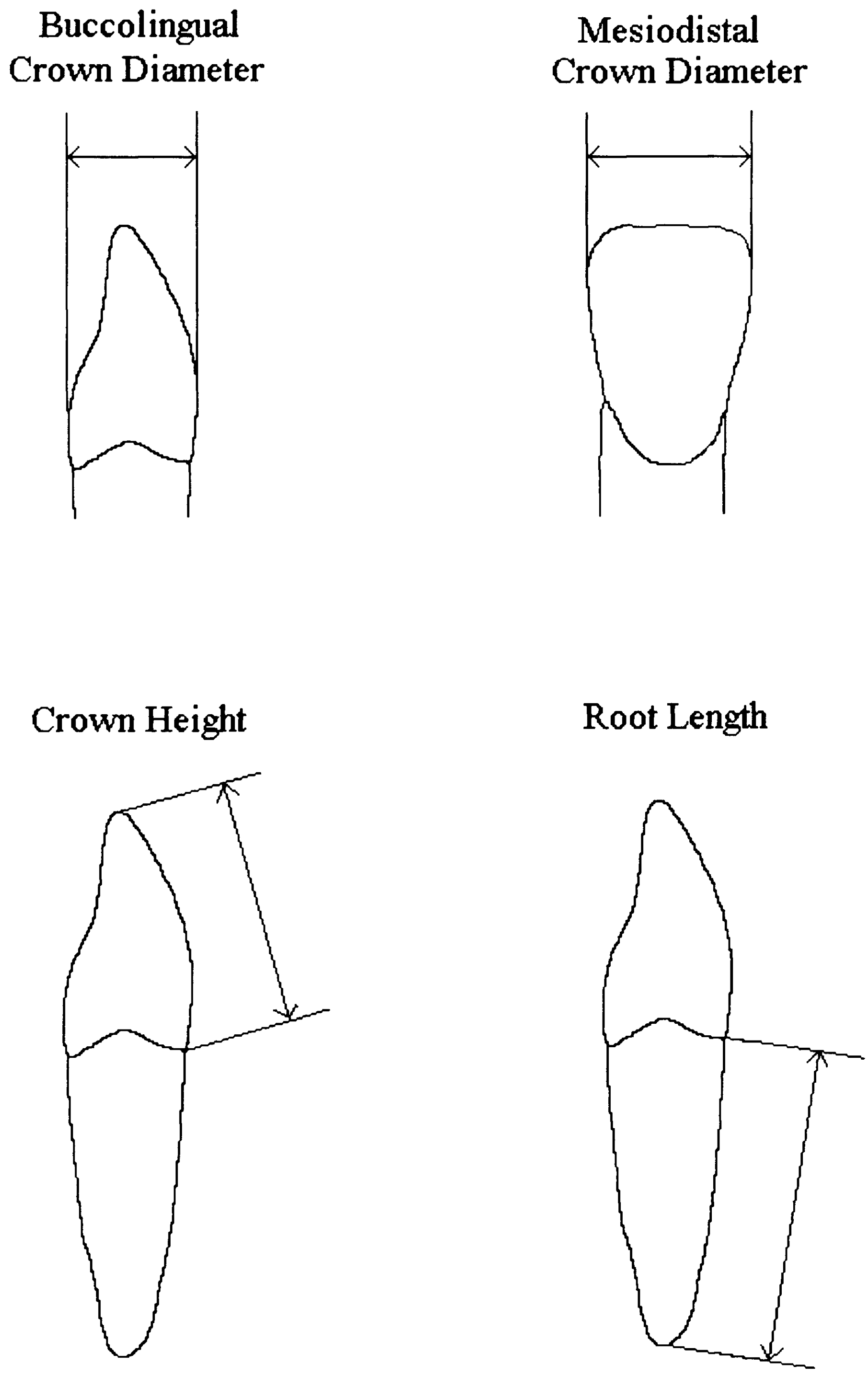
The adult reference samples consisted of 43 males and 34 females from Abingdon, and 88 males and 36 females from Fishergate. The material from Fishergate was derived from both phases of cemetery use. These individuals were selected from the assemblages on the fulfilment of two criteria. Firstly, each had been reliably sexed using established methods, the efficiency of which are described in a publication by the Workshop of European Anthropologists (1980, and see chapter 5). This was imperative because the discriminant technique depends on accurate sexing of the base population sample. Ideally, the second criterion would have been that each skeleton also displayed a complete, unworn dentition because measurements missing from the data set may impede statistical analysis. However, owing to the typically fragmentary nature of the archaeological material, this criterion was modified to include any individual with a minimum of one unworn permanent tooth with the exception of second and third molars. Third molars were omitted from the investigation due to their high frequency of congenital absence (Brothwell *et al.* 1963; Pindborg 1970) and late age of eruption (*c.*21 years) which would provide little advantage over conventional methods of sex determination. Similarly, second molars were excluded due to their comparatively late age of eruption (*c.*12 years) coupled with a high susceptibility to attrition. This led to the selection of mostly younger individuals, under the age of *c.*30 years. Possession of at least one unworn permanent tooth was also the single criterion observed when selecting the skeletons of indeterminate sex.

The dentition of each individual was recorded using the FDI (Fédération Dentaire Internationale) tooth numbering system and occlusion classification (Baume *et al.* 1973). Four measurements were taken on every permanent tooth present in each dental arcade, from first molar to first molar, using 0.1mm vernier callipers:

1. *Maximum mesiodistal crown diameter* - distance between the points of contact with adjacent teeth, parallel to the occlusal plane. Malpositioned teeth were measured from the points where the crown would have been in a 'normal' occlusal relationship (Goose 1963).
2. *Maximum buccolingual crown diameter* - taken perpendicular to the mesiodistal diameter.
3. *Crown Height* - distance between the highest point of the crown and the deepest point of the cemento-enamel junction, taken obliquely on the buccal side.
4. *Root Length* - distance between the deepest point of the cemento-enamel junction and the apex, taken obliquely on the buccal side.

These measurements are also depicted in figure 3.1. This amounted to a maximum of 96 measurements per individual, although dimensions modified by attrition, calculus or pathology were excluded from measurement. In order to record the data systematically, a recording form was devised, presented in appendix 2. All measurements were taken by the author. As a test of intra-observer error in measurement, the dimensions of the right half of the dentition in three individuals were measured five times. For each of the six sets of measurements, a test of the between repeats mean square against the residual mean square was carried out (Cohen and Holliday 1982:206-212). The quotient of these two mean squares was distributed approximately as an F distribution with four and eight degrees of freedom. No significant between repeat effects were found at the 0.05 probability level, suggesting that the implementation of the odontometric method was unlikely to be influenced by intra-observer variation in recording technique.

Figure 3.1 Tooth Measurements



3.3 Data Analysis and Results

It was apparent that a substantial proportion of the measurements were missing. Tooth loss and attrition were the primary reasons for measurements being omitted. Other factors included the presence of tooth decay; post-mortem tooth damage; calculus; tooth anomalies and teeth being firmly held in the jaw thus preventing root measurement. 'Sparse data', inherent to archaeology, is particularly problematical when conducting multivariate analyses. In contrast to univariate methods which are employed to examine single variables, multivariate techniques test relationships between several variables at once. However, it is usually necessary for each case included in the analysis to hold a complete set of values for the variables being examined, otherwise it will be 'thrown out'. Since virtually every individual had a proportion of missing measurements, this criterion would have precluded any multivariate analysis of the data.

In an effort to minimise this limitation, the dental asymmetry (Bailit *et al.* 1970; Hillson 1986:238-240; 1996:75-79; Kieser 1990:96-104) of each reference sample was examined to assess the possibility of combining measurements taken on contralateral teeth, thereby making optimum use of the available data. Paired sample *t*-tests were applied to test the difference between the means of measurements taken on male and female homologous tooth pairs respectively. A non-parametric alternative to the paired sample *t*-test, the sign test, was also applied to a minority of distributions which did not conform to a normal probability curve. As the results in tables 3.1a/b demonstrate, no statistically significant differences ($p>0.05$) were found between the means of any of the measurement pairs taken on the males in the base samples. Of the 96 female measurement pairs, only two from Abingdon displayed a statistically significant difference by *t*-test (15-25 buccolingually; 11-21 mesiodistally). However, a preliminary exploration of the data indicated the presence of outliers (atypical scores) among these measurements, which violate the assumptions underlying the *t*-test model. According to the sign test, which is immune to the influence of outliers, no significant difference was found between these distributions. Consequently, a revised set of combined side variables was generated: where it had been possible to take measurements from both equivalent teeth in a jaw, the mean value was computed; if only one side had been measured, the single value was used. This made maximum use of the available data and also had the effect of making it more manageable, halving the number of dimensions from 96 to 48.

3.3.1 Univariate Tests for Sex Differences in Tooth Measurements

The application of univariate methods may be useful in assessing the degree of sexual dimorphism exhibited by teeth and therefore their suitability as a tool for sex determination. They may also focus attention on individual measurements showing a large degree of dimorphism which are more likely to yield better results in the ensuing discriminant analysis.

Two-tailed *t*-tests were applied to test the difference between male and female means for each of the measurements where the data appeared to be normally distributed; and the equivalent non-parametric test, the Mann-Whitney *U* test, was used to compare medians where the normal distribution was in doubt. In the event, both tests were applied to all the data, the *U* test tending to confirm the *t*-test result, or alternatively indicating that it should be treated with caution (tables 3.2a/b). Per cent sexual dimorphism, 100(male mean/female mean-1.00) (Garn, Lewis, Swindler and Kerewsky 1967) was also calculated for each of the variables (tables 3.3a/b).

The results of the *t* and *U* tests were generally in agreement, as demonstrated in tables 3.2a/b. Within the Abingdon sample, the male mean exceeded the female mean for all 48 measurements. The *t*-tests indicated that the sex difference between the Abingdon means was statistically significant ($p<0.05$) for 35 measurements, and 31 of these were significant at the 1% level. According to the Mann-Whitney *U* tests, 40 Abingdon measurements showed a statistically significant difference between the sexes ($p<0.05$), including 30 with a probability of less than 0.01. For the Fishergate sample, the male mean surpassed the female mean in 44 of the 48 dimensions. The sex difference between means was significant ($p<0.05$) for 24 measurements, thirteen of which were significant beyond the 0.01 probability level. The Mann-Whitney *U* tests indicated that 25 measurements displayed a statistically significant difference between the sexes, twelve of which were significant at the 1% level. Four of the Fishergate dimensions displayed means that were slightly greater in females, but the difference between the sexes was not statistically significant according to the *t* and *U* tests. These anomalies may have been associated with the disparity in the size of the male and female samples. The male samples were substantially larger, whereas the female samples were often particularly small, sometimes comprising less than ten cases.

Whilst being statistically significant, actual mean differences in crown diameters were frequently only of the order of a few tenths of a millimetre. As the results in tables 3.3a/b show, when expressed in percentage terms, male teeth from Abingdon were on average 6.2% larger buccolingually and 4.8% larger mesiodistally than female teeth from Abingdon. Within the Fishergate sample, male teeth were on average 3.4% larger buccolingually and 2.8% larger mesiodistally. The greater buccolingual difference in both cemeteries supports the findings of Garn, Lewis and Kerewsky (1966; 1967) and Lunt (1969), suggesting a sex difference in tooth shape and that the buccolingual diameter may be a more effective parameter for distinguishing the sexes. Some root length and crown height measurements displayed even greater percentage dimorphism, with average values of 9.3% and 11.3% respectively for Abingdon, and 5.6% and 10.9% respectively for Fishergate. Previous investigations into sexual dimorphism in the dentition have seldom considered these dimensions, so these results indicated that future research might gain from the examination of root length and particularly crown height measurements.

From the analysis of percentage dimorphism (tables 3.3a/b), several further trends emerged regarding the hierarchy of tooth types affected. Of all teeth, the lower canine unequivocally displayed the greatest dimorphism in both cemeteries. In the Abingdon sample, the mandibular canine presented an average sex difference of 10.4% in buccolingual diameter, 5.0% in mesiodistal diameter, 10.3% in root length and a striking 22.7% in crown height, all statistically significant at the 1% level by *t*-test. In the Fishergate sample, the lower canine exhibited a mean sex difference of 8.2% in buccolingual diameter, 8.1% in mesiodistal diameter, 5.6% in root length and 13.9% in crown height, again all statistically significant ($p<0.05$) according to the *t*-test results. This tooth was followed by the upper canine in both cemeteries. These findings concord with those of previous studies, which support the view that the canines are the most sexually dimorphic teeth in the dental arcade (Brace and Ryan 1980; Frayer and Wolpoff 1985; Garn *et al.* 1964; Goose 1963; Lunt 1969; Moorrees 1959; Moss 1978; Sciulli *et al.* 1977). However, a gradual decline in the dimorphism of adjacent teeth was not observed, so the findings of this study do not corroborate the canine genetic field theory for sexual dimorphism proposed by Garn, Lewis, Swindler and Kerewsky (1967). On a scale of sexual dimorphism, the premolars tended to yield fairly mediocre rankings, whereas the incisors and molars gave varied rankings for the different measurements. Nevertheless, the comparable magnitude of percentage dimorphism between many of the corresponding maxillary and mandibular tooth dimensions, especially in the Abingdon sample, may suggest that a correlation exists between the size of corresponding teeth in the upper and lower jaws (Hillson 1986:237), although this pattern was less apparent among the Fishergate data.

Overall, the univariate tests demonstrated that males 'as a group' had larger teeth than females 'as a group' and that certain dimensions exhibited a greater degree of dimorphism than others. The univariate analysis also suggested that the Abingdon sample displayed a stronger sexual dimorphism than the sample derived from the Fishergate cemetery, but this may have been associated with the composition of the selected material and need not necessarily imply differences in sexual dimorphism among the wider population. While no single variable could perfectly differentiate the sexes due to the overlap in distribution ranges, the consistency and statistical significance of the results from both cemeteries strongly suggested that sex discrimination could be achieved if a multivariate method were to be applied.

3.3.2 Discriminant Function Analysis of the Reference Samples

Discriminant function analysis was employed to statistically distinguish or 'discriminate' the sexes on the basis of tooth measurement characteristics, in order to build predictive models of group membership for each cemetery. The mathematical objective of the technique was to weight and linearly combine the discriminating variables (tooth measurements) in such a way as to maximise the separation of the sexes, so that ideally, a single dimension could be found on which males were clustered at one end and females at the other. Such combinations of variables are termed 'discriminant functions', which may then be used to permit the probable classification of new cases with values for the discriminating variables but with unknown group membership.

Due to the incomplete nature of both the Abingdon and Fishergate data sets, it was not possible to implement a single discriminant analysis including all 48 variables concurrently for either cemetery. Instead, a series of analyses were performed on 66 different tooth measurement combinations, as devised in a similar study by Rösing (1983) (tables 3.4a/b). A stepwise procedure was used to select single variables into each analysis in a sequence of stages according to their discriminating power, starting with the best discriminating variable. Discriminating power was determined from a change in the statistic Wilks Lambda, the significance of change being determined by an *F* test. At each step, variables already selected were removed if found to reduce discrimination when combined with more recently selected variables. Eventually, either all the variables were selected or if the remaining variables did not contribute to further discrimination, the stepwise procedure halted and further analysis was performed using only the selected variables. Thus the functions were derived from a reduced set of variables which had discriminatory effectiveness equal to or greater than the full set. This is of practical interest to the osteologist as it identifies the minimum number of measurements required for maximum discrimination, thereby saving time when collecting data for new cases in a given population sample, and reducing the number of measurable teeth required for an individual to be eligible for the investigation. The adequacy of each function's ability to discriminate was tested by classifying the cases used to derive them and observing the proportion of 'correct' classifications, i.e. those corresponding to the sex determined by conventional methods. The results of these tests are conveyed in tables 3.4a/b. A histogram of the distribution of cases along one function derived from the Abingdon data is presented in figure 3.2 to provide a visual representation of results.

Fifteen of the functions procured from the Abingdon data correctly classified between 90% and 100% of individuals in the samples submitted for analysis. Another 23 correctly classified over 80% of cases and 10 functions gave results above 70%. The remaining Abingdon functions all produced results well above the 50% success rate that would be expected by 'guessing' alone. The multivariate difference between the sexes was statistically significant ($p<0.05$) for 51 of the measurement combinations tested using the Abingdon data, and 36 of these were significant beyond the 1% level. Unfortunately, the discriminant analysis of the Fishergate data was hampered by the deficiency in the number of females in the sample. Analyses were aborted for 16 of the 66 measurement combinations submitted for testing due to a total absence of females with the required set of measurements, and a further two analyses were skipped because no cases of either sex possessed the necessary data set. Of the functions which were generated from the Fishergate data, six succeeded in correctly classifying between 90% and 100% of cases submitted for analysis, seven correctly classified over 80% of cases, and fifteen functions yielded a success rate above 70%. Eleven functions correctly classified over 60% of cases, five produced a success rate above 50%, but functions could not be derived from four measurement combinations due to their lack of discriminating power. Nevertheless, the multivariate sex difference was statistically significant ($p<0.05$) for 29 of the Fishergate functions, and 10 of these were significant at the 1% level. A further three functions displayed a multivariate sex difference which approached statistical significance ($p<0.10$). Overall, there was no sex bias in the incidence of misclassified cases from either cemetery, which implies that the method may be applied to discriminate males and females with equal confidence. As predicted, measurements that performed well in the univariate tests tended to be selected as good discriminators by the stepwise procedure. Buccolingual diameter and crown height measurements were frequently selected. This supports the view that future studies could benefit from the inclusion of crown height measurements. The performance of the parameters root length and mesiodistal diameter varied depending on their relative correlation with other variables submitted for analysis.

Unfortunately, due to the problem of missing data, it was difficult to compare the effectiveness of each function directly as each had different and a varying number of cases contributing to its derivation. For this reason, it is possible that several of the functions producing a comparatively low significance or correct classification rate were not intrinsically poor sex discriminators, but there were simply an insufficient number of cases possessing the required number of variables for a valid formulation and assessment of the function to be made.

Despite this, it was apparent that the mandibular canine provided the most effective discrimination of the single tooth runs in both cemeteries. The buccolingual diameter and crown height of the lower canine were identified as providing the best discriminating power among the Abingdon material. The discriminant function derived from these variables correctly classified 93.8% of the sample ($n=32$), and the multivariate sex difference was statistically significant at the 0.0001 probability level (function 9). The stepwise procedure selected crown height and mesiodistal diameter as the parameters which provided the greatest discriminating power among the lower canine data from Fishergate. The function derived using this combination of variables was also significant at the 0.0001 probability level, and was able to correctly classify 88.1% of cases (n=67) analysed (function 9). These measurements all performed well in the preceding univariate analyses and the good discriminating power of the mandibular canine concords with the findings of other studies (Ditch and Rose 1972; Garn *et al.* 1977; 1979; Potter 1972; Rösing 1983; Sciulli *et al*, 1977; Scott and Parham 1979). The strong discrimination provided by the parameter crown height reiterates its value as an indicator of sexual dimorphism.

Of the other single tooth analyses performed on the Abingdon data, functions derived from measurements taken on the upper canine and premolar teeth also provided good discrimination (functions 3, 4, 5, 10 and 11). These correctly classified between 79% and 89% of their respective samples, and all were statistically significant beyond the 0.01 probability level. The performance of functions derived from incisor and molar teeth varied (functions 1, 2, 6, 7, 8 and 12). Most provided correct classification rates of between 75% and 100%, but the functions derived from the mandibular first molars and second incisors were not statistically significant (p>0.05) (functions 6 and 8). However, these functions were also derived from relatively small sample sizes, which probably arose from the morphology and function of these tooth classes. Both are highly susceptible to attrition and the conical shape of the incisor roots frequently results in their loss post-mortem. The argument of reduced sample size may also be extended to explain the reduction in effectiveness demonstrated by many of the multiple tooth combinations compared with the single tooth runs. Although it might be expected that measurements performing well in single tooth analyses would be even more effective when combined, performance was reduced because fewer cases possessed the greater number of variables required for derivation of the functions (e.g. functions 22, 27, 53, 57 and 60). Effectiveness did improve in other multiple tooth runs (e.g. functions 30, 17) but these tended to include canine or premolar measurements and so provide little advantage over the single tooth functions.

The problem of sparse data, especially the deficit in the number of females, had an even more detrimental effect on the ability to make a comparative assessment of the functions derived from the Fishergate data. Of the single tooth runs, the upper canine correctly classified 78.1% of individuals, and the function was statistically significant at the 0.001 probability level (function 3). Unlike Abingdon, the discrimination provided by the premolar teeth was not particularly effective (function 4, 5, 10 and 11). Only the function derived from the maxillary first premolar yielded what might be considered a respectable success rate of 80.0%, but the multivariate difference between the sexes only approached statistical significance (p=0.0990), suggesting that this result may have been influenced by the chances of sampling (function 4). The attempt to develop a function from maxillary first molar measurements was aborted due to a lack of discriminating power (function 6), and functions could not be generated for the mandibular first molar and first incisor due to an absence of female data (functions 12 and 7). The maxillary first and second incisors produced success rates of 73.3% and 75.0% respectively (function 7 and 8), although only the function derived from the second incisor was statistically significant (p=0.0007). The function generated from the lower second incisor did yield an impressive success rate of 94%, albeit in a small sample of individuals (n=17), and the multivariate difference between the sexes was statistically significant at the 5% level (p=0.0355) (function 8). Indeed, the multiple tooth runs which provided the most effective discrimination were those which included measurements taken on this tooth, or the canines (e.g. functions 14, 15, 41, 42, 46, 47, 63, 64). However, like Abingdon, since these teeth also provided the best discrimination in the single tooth runs, there was little to be gained from the multiple tooth approach.

The differences observed between the two cemeteries in the performance of the various tooth measurement combinations may suggest that intrinsic differences exist in the pattern of sexual dimorphism. Alternatively, the differences may be a manifestation of the composition of the selected samples, especially the disparities between sample sizes.

3.3.3 Sex Allocation of Subadults

While the sample resubstitution method provides a good indication of each function's discriminating ability, it may provide an over-optimistic estimation of their effectiveness as a tool for classifying cases with unknown group membership (Owsley and Webb 1983). This is due to circularity in the technique, whereby the functions are computed from data provided by the same cases that are subsequently reclassified, resulting in a bias toward correct prediction of group membership. The effect may be particularly profound when functions are procured from small samples.

To produce a more conservative estimate of correct prediction rate, a holdout sampling method was employed (Ditch and Rose 1972). A further group of sexed individuals could not be extracted from either cemetery collection because all suitable material had already been selected. Therefore, the larger samples which produced functions with high discriminating ability and a statistically significant difference in multivariate means were randomly split into two (Abingdon functions 3, 4, 5, 9, 10 and 11; Fishergate functions 2, 3, 4, 5, 8, 9, 10, 11). Each function was then derived again from the data of one half of the sample and used to classify the remaining cases. As halving the sample size may impair results *per se*, the process was repeated ten times with different cases randomly selected for the base population on each occasion. The average prediction rates were then calculated, which have been included in tables 3.4a/b. Reductions in classification rate of between 2% and 14% were observed, although some functions displayed a small rise in correct classification rate, of up to 5%. According to the holdout method, the functions derived from the mandibular canine yielded an accuracy above 90% for both cemeteries. No sex bias in misclassification was noted. Therefore, while correct prediction rates were lower for some functions using the holdout method, they were of sufficient magnitude to suggest that the discriminant functions would provide an effective method for allocating cases with unknown group membership.

Hence, these functions were applied to the equivalent measurements taken from the teeth of the subadults of unknown sex, to produce discriminant scores for each individual. The discriminant scores were compared to the mean scores of the known male and female groups to produce values for the probability of group membership. In practical terms, this was achieved by comparing each indeterminate's tooth measurement pattern to the typical male and female patterns, then assigning them to the group that was most similar. However, caution was taken when implementing the rule of highest probability as it necessitates a strict dividing line (Kieser 1990:44-48, Kieser and Groeneveld 1989a; 1989b). A 51% chance of being male versus a 49% chance of being female would result in a male classification, yet in reality the individual would not clearly be falling into either category. Thus zones of ambiguity were defined around the dividing points of each function, depending on the dispersion and overlap of the sexed groups along the discriminant function continuum. Indeterminate individuals within these zones were classified as either 'probable' males or 'probable' females. Confidence in allocation was improved further by comparing the probability of group membership resulting from the respective functions. Precedence was given to the classification provided by the mandibular canine, but in cases where the sex probability was marginal, or measurement of this tooth was not possible, reliability in classification was assessed by observing probabilities obtained from other tooth types.

Sex assignments were attributed to 46 subadults from Abingdon and 37 subadults from Fishergate. The proportions allotted to each sex classification are illustrated by the pie charts in figure 3.3a/b, and the frequencies are presented according to sex and age in tables 3.5 and 3.6. A greater proportion of the Fishergate subadults were classified as being of 'probable' sex, compared with those from Abingdon. This was largely because there were fewer mandibular canines available in the Fishergate sample. The proportion of male classifications exceeded the proportion of female classifications in both cemeteries. Chi-square tests revealed that the ratio of boys to girls in each assemblage was not statistically significantly different from that which would be expected by pure chance ($p>0.05$) and no association was found between sex and age at death ($p>0.05$) (table 3.5 and 3.6). However, this would probably be expected given the relatively small size of the samples. The youngest individual ascribed a sex classification was estimated to be aged five. The minimum age for sex classification using the mandibular canine was six years. This was possible because crown formation of the lower canine is complete around that age, even though eruption has not taken place (Hillson 1996:125). One benefit of the fragmentary nature of archaeological remains is that post-mortem fracturing of the mandible often occurs at the foramina mentalia to reveal the unerupted mandibular canines.

3.4 Discussion and Conclusions

Analysis of permanent tooth measurements taken on the sexed reference samples of 77 adults (43 male and 34 female) from Abingdon and 124 adults (88 male and 36 female) from Fishergate demonstrated that clear, consistent differences existed between the size of male and female teeth. Mean male values exceeded mean female values in virtually all of the 48 dimensions examined. Univariate analysis of the data demonstrated that for the majority of these measurements, the sex difference was statistically significant ($p<0.05$). Discriminant function analysis enabled the sexes to be distinguished entirely on the basis of tooth size. A function combining the buccolingual diameter and crown height of the mandibular canine provided the most effective discrimination within the Abingdon group, assigning 94% of the reference sample ($n=32$) to the sex allocations provided by conventional methods. A function which combined the crown height and mesiodistal diameter of the mandibular canine provided the most effective discrimination within the Fishergate group, correctly allocating 88% of cases in the reference sample ($n=67$). Results of a holdout sampling procedure supported the hypothesis that the discriminant functions derived from the base samples could be used to predict the sex of subadults from the cemeteries. Sex classifications were attributed to 46 subadults from Abingdon and 37 subadults from Fishergate, aged between five and eighteen years. Aside from permitting the sexual diagnosis of subadults, a further application of the technique might be to infer the sex of adults which have been designated as 'indeterminate' using traditional methods, due to incomplete bone preservation or poorly developed sexually dimorphic features in the skeleton, although increased dental attrition with advancing age may be preclude this application. Alternatively, the method might be used to verify other experimental methods of subadult sex determination (Molleson *et al.* 1998).

Accuracy in sex allocation would appear to be similar to that achieved by other metrical sexing methods (Giles 1964; 1966; Giles and Elliot 1963; Kieser *et al.* 1992; Pons 1955; Schutkowski 1993; St Hoyme and Iscan 1989; Thieme and Schull 1957; Van Gerven 1972; Workshop of European Anthropologists 1980). Efforts were made to improve reliability in subadult classification by taking measures of the probability of group membership into consideration, for all appropriate functions. Nevertheless, the reliability of the subadult sex assignments cannot be quantified definitively because an alternative method of confirming sex is not available. An independent sexing method using DNA extraction was attempted on a sample from the Abingdon cemetery, in a collaborative study by Evison (1996). Although seven of the twelve samples examined did yield PCR products, these were attributed to modern contamination. An alternative method of determining the reliability of subadult sex classifications might be provided by applying the technique to a modern series with known sex (Garn *et al.* 1977; 1979). However, this would depend on the assumption that expression of dental sexual dimorphism is similar between modern and archaeological samples (Frayer and Wolpoff 1985; Garn, Lewis, Swindler and Kerewsky 1967; Hanihara 1989; 1990; Matsumura 1989) which are comprised of a different genetic composition and are likely to have been subjected to different environmental influences. This is a problem acknowledged, yet accepted, in other areas of biological anthropology such as stature estimation (Trotter 1970), although it could be argued that misclassification due to this limitation may have more significant implications when determining discontinuous as opposed to continuous traits.

Although no sex bias in the incidence of misclassification was evident in the discriminant analyses, one possible source should be recognised concerning the early gradation of occlusal and approximal attrition. Whilst every effort was made to ensure that teeth selected for the adult reference samples exhibited no evidence of attrition, this was nevertheless a subjective judgement. It is conceivable that teeth with just a few tenths of a millimetre of enamel tissue loss, not apparent to the eye, were included. In practice, this might imply that girls have slightly larger teeth than women, and boys might have slightly larger teeth than adult men. Since mean sex differences in tooth dimensions were sometimes of a similar magnitude, it is possible that some subadult females may have been misclassified as males. The converse is unlikely to occur as this factor would simply result in boys being placed further along the discriminant function continuum into the male cluster. Unfortunately, it is envisaged that this potential source of bias would be almost impossible to quantify. Firstly, while general reductions in tooth size due to attrition might be estimated for the total sample by correlating tooth size with skeletal age, such a procedure would depend on the circular assumption that equal proportions of subadult males and females were present in the sample, otherwise advancement in attrition might be masked by sex differences in tooth size. Secondly, on an individual level, the extent of such slight, early attrition could depend on dietary preferences or availability. Another possible source of sex bias in misclassification may be associated with the idea that individuals experiencing poor health and nutrition during childhood may be predisposed to a premature death. Poor health and nutrition during growth may impair dental development, possibly resulting in reduced tooth size, and Goodman and colleagues (1984) have commented that the canines are relatively susceptible to environmental stress. Thus individuals experiencing childhood mortality may tend to exhibit smaller tooth dimensions. Although difficult to demonstrate, this could lead to a bias toward female classification (Mays 1998:42; Molleson *et al.* 1998). The theory that males have a greater biological sensitivity to environmental stress might also leave males more prone to reduced tooth size as a result of poor health or nutrition (see chapter 6). This could potentially lead to reduced dimorphism (Goodman *et al.* 1984; Stini 1985), or again, perhaps result in a bias toward female classification. This limitation might have more profound effects within populations subject to greater levels of environmental stress.

Practical limitations of the method were that the collection of data was a time consuming operation and predominantly, that missing values greatly impeded statistical analysis, especially the derivation of discriminant functions. This suggests that the technique is only suitable for large, well preserved cemeteries from which an adequate base sample can be procured. Indeed, attempts were made to apply the method to the assemblage from the cemetery of St Nicholas Shambles, London, but the poor preservation of the material impeded the ability to construct adequate reference data (see section 2.2 and 5.3). This inevitably returns the question as to whether discriminant functions derived from one cemetery sample can be applied to another. Cross-sample application of discriminant functions would eliminate the need to derive functions from a base sample of sexed material, providing a quick, simple procedure for sex determination.

The majority of studies which have investigated sample specificity of discriminant functions have focused on osteological rather than dental material, and on groups which might be considered ethnically diverse. Giles and Elliot (1963) derived 21 discriminant functions from cranial data of 75 black Americans, 75 white Americans and from the two samples combined. Sex classification rates of between 82-89% were achieved from all samples. They concluded that 'discriminant functions based on the two races combined do, for practical purposes, equally well for both races as do those based on and applied to a single race. This important result suggests that the sex discriminant function is employing basic differences and relationships in cranial morphology which are largely independent of racial variation' (p.64). Giles (1966) refers to two further studies in which these functions were applied to correctly sex 87% of a sample of 45 Aboriginal crania, and 88 out of 91 Japanese crania.

Conversely, Calcagno (1981) derived discriminant functions from the mandibular dimensions of 97 'American Whites', 100 'American Blacks' and an archaeological sample of 72 American Indians. Classification rates of up to 96% were achieved when the functions were applied to their respective samples. Functions derived from the American Whites were then used to classify the American Blacks and vice versa. Although classification rates above 85% were achieved, there was a discrepancy in the proportion of males and females correctly allocated. A similar result was realised when functions derived from the combined American black and white samples were used to classify the American Indians. Calcagno attributes this finding to size variation within the same sex of different populations, concluding that discriminant functions 'work with tremendous accuracy on the population upon which they are based . . . However, the reliability of the technique markedly decreases when populations are sexed by functions based on unrelated populations' (p.198).

Defining the ethnic or genetic composition of an archaeological assemblage is perhaps an impossible task, and is a contentious issue; but perhaps discriminant functions could be derived that are generally applicable to cemetery samples which might be considered to be more homogeneous than those tested in the studies described above. Additionally, cross-sample application of discriminant functions based on dental measurements may offer a more promising area of research than those based on bone (Falk and Corruccini 1982), owing to the differing degree of genetic and environmental influences exerted on bone and tooth development. Bone development may be strongly influenced by environmental factors, and following the cessation of growth, bone continues to be remodelled via osteoclastic/blastic activity which can also be affected by environmental pressures. Research suggests that tooth size is more strongly governed by genetic factors (Hillson, 1986:235-242). Furthermore, once development is complete within the jaws, tooth form is not altered by repair processes. Thus cross-sample application of functions based on dental measurements may be less affected by differences in metrical variation resulting from local environmental influences. Bone is also more susceptible to deformation following burial.

To give an indication of whether this approach might work in practice, the most effective discriminant function derived from the Abingdon reference sample (function 9) was used to classify the reference sample from Fishergate (function 9), and vice versa. Both functions utilised measurements taken on the mandibular canine. The results, presented in table 3.7, indicated a similar success rate for both functions. That derived from the Fishergate reference sample correctly classified 81.3% of individuals from Abingdon (*n*=32), and the function derived from the Abingdon base sample correctly classified 79.4% of individuals from Fishergate (*n*=68). There was no sex bias in the proportion of individuals misclassified from either cemetery. The same procedure was applied to sex the subadults from the respective cemeteries for which the appropriate mandibular canine measurements had been recorded. The functions derived from the Abingdon and Fishergate reference samples ascribed the same sex classification to 83.7% of subadults from Abingdon (*n*=43), and 77.8% of subadults from Fishergate (*n*=27). Since a similar proportion of subadult sex assignments were in agreement, and a similar proportion of adults were correctly sexed when the functions were cross-applied, this may suggest a similar pattern of dimorphism in both cemeteries. This may imply that the development of a generally applicable discriminant function would be feasible. However, extensive further research would clearly be necessary to assess this possibility.

Of critical importance would be the need to determine exactly how generally applicable a given function might be. There is evidence that variations do exist in the pattern of sexual dimorphism between cemeteries, which could defeat the possibility of constructing widely applicable discriminant functions. For example, Molleson and co-workers (Molleson *et al.* 1985; Molleson 1989; 1993:180) identified pronounced sexual dimorphism in the buccolingual and mesiodistal crown diameters of adults from the Romano-British site of Poundbury, Dorset, which enabled the sex of subadults from the site to be assessed. By contrast, Molleson and Cox (1993:23-25) detected only weak dimorphism in these measurements among the adults retrieved from the crypt at Spitalfields, dating to the eighteenth and nineteenth centuries, which prohibited any attempt to sex subadults from the assemblage. An alternative possibility might therefore be to construct functions for use on certain groups.

The results of this study indicate that future research directions should focus on large, well preserved collections and on the construction of reference data derived from very young adults with no visible tooth wear, which have been tightly sexed using conventional methods. While the lower canine may offer the greatest potential for indicating sex, it may be beneficial to include all tooth types, for use on marginal cases or those lacking mandibular canines. Crown height measurements should be included in all analyses. Inter-observer variation in measurement would be a critical factor for evaluation in any attempt to construct generally applicable discriminant functions. With such small mean sex differences observable in many dimensions, this could have a serious impact on results. Rather than assessing the success of any tooth sexing function according to the proportion of correctly sexed individuals in an entire sample, perhaps future research should also focus on measures of the probability of group membership. This approach may at least enable a proportion of subadults to be sexed with confidence, even if sex assignments cannot be reliably placed on all subadults in a given assemblage. Discriminating power could be determined using posterior and typicality probability methods advocated by Kieser (1990:44-49). These might be particularly appropriate for use in the assessment of cross-sample applications of discriminant functions.

Another area for future research might be sexual dimorphism in the deciduous dentition. Black (1978) was able to correctly sex up to 75% of a living sample of 69 boys and 64 girls from Michigan, USA, using buccolingual and mesiodistal deciduous crown diameters. Similarly, DeVito and Saunders (1980; 1989) found statistically significant differences in all 40 deciduous crown measurements (20 mesiodistal and 20 buccolingual) taken from a group of 162 Canadian children, and discriminant function analysis enabled 76-96% of a holdout sample to be correctly classified by sex. If discriminant functions based on permanent teeth could be developed for general application to archaeological cemetery series, it may be possible to correlate sexual dimorphism in deciduous teeth via the period of mixed dentition. This might enable sex determination of individuals as young as one year post-partum, when all deciduous tooth crowns are complete.

Table 3.1a Difference between contralateral tooth measurements within the Abingdon base sample
(*t*-tests applied to all measurement sample pairs; sign tests applied to samples not conforming to a normal distribution)

n number of individuals in sample *p* probability

		Buccolingual			Mesiodistal			Crown Height			Root Length		
	Tooth Pair	*n*	*t*	*p*	*n*	*t*	*p*	*n*	*t*	*p*	*n*	*t*	*p*
Paired sample *t*-tests on males	11 - 21	21	-0.118	.908	12	1.318	.214	5	0.272	.799	22	-1.560	.134
	12 - 22	16	-0.255	.802	13	-0.834	.420	9	1.018	.388	15	1.815	.091
	13 - 23	24	-1.735	.096	20	-1.159	.261	11	0.697	.502	21	0.889	.385
	14 - 24	22	-0.111	.912	19	1.552	.138	13	0.378	.712	12	1.442	.177
	15 - 25	21	-0.627	.538	19	-0.335	.742	12	0.709	.493	9	0.989	.352
	16 - 26	18	-0.542	.595	14	-1.629	.127	7	-0.385	.714	2	-1.000	.500
	31 - 41	16	-1.315	.208	8	1.667	.140	1	-	-	19	-0.291	.775
	32 - 42	21	0.902	.378	10	-0.957	.364	4	0.567	.610	23	-1.988	.058
	33 - 43	28	-0.999	.327	19	0.524	.607	9	-0.114	.912	22	0.157	.876
	34 - 44	29	0.142	.888	24	-0.378	.709	11	1.654	.129	22	-0.969	.343
	35 - 45	25	-0.740	.467	22	0.364	.719	10	1.411	.192	16	-1.448	.168
	36 - 46	18	-0.987	.337	17	-0.192	.850	2	1.000	.500	0	-	-
Paired sample *t*-tests on females	11 - 21	14	0.400	.696	7	3.286	.017	2	-1.333	.410	14	-1.499	.158
	12 - 22	16	-0.775	.451	13	-1.740	.107	11	-0.215	.834	17	-1.233	.235
	13 - 23	17	0.482	.636	15	0.480	.638	11	-1.183	.264	15	0.812	.430
	14 - 24	19	-0.626	.539	16	-1.027	.321	11	-0.922	.378	11	0.782	.452
	15 - 25	18	2.263	.037	15	-0.397	.698	8	-0.426	.683	11	-1.096	.299
	16 - 26	11	1.747	.111	11	-0.449	.663	2	-	-	1	-	-
	31 - 41	20	1.577	.131	13	1.612	.133	2	-0.385	.766	17	-0.401	.694
	32 - 42	22	-0.399	.694	18	1.144	.269	5	0.784	.477	25	-1.832	.079

Table 3.1a contd. . . . /

Table 3.1a (contd.)

		Buccolingual			Mesiodistal			Crown Height			Root Length		
	Tooth Pair	*n*	*t*	*p*	*n*	*t*	*p*	*n*	*t*	*p*	*n*	*t*	*p*
	33 - 43	24	-1.199	.243	22	0.681	.503	12	1.644	.128	23	-0.661	.515
	34 - 44	25	-0.352	.728	25	-0.323	.749	15	1.239	.236	21	0.102	.919
	35 - 45	20	0.687	.500	19	0.187	.854	10	-0.711	.495	16	1.360	.194
	36 - 46	13	-0.551	.592	10	0.573	.581	2	-0.500	.705	2	1.667	.344
Sign tests on males	11 - 21							5		1.000			
	12 - 22							9		.453			
	15 - 25										9		.508
	16 - 26							7		1.000	2		.317
	31 - 41				8		.289						
	32 - 42				10		1.000	4		1.000			
	33 - 43							9		1.000			
	36 - 46							2		.317			
Sign tests on females	11 - 21				7		.388	2		.500			
	15 - 25	18		.453				8		.453			
	16 - 26							2		.500			
	31 - 41							2		1.000			
	32 - 42							5		1.000			
	36 - 46							2		1.000	2		.500

Table 3.1b Difference between contralateral tooth measurements within the Fishergate base sample
(*t*-tests applied to all measurement sample pairs; sign tests applied to samples not conforming to a normal distribution)

n number of individuals in sample *p* probability

		Buccolingual			Mesiodistal			Crown Height			Root Length		
	Tooth Pair	*n*	*t*	*p*	*n*	*t*	*p*	*n*	*t*	*p*	*n*	*t*	*p*
Paired sample	11 - 21	25	-0.575	.571	12	0.340	.740	0	-	-	25	1.133	.269
t-tests on	12 - 22	30	-0.875	.389	25	0.899	.378	7	2.121	.078	19	0.499	.624
males	13 - 23	48	-0.199	.843	39	0.596	.555	9	-0.492	.636	21	1.526	.143
	14 - 24	50	-0.562	.577	42	-0.784	.437	22	1.150	.263	11	1.040	.323
	15 - 25	41	0.666	.509	25	-1.345	.191	15	-0.902	.382	6	0.412	.698
	16 - 26	36	-0.892	.379	22	0.646	.525	8	-2.236	.060	3	-1.562	.259
	31 - 41	31	0.373	.712	11	1.789	.104	1	-	-	25	-0.930	.362
	32 - 42	38	0.699	.489	22	-0.365	.719	3	-0.229	.840	33	1.839	.075
	33 - 43	48	-0.082	.935	41	1.612	.133	7	0.447	.671	27	0.909	.929
	34 - 44	58	0.329	.744	53	-0.620	.538	21	-0.502	.621	24	0.396	.696
	35 - 45	57	-1.857	.069	47	0.102	.919	15	0.530	.604	24	0.724	.477
	36 - 46	40	-1.629	.127	30	-0.411	.684	0	-	-	2	3.000	.205
Paired sample	11 - 21	11	-0.199	.846	4	2.449	.092	1	-	-	10	-1.701	.123
t-tests on	12 - 22	11	-1.148	.278	9	0.756	.471	4	-0.182	.867	11	-0.502	.626
females	13 - 23	14	-0.234	.818	13	0.000	1.000	4	0.962	.407	7	-0.745	.484
	14 - 24	12	0.801	.440	11	0.653	.528	5	-0.069	.948	2	-0.885	.539
	15 - 25	14	-0.939	.365	9	0.526	.613	5	0.302	.778	3	-0.878	.473
	16 - 26	9	0.994	.349	7	2.248	.066	0	-	-	1	-	-
	31 - 41	18	0.345	.734	2	3.000	.205	0	-	-	11	-0.343	.739
	32 - 42	17	1.542	.143	5	-1.177	.305	3	1.562	.259	12	0.401	.696

Table 3.1b contd. . . /

Table 3.1b (contd.)

	Tooth Pair	Buccolingual			Mesiodistal			Crown Height			Root Length		
		n	*t*	*p*	*n*	*t*	*p*	*n*	*t*	*p*	*n*	*t*	*p*
	33 - 43	22	1.739	.097	20	1.747	.111	1	-	-	15	-0.057	.955
	34 - 44	25	1.706	.101	24	-0.290	.774	14	0.338	.741	16	0.687	.503
	35 - 45	23	-1.960	.063	20	-1.301	.209	6	0.990	.368	12	0.273	.790
	36 - 46	18	-1.740	.107	15	0.685	.505	0	-	-	0	-	-
Sign tests on males	11 - 21												
	12 - 22							7		.219			
	13 - 23							9		1.000			
	15 - 25										6		.688
	16 - 26							8		.219	3		.250
	31 - 41												
	32 - 42							3		1.000			
	33 - 43							7		.688			
	36 - 46										2		.500
Sign tests on females	11 - 21				4		.250						
	12 - 22				9		1.000	4		1.000			
	13 - 23							4		.625	7		1.000
	14 - 24							5		1.000	2		1.000
	15 - 25				9		1.000	5		1.000	3		1.000
	16 - 26	9		1.000	7		.219						
	31 - 41				2		.500						
	32 - 42				5		.625	3		1.000			
	35 - 45							6		.219			
	36 - 46												

Table 3.2a Sex difference in tooth measurements within the Abingdon base sample (two-tailed *t*-tests and Mann-Whitney *U* tests)

n number of individuals in sample $\bar{x}$ sample mean *p* probability

		Males		Females		*t*-test		*U*-test	
	Tooth	*n*	$\bar{x}$	*n*	$\bar{x}$	*t*	*p*	*U*	*p*
Buccolingual	I^1	29	7.0	22	6.7	2.93	0.005	175.5	0.006
	I^2	30	6.2	26	5.9	2.70	0.009	234.5	0.011
	C^1	34	8.3	27	7.6	5.82	0.000	137.0	0.000
	P^1	31	8.6	25	8.2	3.10	0.003	221.0	0.006
	P^2	33	8.9	27	8.3	4.17	0.000	193.5	0.000
	M^1	22	11.3	20	10.8	3.53	0.001	96.5	0.002
	I_1	26	5.9	24	5.6	3.63	0.001	145.5	0.001
	I_2	27	6.3	30	6.0	2.84	0.006	236.0	0.007
	C_1	36	7.8	30	7.1	7.80	0.000	92.5	0.000
	P_1	37	7.5	30	7.2	2.90	0.005	314.0	0.002
	P_2	36	8.0	29	7.5	4.62	0.000	204.5	0.000
	M_1	29	10.4	20	10.1	1.50	0.141	170.5	0.015
Mesiodistal	I^1	16	8.5	15	8.0	2.99	0.006	43.5	0.002
	I^2	22	6.5	23	6.4	0.72	0.474	206.5	0.290
	C^1	26	7.6	22	7.2	4.38	0.000	115.0	0.000
	P^1	25	6.6	24	6.2	3.55	0.001	121.0	0.000
	P^2	25	6.4	24	6.1	3.58	0.001	137.5	0.001
	M^1	22	10.4	19	9.7	4.25	0.000	71.0	0.000
	I_1	13	5.2	15	5.1	0.83	0.412	75.0	0.298
	I_2	16	5.8	23	5.7	0.77	0.449	131.0	0.128
	C_1	27	6.6	24	6.3	3.37	0.001	155.0	0.001
	P_1	31	6.7	29	6.3	3.28	0.002	224.0	0.001
	P_2	30	6.8	27	6.5	2.53	0.014	252.5	0.015
	M_1	26	11.0	18	10.3	3.90	0.000	95.5	0.001
Crown Height	I^1	9	11.0	6	9.1	2.81	0.015	6.0	0.013
	I^2	14	9.4	16	8.9	1.86	0.073	63.0	0.041
	C^1	17	10.1	18	8.9	3.09	0.004	55.5	0.001
	P^1	18	8.0	19	7.1	3.74	0.001	72.0	0.003
	P^2	17	7.3	17	6.7	2.57	0.015	76.5	0.019
	M^1	8	7.1	6	6.5	1.90	0.082	14.0	0.194
	I_1	5	8.6	3	7.9	0.96	0.375	5.0	0.456
	I_2	9	9.0	9	8.3	1.93	0.071	18.0	0.047
	C_1	14	11.0	19	9.0	5.60	0.000	22.0	0.001
	P_1	18	7.9	24	7.0	3.43	0.001	94.5	0.002
	P_2	13	7.8	16	6.8	2.86	0.008	45.0	0.010
	M_1	2	7.1	3	7.0	0.09	0.933	2.5	0.767

Table 3.2a contd. . . /

Table 3.2a (contd.)

		Males		Females		*t*-test		*U*-test	
	Tooth	*n*	$\bar{x}$	*n*	$\bar{x}$	*t*	*p*	*U*	*p*
Root Length	I^1	28	13.2	23	11.6	4.08	0.000	117.0	0.001
	I^2	34	12.9	26	11.9	2.73	0.008	271.0	0.011
	C^1	29	16.4	24	14.7	2.74	0.008	165.5	0.001
	P^1	21	13.1	21	12.2	1.67	0.104	149.5	0.074
	P^2	21	13.8	19	12.3	3.50	0.001	83.5	0.002
	M^1	13	13.0	9	11.3	2.91	0.009	19.5	0.009
	I_1	28	13.2	24	11.9	3.58	0.001	154.5	0.001
	I_2	35	14.5	30	13.5	2.62	0.011	314.0	0.006
	C_1	39	15.6	29	14.1	3.83	0.000	287.0	0.001
	P_1	35	13.9	27	13.7	0.45	0.652	334.0	0.049
	P_2	30	14.7	29	13.9	1.77	0.083	301.0	0.042
	M_1	4	14.5	6	12.9	1.65	0.137	6.0	0.201

Table 3.2b Sex difference in tooth measurements within the Fishergate base sample (two-tailed *t*-tests and Mann-Whitney *U* tests)

n number of individuals in sample $\bar{x}$ sample mean *p* probability

		Males		Females		*t*-test		*U*-test	
	Tooth	*n*	$\bar{x}$	*n*	$\bar{x}$	*t*	*p*	*U*	*p*
Buccolingual	I^1	51	7.0	16	6.7	2.15	0.036	254.0	0.023
	I^2	57	6.1	23	6.0	1.10	0.273	549.5	0.259
	C^1	71	8.2	23	7.7	3.25	0.002	463.0	0.002
	P^1	72	8.6	22	8.6	0.22	0.829	744.5	0.671
	P^2	68	8.9	20	8.9	-0.16	0.870	648.0	0.750
	M^1	57	11.0	15	10.8	1.57	0.121	327.0	0.163
	I_1	55	5.8	21	5.6	1.43	0.157	488.0	0.298
	I_2	59	6.2	27	5.9	2.36	0.020	584.5	0.048
	C_1	78	7.7	31	7.1	5.79	0.000	509.0	0.000
	P_1	81	7.4	32	7.2	1.90	0.060	1031.0	0.091
	P_2	79	8.0	33	7.7	2.67	0.009	930.0	0.017
	M_1	59	10.3	29	9.9	2.82	0.006	590.0	0.018
Mesiodistal	I^1	35	8.4	7	8.0	1.84	0.073	63.0	0.044
	I^2	52	6.4	20	6.2	2.51	0.014	312.0	0.009
	C^1	68	7.5	23	7.1	4.40	0.000	335.0	0.000
	P^1	67	6.5	23	6.5	0.65	0.517	723.5	0.663
	P^2	55	6.3	20	6.4	-1.04	0.301	457.0	0.264
	M^1	49	9.9	17	9.7	1.12	0.268	335.5	0.234
	I_1	23	5.2	5	5.3	-0.56	0.583	51.5	0.718
	I_2	42	5.8	10	5.7	0.77	0.446	180.0	0.485
	C_1	70	6.7	28	6.2	6.34	0.000	306.5	0.000
	P_1	79	6.6	31	6.4	1.87	0.065	1003.0	0.141
	P_2	71	6.7	32	6.6	2.34	0.021	821.0	0.025
	M_1	56	10.9	28	10.6	2.75	0.007	478.5	0.004
Crown Height	I^1	12	10.9	3	10.5	0.74	0.470	13.0	0.469
	I^2	34	9.6	14	8.7	3.62	0.001	88.5	0.001
	C^1	45	10.2	16	9.2	4.04	0.000	139.0	0.000
	P^1	48	7.8	15	7.3	2.18	0.033	230.0	0.036
	P^2	36	7.0	9	6.6	1.64	0.109	113.0	0.164
	M^1	18	6.6	3	6.3	0.93	0.363	17.5	0.338
	I_1	4	9.3	0	-	-	-	-	-
	I_2	17	9.4	4	8.5	3.04	0.007	8.0	0.020
	C_1	50	11.2	18	9.8	6.84	0.000	97.5	0.000
	P_1	58	8.2	24	7.4	3.47	0.001	314.0	0.000
	P_2	42	7.4	16	6.8	3.15	0.003	164.5	0.003
	M_1	2	8.6	3	6.0	1.32	0.279	1.0	0.248

Table 3.2b contd. . . /

Table 3.2b (contd.)

		Males		Females		*t*-test		*U*-test	
	Tooth	*n*	$\bar{x}$	*n*	$\bar{x}$	*t*	*p*	*U*	*p*
Root Length	I^1	50	12.9	16	12.3	1.33	0.188	301.0	0.138
	I^2	51	13.2	22	12.8	1.25	0.215	524.0	0.656
	C^1	48	16.8	20	15.4	2.22	0.030	342.5	0.064
	P^1	36	13.3	10	12.3	1.35	0.183	130.5	0.187
	P^2	33	14.4	12	13.5	1.48	0.146	133.5	0.098
	M^1	11	12.8	8	11.2	2.56	0.020	17.0	0.026
	I_1	47	13.3	20	12.6	2.07	0.042	327.0	0.050
	I_2	54	14.6	27	13.9	2.15	0.034	461.0	0.007
	C_1	63	16.0	30	15.1	2.01	0.047	732.5	0.081
	P_1	55	14.5	29	14.4	0.29	0.772	730.0	0.525
	P_2	49	15.4	30	14.9	1.34	0.183	621.5	0.251
	M_1	13	13.2	6	13.3	-0.09	0.928	38.0	0.930

Table 3.3a Per cent sexual dimorphism and relative rankings of dimorphism for teeth in the maxilla and mandible within the Abingdon base sample

n number of individuals in sample % per cent sexual dimorphism

		Maxilla			Mandible		
	Tooth	*n*	%	Rank	*n*	%	Rank
Buccolingual	I1	51	4.8	6	50	5.6	3
	I2	56	5.2	5	57	5.1	5
	C	61	9.7	1	66	10.4	1
	P1	56	5.9	3	67	5.2	4
	P2	60	7.3	2	65	7.6	2
	M1	42	5.3	4	59	2.8	6
Mesiodistal	I1	31	5.6	3	28	2.2	5
	I2	45	1.8	6	39	1.6	6
	C	48	6.4	2	61	5.0	3
	P1	49	5.3	5	60	5.6	2
	P2	49	5.6	3	57	4.2	4
	M1	41	7.3	1	44	6.6	1
Crown Height	I1	15	20.2	1	8	9.2	4
	I2	30	5.7	6	18	9.2	4
	C	35	13.2	2	33	22.7	1
	P1	37	12.4	3	42	13.1	3
	P2	38	8.8	4	29	13.5	2
	M1	14	8.0	5	5	0.4	6
Root Length	I1	51	13.2	2	52	10.8	1
	I2	60	8.1	5	65	7.6	4
	C	53	11.3	4	68	10.3	2
	P1	42	7.3	6	62	1.6	6
	P2	40	12.2	3	59	5.5	5
	M1	22	14.6	1	10	9.1	3

Table 3.3b Per cent sexual dimorphism and relative rankings of dimorphism for teeth in the maxilla and mandible within the Abingdon base sample

n number of individuals in sample % per cent sexual dimorphism

		Maxilla			Mandible		
		n	%	Rank	*n*	%	Rank
Buccolingual	I1	67	4.1	2	76	2.8	4
	I2	80	1.9	4	86	3.7	3
	C	94	5.5	1	109	8.2	1
	P1	94	0.3	5	113	2.8	4
	P2	88	-0.3	5	112	4.3	2
	M1	72	2.6	3	88	4.3	2
Mesiodistal	I1	42	4.6	3	28	-1.9	5
	I2	72	4.8	2	52	1.8	6
	C	91	5.9	1	98	8.1	1
	P1	90	1.0	5	110	2.8	4
	P2	75	-1.6	4	103	3.0	3
	M1	66	1.6	4	84	3.1	2
Crown Height	I1	15	3.8	6	4	-	-
	I2	48	10.5	2	21	11.2	3
	C	61	11.1	1	68	13.9	2
	P1	63	5.9	4	82	10.9	4
	P2	45	6.1	3	58	9.1	5
	M1	21	4.7	5	5	43.3	1
Root Length	I1	66	4.9	5	67	5.5	3
	I2	73	3.5	6	81	5.6	1
	C	68	9.3	2	93	5.6	1
	P1	46	7.6	3	84	0.8	5
	P2	45	6.3	4	79	3.2	4
	M1	19	15.1	1	16	-0.5	6

Table 3.4a Results of the Discriminant Analyses for the Abingdon base sample

m number of measurements submitted for analysis after Rösing (1983) *nm* number of males nm_f number of males misclassified

nf number of females nf_f number of females misclassified %*r* percentage of correctly classified individuals

%*rH* percentage of correctly classified individuals using the holdout method

Measurement prefixes to tooth types: BL = buccolingual diameter; MD = mesiodistal diameter; CH = crown height; RL = root length
a = Discriminant analysis not conducted because all cases submitted for analysis were of the same sex
b = Discriminant analysis not conducted because no cases qualified for inclusion
c = F values for all variables submitted were insufficient for discriminant analysis to proceed

Function	Teeth (*m*)	Measurements selected by stepwise procedure	nm/nm_f	nf/nf_f	%*r*	*p*	%*rH*
1	I^1 (4)	RLI^1 CHI^1 BLI^1	6/0	9/0	100.0	0.0024	
2	I^2 (4)	BLI^2 RLI^2 CHI^2	12/5	16/2	75.0	0.0151	
3	C^1 (4)	BLC^1 MDC^1	26/5	22/5	79.2	0.0000	76.5
4	P^1 (4)	MDP^1 BLP^1 CHP^1	17/3	19/2	86.1	0.0001	81.2
5	P^2 (4)	BLP^2 MDP^2 RLP^2	17/3	17/3	82.4	0.0001	77.9
6	M^1 (4)	CHM^1 RLM^1	6/1	4/0	90.0	0.0242	
7	I_1 (4)	RLI_1 BLI_1	23/5	22/5	77.8	0.0475	
8	I_2 (4)	RLI_2 CHI_2	9/1	9/2	83.3	0.0924	
9	C_1 (4)	BLC_1 CHC_1	13/1	19/1	93.8	0.0000	91.8
10	P_1 (4)	MDP_1 CHP_1 RLP_1 BLP_1	17/4	23/4	80.0	0.0003	78.2
11	P_2 (4)	BLP_2 CHP_2 RLP_2	12/1	16/2	89.3	0.0000	87.2
12	M_1 (4)	CHM_1	2/0	3/2	60.0	0.2674	
13	I^1 I_1 (8)	CHI^1 CHI_1	5/0	1/0	100.0	0.0537	
14	I^2 I_2 (8)	RLI^2	34/14	26/11	58.3	0.0204	
15	C^1 C_1 (8)	BLC_1	36/7	30/5	81.8	0.0000	
16	P^1 P_1 (8)	BLP^1 CHP^1 MDP_1	18/3	19/2	86.5	0.0005	
17	P^2 P_2 (8)	RLP_2 RLP^2 CHP^2 BLP^2 MDP_2	14/2	13/0	92.6	0.0000	

Table 3.4a contd. . . /

Table 3.4a (contd.)

Function	Teeth (*m*)	Measurements selected by stepwise procedure	*nm* / *nm*$_f$	*nf* / *nf*$_f$	%*r*	*p*
18	M^1 M_1 (6)	BLM_1 RLM^1 MDM_1	11/4	6/0	76.5	0.0071
19	I^1 M^1 (7)	CHI^1 MDI^1 MDM^1 BLI^1	8/0	4/1	91.7	0.0093
20	I_1 M_1 (7)	BLM_1	29/6	20/9	69.4	0.2906
21	I^1 M^1 I_1 M_1(14)	a				
22	I^1 C^1 (8)	BLC^1 BLI^1 RLC^1 RLI^1 CHC^1	15/5	15/2	76.7	0.0005
23	I_1 C_1 (8)	BLC_1 MDI_1 RLC_1	13/2	15/2	85.7	0.0017
24	I^1 C^1 I_1 C_1 (16)	BLI^1 RLC^1	25/8	20/13	53.3	0.0335
25	I^1 I^2 C^1 (12)	BLI^1 RLC^1 BLC^1 RLI^1 CHC^1 MDC^1 RLI^2 CHI^2	9/1	12/2	85.7	0.0062
26	I_1 I_2 C_1 (12)	BLC_1 MDI_1 RLC_1	13/2	15/2	85.7	0.0128
27	I^1 I^2 C^1 I_1 I_2 C_1 (24)	RLC^1	29/12	24/3	71.0	0.1968
28	P^1 P^2 M^1 (11)	MDP^1 RLP^2 RLP^1 BLM^1	14/2	11/2	84.0	0.0001
29	P_1 P_2 M_1 (11)	BLP_2 CHP_1 RLP_2 BLM_1 RLP_1	14/1	16/10	63.33	0.0032
30	C^1 P^1 P^2 M^1 (15)	BLP^1 BLP^2 RLP^2 MDP^2 MDP^1 RLP^1 RLP^1	10/0	6/1	93.8	0.0000
31	C_1 P_1 P_2 M_1 (15)	BLP_2 CHC_1 RLP_1 BLM_1 MDM_1	13/2	13/9	57.7	0.0031
32	I^2 C^1 (8)	BLC^1 CHC^1	17/2	18/3	85.7	0.0001
33	I_2 C_1 (8)	BLC_1 RLC_1 MDC_1	24/4	24/4	83.3	0.0000
34	I^2 C^1 I_2 C_1 (16)	BLC_1 RLI_2 BLI^2 BLI_2	20/2	22/2	90.5	0.0029
35	I^1 (3)	CHI^1	9/4	6/1	66.7	0.0330
36	I^2 (3)	BLI^2 CHI^2	13/2	16/5	75.9	0.0151
37	C^1 (3)	BLC^1 MDC^1	26/5	22/5	79.2	0.0000
38	P^1 (3)	BLP^1 CHP^1	18/3	19/2	86.5	0.0000
39	P^2 (3)	BLP^2 CHP^2	17/3	17/3	82.4	0.0002
40	I_1 (3)	BLI_1	26/10	24/6	68.0	0.1669
41	I_2 (3)	BLI_2 CHI_2	6/2	9/2	73.3	0.1605

Table 3.4a contd. . . /

Table 3.4a (contd.)

Function	Teeth (*m*)	Measurements selected by stepwise procedure	*nm* /*nm*$_f$	*nf* /*nf*$_f$	%r	*p*
42	C_1 (3)	BLC_1 CHC_1	13/1	19/1	93.8	0.0000
43	P_1 (3)	CHP_1 BLP_1 MDP_1	18/5	24/5	76.2	0.0059
44	P_2 (3)	BLP_2 CHP_2	13/2	16/2	86.2	0.0000
45	I^1 I_1 (6)	CHI^1 CHI_1	5/0	1/0	100.0	0.0537
46	I^2 I_2 (6)	BLI^2	30/13	26/8	62.5	0.0676
47	C^1 C_1 (6)	BLC_1 CHC_1	13/1	19/1	93.8	0.0000
48	P^1 P_1 (6)	CHP^1 BLP^1 MDP_1	18/3	19/2	86.5	0.0000
49	P^2 P_2(6)	BLP_2 CHP^2 MDP_2	17/5	17/1	82.4	0.0000
50	I^1 M^1 (6)	BLM^1 MDM^1 MDI^1 CHI^1 CHM^1	6/0	3/0	100.0	0.0369
51	I_1 M_1 (6)	CHM_1	2/0	3/2	60.0	0.2674
52	I^1 M^1 I_1 M_1 (12)	CHM_1	2/0	3/2	60.0	0.2674
53	I^1 C^1 (6)	BLC^1 BLI^1 MDI^1	16/4	14/2	80.0	0.0653
54	I_1 C_1 (6)	MDI_1 BLC_1 BLI_1 CHI_1	4/0	2/0	100.0	0.0119
55	I^1 C^1 I_1 C_1 (12)	BLI^1 MDI^1	16/5	15/6	64.5	0.0902
56	I^1 I^2 C^1 (9)	BLC^1 BLI^1 MDI^1	16/4	14/2	80.0	0.0309
57	I^1 I_2 C_1 (9)	MDI_1 BLC_1 BLI_1	12/3	15/4	66.7	0.0711
58	I^1 I^2 C^1 I_1 I_2 C_1 (18)	BLI_2	27/1	30/18	66.7	0.2801
59	P^1 P^2 M^1 (9)	CHM^1 BLP^2 BLM^1	8/2	6/0	85.7	0.0037
60	P_1 P_2 M_1 (9)	CHP_1 MDP_1 MDM_1	17/1	17/12	61.8	0.0254
61	C^1 P^1 P^2 M^1 (12)	BLM^1 MDP^1 MDC^1 CHM^1 BLP^2	8/1	5/0	92.3	0.0254
62	C_1 P_1 P_2 M_1 (12)	CHP_1 MDP_1 MDM_1	17/1	17/12	61.8	0.0254
63	I^2 C^1 (6)	BLC^1 CHC^1	17/2	18/2	88.6	0.0000
64	I_2 C_1 (6)	BLC_1	36/8	30/5	80.3	0.0000
65	I^2 C^1 I_2 C_1 (12)	BLC_1 CHC^1 MDC_1 BLI^2 CHI_2	6/0	7/0	100.0	0.0150
66	I^1 I^2 C_1 (9)	BLC_1 MDI^1	15/3	14/0	89.7	0.0009

Table 3.4b Results of the Discriminant Analyses for the Fishergate base sample

m number of measurements submitted for analysis after Rösing (1983) *nm* number of males nm_f number of males misclassified
nf number of females nf_f number of females misclassified *%r* percentage of correctly classified individuals
%rH percentage of correctly classified individuals using the holdout method
Measurement prefixes to tooth types: BL = buccolingual diameter; MD = mesiodistal diameter; CH = crown height; RL = root length
a = Discriminant analysis not conducted because all cases submitted for analysis were of the same sex
b = Discriminant analysis not conducted because no cases qualified for inclusion
c = F values for all variables submitted were insufficient for discriminant analysis to proceed

Function	Teeth (*m*)	Measurements selected by stepwise procedure	nm/nm_f	nf/nf_f	%*r*	*p*	%*rH*
1	I^1 (4)	BLI^1 CHI^1	12/2	3/2	73.3	0.3105	
2	I^2 (4)	MDI^2 CHI^2	34/10	14/2	75.0	0.0007	80.3
3	C^1 (4)	CHC^1 RLC^1 MDC^1	28/6	13/3	78.1	0.0008	82.7
4	P^1 (4)	CHP^1 BLP^1 RLP^1	27/5	8/2	80.0	0.0990	72.9
5	P^2 (4)	CHP^2	36/12	9/4	64.4	0.1572	50.6
6	M^1 (4)	c					
7	I_1 4)	a					
8	I_2 (4)	CHI_2 BLI_2 RLI_2	13/1	4/0	94.1	0.0355	86.9
9	C_1 (4)	CHC_1 MDC_1	49/5	18/3	88.1	0.0000	90.1
10	P_1 (4)	CHP_1	58/20	24/6	68.3	0.0138	69.0
11	P_2 (4)	CHP_2 MDP_2	41/16	16/2	68.4	0.0202	74.2
12	M_1 (4)	a					
13	I^1 I_1 (8)	a					
14	I^2 I_2 (8)	CHI_2 BLI_2 RLI_2 BLI^2 MDI^2 MDI_2 CHI^2	8/0	3/0	100.0	0.0079	
15	C^1 C_1 (8)	CHC_1 MDC_1	49/9	18/3	82.1	0.0002	
16	P^1 P_1 (8)	CHP^1 BLP^1 MDP_1 MDP^1 CHP_1	38/7	13/5	76.5	0.0031	
17	P^2 P_2 (8)	MDP_2	71/30	32/12	59.2	0.0423	

Table 3.4b contd. . . /

Table 3.4b (contd.)

Function	Teeth (*m*)	Measurements selected by stepwise procedure	*nm* /*nm*$_f$	*nf* /*nf*$_f$	%*r*	*p*
18	M^1 M_1 (6)	b				
19	I^1 M^1 (7)	MDI^1 RLM^1 BLI^1	5/2	3/0	75.0	0.4250
20	I_1 M_1 (7)	b				
21	I^1 M^1 I_1 M_1(14)	b				
22	I^1 C^1 (8)	RLC^1 MDI^1 RLI^1	23/4	6/4	72.4	0.3119
23	I_1 C_1 (8)	a				
24	I^1 C^1 I_1 C_1 (16)	a				
25	I^1 I^2 C^1 (12)	CHC^1 RLI^2 BLI^2	30/14	12/1	64.3	0.0964
26	I_1 I_2 C_1 (12)	a				
27	I^1 I^2 C^1 I_1 I_2 C_1 (24)	a				
28	P^1 P^2 M^1 (11)	a				
29	P_1 P_2 M_1 (11)	MDP_1 CHP_2 BLM_1	36/11	13/2	73.5	0.2606
30	C^1 P^1 P^2 M^1 (15)	a				
31	C_1 P_1 P_2 M_1 (15)	a				
32	I^2 C^1 (8)	CHC^1 RLC^1	28/8	13/2	75.6	0.0008
33	I_2 C_1 (8)	MDC_1 CHC_1 BLC_1	49/18	18/1	71.6	0.0125
34	I^2 C^1 I_2 C_1 (16)	CHC_1 RLC^1 BLC^1 MDC_1 BLI^2	29/13	8/0	64.9	0.0029
35	I^1 (3)	BLI^1 CHI^1	12/2	3/2	73.3	0.3105
36	I^2 (3)	CHI^2 MDI^2	34/9	14/3	75.0	0.0015
37	C^1 (3)	CHC^1 MDC^1	45/13	16/5	70.5	0.0002
38	P^1 (3)	CHP^1 BLP^1	46/16	14/3	68.3	0.0376
39	P^2 (3)	CHP^2	36/16	9/4	55.6	0.2967
40	I_1 (3)	a				
41	I_2 (3)	CHI_2 BLI_2	15/3	4/0	84.2	0.0213

Table 3.4b contd. . . /

Table 3.4b (contd.)

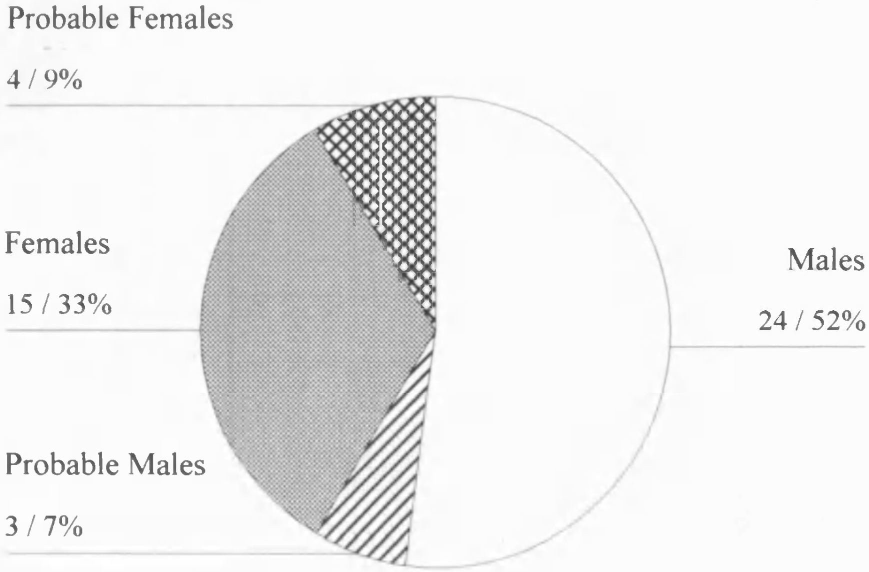
Function	Teeth (*m*)	Measurements selected by stepwise procedure	*nm* /*nm_f*	*nf* /*nf_f*	%*r*	*p*
42	C_1 (3)	CHC_1 MDC_1	49/5	18/3	88.1	0.0000
43	P_1 (3)	CHP_1	58/20	24/6	68.3	0.0008
44	P_2 (3)	CHP_2 BLP_2	42/11	16/4	74.1	0.0045
45	I^1 I_1 (6)	a				
46	I^2 I_2 (6)	CHI_2 BLI_2 BLI^2	11/1	4/0	93.3	0.0099
47	C^1 C_1 (6)	CHC_1 MDC_1	49/7	18/3	85.1	0.0000
48	P^1 P_1 (6)	CHP_1 BLP^1 MDP_1	51/12	17/5	75.0	0.0099
49	P^2 P_2(6)	CHP^2	36/16	9/4	55.6	0.1249
50	I^1 M^1 (6)	c				
51	I_1 M_1 (6)	a				
52	I^1 M^1 I_1 M_1 (12)	b				
53	I^1 C^1 (6)	CHC^1 BLI^1	32/15	10/8	57.1	0.2236
54	I_1 C_1 (6)	a				
55	I^1 C^1 I_1 C_1 (12)	a				
56	I^1 I^2 C^1 (9)	CHC^1 BLI^2	37/14	13/3	66.0	0.1423
57	I^1 I_2 C_1 (9)	BLI_2 MDI_2 CHC_1 MDC_1 MDI^1	14/5	3/1	64.7	0.0103
58	I^1 I^2 C^1 I_1 I_2 C_1 (18)	a				
59	P^1 P^2 M^1 (9)	BLP^1 CHP^2	34/4	8/5	78.6	0.1286
60	P_1 P_2 M_1 (9)	BLM_1 CHM_1	2/0	3/0	100.0	0.0118
61	C^1 P^1 P^2 M^1 (12)	BLP^1 MDC^1 CHM^1 BLP^2	15/1	2/0	94.1	0.1345
62	C_1 P_1 P_2 M_1 (12)	BLP_2	79/23	33/29	53.6	0.0603
63	I^2 C^1 (6)	CHC^1 CHI^2	26/6	10/1	80.6	0.0001
64	I_2 C_1 (6)	BLI_2 MDC_1 CHI_2	14/1	4/0	94.4	0.0145
65	I^2 C^1 I_2 C_1 (12)	CHC_1 MDC_1 BLC^2	45/18	12/0	68.4	0.0012
66	I^1 I^2 C_1 (9)	CHC_1 MDI^1	27/12	5/0	62.5	0.0034

Figure 3.2 SPSS output plot illustrating the distribution of adult males and females from Abingdon along the discriminant function continuum for function 9 (crown height and buccolingual diameter of the mandibular canine)

```
              All-groups Stacked Histogram

            Canonical Discriminant Function 9

            1=male
            2=female

    4 +                 1                         +
      |                 1                         |
      |                 1 11    2 2               |
      |                 1 11    2 2               |
    2 +              11 1111    2 22 2            +
      |              11 1111    2 22 2            |
      |             11111111 212222 2 2           |
      |             11111111 212222 2 2           |
       X----+----+----+----+----+----+----+----X
     Out -6.0 -4.0 -2.0    .0  2.0  4.0  6.0    Out
  Group   11111111111111111111112222222222222222222
Centroids                  1        2

F  46.1986      Wilks Lambda  0.2389      D squared  12.3833
P   0.0000
```

Figure 3.3a/b Pie charts illustrating the proportion of subadult males and females allotted to each sex classification

(a) Abingdon



(b) Fishergate

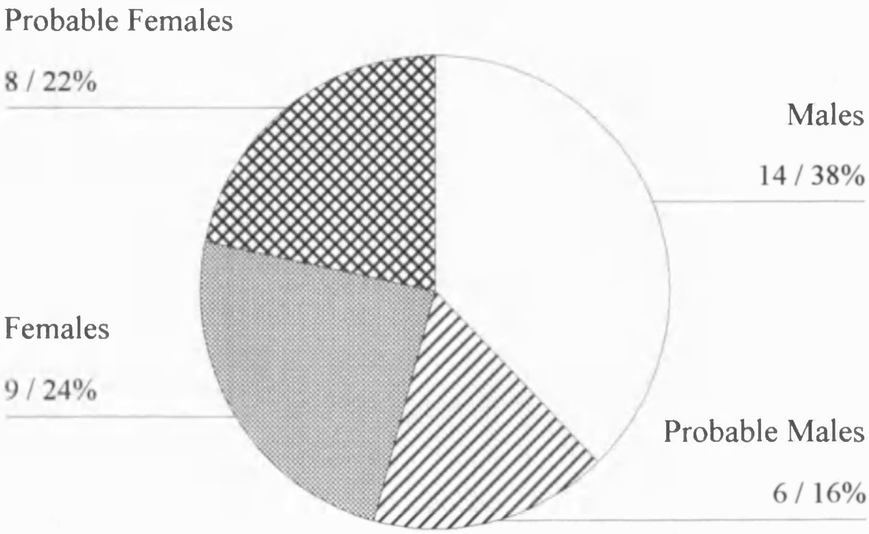


Table 3.5 Frequency of subadults attributed to each sex classification

χ^2 chi-square statistic ('males' pooled with 'probable males'; 'females' pooled with 'probable females') *p* probability

	Males	Probable Males	Females	Probable Females	Total	χ^2	*p*
Abingdon	24	3	15	4	46	1.391	.238
Fishergate	14	6	9	8	37	.243	.622
Total	38	9	24	12	83	1.458	.227

Table 3.6 Frequency of males and females according to age category
('males' pooled with 'probable males'; 'females' pooled with 'probable females')

χ^2 chi-square statistic on cross-tabulated age/sex data *p* probability

	*c.*5-13 years	*c.*13-18 years	χ^2	*p*
Abingdon Males	21	5		
Abingdon Females	14	4	.058	.809
Fishergate Males	11	9		
Fishergate Females	13	4	1.859	.173
Total Males	32	14		
Total Females	27	8	.577	.448

Table 3.7 Cross-sample application of discriminant functions

nm number of males nm_f number of males misclassified *nf* number of females nf_f number of females misclassified
nt total number of individuals nt_f total number of individuals misclassified

				% of sample correctly classified			% of sample incorrectly classified		
Sample being tested	nm/nm_f	nf/nf_f	nt/nt_f	Males	Females	Total	Males	Females	Total
Fishergate cases classified on the basis of the Abingdon 'best' function 9	50/10	18/4	68/14	80.0	78.0	79.4	20.0	22.0	20.6
Abingdon cases classified on the basis of the Fishergate 'best' function 9	13/3	19/3	32/6	76.9	84.2	81.3	23.1	15.8	18.8

4. Database Design

The comparative investigation of male and female pathology and demography involved the analysis of a large volume of skeletal data. The most effective method of managing this information was to computerise it as a database which could also be used for analytical purposes. Following an initial survey of various skeletal recording forms used to document the laboratory examination of skeletal remains, three key design requirements were recognised:

1. The structure should enable the easy entry, retrieval and analysis of data.
2. It should accommodate differences in osteological recording methods.
3. Despite requirements 1 and 2, the detail or accuracy of information stored should not be compromised.

In order to meet these demands, the database was constructed using SPSS (Statistical Package for the Social Sciences) for Windows (SPSS Inc.). This package was chosen because it offered an extensive range of statistical procedures and data-management facilities, especially its flexibility to select, transform and combine data. The basic database structure consisted of eight separate files, as indicated in appendix 3. One file primarily provided for the entry of what may be described as demographic data, another served as an inventory of extant bones and joints, and the remaining six files corresponded to the major areas of pathology which were under investigation: anaemia, enamel hypoplasia, infectious disease, trauma, joint disease, and dental disease. This structure satisfied the first design requirement as it organised the data into manageable, logical divisions, rather than including it all in a single, unwieldy file which may have created difficulties in the location of specific data.

To illustrate the format of an SPSS data file, an extract of that which contained the demographic data is given in figure 4.1a. Each row in the matrix represented a case, or an individual skeleton, and each column represented a variable, or skeletal characteristic. The chief variables used in the data files are listed appendix 3. Two variables were common to all files. These provided for the entry of each skeleton's identification number and the cemetery from which it originated respectively. Although the database was composed of separate files, SPSS enables any number of files, or variables within them, to be combined for analytical purposes, and these two variables were used to match cases between files. Therefore, the format was similar to a relational database in which the two variables acted as 'unique identifiers', enabling statistical testing between data files.

The majority of data were entered onto the database using a numeric coding system, as depicted in figure 4.1a. However, each code was also tagged with an explanatory value label, which could be displayed on the screen or on analytical printouts if required in order to provide an instant description of what the codes represented. This facility is illustrated in figure 4.2b. Appendix 3 lists many of the codes used in the data files. The coding method was employed in order to expedite the process of data entry and to reduce the inherent problems associated with string searches, such as typing errors. As much of the data had already been encoded on the skeletal recording forms, or organised in a categorical format, this system was convenient to implement. Even data which had been recorded qualitatively could be accommodated by the addition of new codes as necessary. Furthermore, SPSS provides an automatic re-coding facility which enabled any number of codes to be changed or aggregated for data processing purposes, such as to correlate differences in recording protocols.

The numeric coding system and the use of variables therefore fulfilled the second and third database design requirements. Through the simple addition of a new code or variable, the detail of information which could be stored was almost limitless, and all recording protocols could be accommodated, adapted, or correlated where appropriate.

All data entered onto the database were checked at least twice prior to any analysis being undertaken, in order to minimise the potential problems associated with data transcription errors. Occasionally, minor inconsistencies were noted between data presented in skeletal reports and that which had been logged on the skeletal recording forms. In these instances, the details on the recording forms were normally entered onto the database, on the premise that this was more likely to reflect the original laboratory findings, unless there was evidence indicating to the contrary.

Figure 4.1a Extract from an SPSS data file (demography), illustrating the numeric coding system for data entry

File Edit View Data Transform Statistics Graphs Utilities Window Help

229:site 1

	site	skelno	sex	sex2	ageyrs	agecat	agecat2	stature	notes
229	1	6217	4	2		9			
230	1	6218	1	1	.	7	2	176.00	
231	1	6220	4	2	30.0	5	1	.	
232	1	6224	1	1	.	7	2	166.00	
233	1	6239	1	1	.	7	2	179.00	
234	1	6244	1	1	.	7	2	170.00	
235	1	6248	3	2	.	7	2	158.00	
236	1	6257	1	1	40.0	6	2	170.00	
237	1	6258	1	1	43.0	6	2	167.00	
238	1	6259	4	2	.	7	2	168.00	
239	1	6270	1	1	.	7	2	180.00	
240	1	6272	1	1	.	7	2	172.00	
241	1	6274	1	1		7	2	170.00	
242	1	6279	1	1	32.0	5	1	163.00	
243	1	6287	3	2	.	7	2	163.00	
244	1	6289	1	1	.	7	2	189.00	

SPSS Processor is ready

Figure 4.1b Ditto figure 4.1a but with the 'explanatory value labels' option selected

File Edit View Data Transform Statistics Graphs Utilities Window Help

229:site 1

	site	skelno	sex	sex2	ageyrs	agecat	agecat2	stature	notes
229	Abingdon	6217	Probable female	Female		Adult	.	.	
230	Abingdon	6218	Male	Male	.	c.>45	c.>35	176.00	
231	Abingdon	6220	Probable female	Female	30.0	c.25-35	c.18-35	.	
232	Abingdon	6224	Male	Male	.	c.>45	c.>35	166.00	
233	Abingdon	6239	Male	Male	.	c.>45	c.>35	179.00	
234	Abingdon	6244	Male	Male	.	c.>45	c.>35	170.00	
235	Abingdon	6248	Female	Female	.	c.>45	c.>35	158.00	
236	Abingdon	6257	Male	Male	40.0	c.35-45	c.>35	170.00	
237	Abingdon	6258	Male	Male	43.0	c.35-45	c.>35	167.00	
238	Abingdon	6259	Probable female	Female	.	c.>45	c.>35	168.00	
239	Abingdon	6270	Male	Male	.	c.>45	c.>35	180.00	
240	Abingdon	6272	Male	Male	.	c.>45	c.>35	172.00	
241	Abingdon	6274	Male	Male	.	c.>45	c.>35	170.00	
242	Abingdon	6279	Male	Male	32.0	c.25-35	c.18-35	163.00	
243	Abingdon	6287	Female	Female	.	c.>45	c.>35	163.00	
244	Abingdon	6289	Male	Male	.	c.>45	c.>35	189.00	

SPSS Processor is ready

5. Demography

5.1 Introduction

This chapter focuses on what may be described as the demographic structure of the selected cemetery samples, namely their sex and age composition. When the inventory of excavated English medieval cemeteries (section 2.1) was compiled prior to the selection of material to be included in this project, it became apparent that the majority of assemblages contained a predominance of male skeletons. This was frequently a reason for eliminating cemeteries that were initially identified, and despite the original selection criterion that the assemblages should display sex ratios close to unity, the number of males exceeded the number of females among all those finally included. Cemeteries associated with monastic communities can be expected to display an inflated proportion of males due to the large component of brethren burials. However, it is less easy to explain the common tendency for males to predominate in collections that are associated with secular communities. The male bias is not always of a great magnitude, but the trend is a fairly consistent one.

In fact, surveys of skeletal assemblages from other periods and geographical areas have revealed that this is an almost universal phenomenon, receiving comment from several authors (Larsen 1997:335). For example, having compiled a list of 43 skeletal collections from prehistoric and historic sites, including Amerindian, African and European collections, Weiss (1972) remarked that there is an 'excess of males in the worldwide skeletal sample' which is 'systematic, obvious and statistically significant when compared to a hypothetical expectation of 50% male'. Only ten of the samples displayed a predominance of females compared to the 33 which contained an excess of males. Bennike (1985:31-36) has analysed the sex composition of a series of Danish collections dating from the Mesolithic to the Middle Ages, and found a preponderance of males in nearly all periods, amounting to an overall superiority in male numbers. Waldron (1994:23) too has commented, 'it is an interesting observation . . . that Romano-British populations frequently have an excess of males', and supports this statement by presenting data from a series of 13 sites, of which 11 displayed a sex ratio skewed toward males. Mays (1995a:8) describes the surplus of males among Romano-British cemeteries as a 'long-standing conundrum', and found a sex ratio of 1.46:1 in favour of males within a sample of 2,400 burials from Romano-British sites. Similarly, Brothwell (1972) has compiled data from 27 skeletal populations around the world and upon finding that 18 were biased toward males, concluded that 'in most earlier human populations, the proportion of males to females is roughly equal, but with a tendency to have a slight predominance of males' (Brothwell 1972:84). Furthermore, from a review of the literature, no studies were encountered which reported a consistent preponderance of females across a given range of archaeological assemblages.

This pattern contrasts with that observed in modern populations. Although figures for modern Europe and the United States document a slightly higher male birth rate, approximately 105 males being born for every 100 females, the predominance of males drops to a ratio of approximately 1.00 in adolescence with a further reduction in the proportion of males among the adult population (Hanawalt 1993:58; Russell 1948:148; Stinson 1985:126). Similarly, following a survey of adult census figures for 31 modern pre-industrial populations, Weiss (1972) found that only 13 groups displayed a predominance of males, the average proportion for all 31 samples combined being 48.8% male (n=39,843).

Several hypotheses have been proposed to account for the apparent disparity between the sex ratio of modern population samples and skeletal assemblages from archaeological sites. These generally revolve around three central themes:

1. there may be a systematic bias in the application of skeletal sexing methods towards male classification;
2. there may be a sex difference in the preservation or recovery of skeletal material; or
3. sex imbalances may actually be representative of the populations interred, the distortion in sex ratios having arisen through various demographic or cultural factors.

The object of this study was to statistically examine the sex ratios of the seven medieval cemetery samples in order to evaluate the frequency of males and females within each assemblage and the relative difference between the samples; and to explore the validity of the above hypotheses in relation to any patterns identified. It was important to evaluate the possible explanations for the apparent over-representation of males because it presented several important potentialities for the entire project. For example, a systematic bias in sexing methodology could undermine the comparison of male and female pathology data through the inclusion of a disproportionately large component of mis-sexed females into the male sample; a sex bias in preservation would have substantial implications for the computation of pathology prevalence figures (see section 6.5.2); or alternatively, if the sex ratios were representative of the samples interred, they could imply differences in male and female mortality patterns.

A further aim was make a comparative study of male and female age at death. Previous demographic studies of skeletal data have identified a general trend for adult females to display an earlier age at death (Wells 1964:178-179; 1975). For example, of the 460 sexed individuals excavated from the medieval cemetery of St Helen-on-the-Walls in York, Dawes and Magilton (1980:63-66) found that 56% of the females had died before the age of 35 compared with 36% of males. The authors viewed this as providing a 'measure of the strains and stresses of childbearing and its associated traumas in the days before restricted family size, supplemented diets and modern medicine' (Dawes and Magilton 1980:63). Brothwell (1972) has examined male and female age at death in a range of British collections dating from the Neolithic to the Middle Ages, and identified a shorter lifespan among females from all periods. Again, this was interpreted as being 'related to the perils of childbirth in all these early communities' (Brothwell 1972:83). The risks lay not only in the birth itself, but also in complications such as pre-eclampsia, haemorrhage, and infection. Presumably, the number of pregnancies was greater than today, which probably served to compound these risk factors. Manchester (1983:8-9) has reviewed the data compiled by Brothwell (1972) and confirmed that the number of female deaths exceeded male deaths among those of childbearing age, with the reverse trend occurring among those surviving past the age of 35. While Manchester supports the contention that childbearing was undoubtedly a major contributory factor in the reduced longevity of females, he suggests that this may be a rather unilateral interpretation. An alternative possibility might be that females experienced a lower social status with consequent diminished health status, which may have rendered them 'more susceptible to disease and early death' (Manchester 1983:9). This is a view shared by Wells (1964:178-179; 1975) and Grauer (1991). Manchester also points out that the two factors are not inseparable, as inferior health would tend to exacerbate the problems of childbearing and vice versa. The purpose of this study therefore was to examine whether any association could be identified between sex and age at death among the medieval cemeteries, and to consider the possible reasons for any patterns detected.

5.2 Method

The methods which had been used to identify adult sex were essentially the same for all the cemetery samples, as illustrated in table 5.1. The range of currently accepted anthropological techniques (Bass 1987; Brothwell 1981; Workshop of European Anthropologists 1980; Mays 1998; St Hoyme and Iscan 1989) were applied to the extant sex characteristics of each individual in order to attribute them to one of four classifications: 'male', 'probable male', 'female' or 'probable female'. These categories were adopted for the purposes of analysis. Diagnoses had primarily relied on the morphological characteristics of the pelvis and skull, the more reliable pelvic indicators taking preference in cases where pelvic and skull traits produced contradictory results. Metrical data was used to designate skeletons which could not be classified morphologically, due to ambiguity or incompleteness. For the same reasons, there was inevitably a proportion of adult remains in each sample for which no estimate of sex could be made, as quantified in table 5.4. These were classified as 'indeterminate' and excluded from all further statistical analyses.

The methods employed to estimate age at death in adult skeletons (Bass 1987; Brothwell 1981; Workshop of European Anthropologists 1980; Mays 1998; St Hoyme and Iscan 1989) were more varied between the collections than those used for sexing, as indicated in table 5.2, so the decision as to what would be the most appropriate system of categorising the data for the purposes of analysis, in this and the subsequent chapters, was more problematic. Brothwell's (1981:figure 3.9) tooth wear method had been applied to all the samples. This classifies molar attrition into four functional stages, which roughly correspond to the following age groups: 17-25 years, 25-35 years, 35-45 years, and >45 years. Miles' method (1962, 1963), a precursor to that developed by Brothwell, was also used to supplement the dental age assessments of the Fishergate material (Stroud and Kemp 1993:162-163). Besides tooth wear, the state of cranial suture closure was noted for the Jewbury remains, although this was largely restricted to recording whether the changes were characteristic of an individual greater or less than 22

Table 5.1 Criteria used for adult sex determination

	Abingdon	Fishergate	Ipswich/ Wharram	Jewbury	St Nicholas
Sciatic Notch	•	•	•	•	•
Preauricular sulcus	•	•	•	•	•
Sub-pubic angle	•	•	•		•
Ischiopubic ramus	•	•	•		•
Ventral arc	•	•	•		•
Sacrum	•	•	•		•
Mastoid Process	•	•	•	•	•
Post. Zygomatic arch	•	•	•	•	•
Supraorbital ridges	•	•	•	•	•
Nuchal crest	•	•	•	•	•
Metric standards developed from skeletal sample		•			
Assessment of size and robustness of femur	•			•	•

Table 5.2 Criteria used for adult age determination

	Abingdon	Fishergate	Ipswich/ Wharram	Jewbury	St Nicholas
Dental attrition (Brothwell 1981)	•	•	•	•	•
Dental attrition (Miles 1962, 1963)		•			
Cranial suture closure (Meindl and Lovejoy 1985)	•	•	•	•	•
Pubic symphysis (Suchey *et al.* unpub.)	•	•	•		•
Pubic symphysis (Meindl *et al.* 1985)		•			
Auricular surface (Lovejoy *et al.* 1985a)	•	•			
Sternal end of ribs (Iscan *et al.* 1984a, 1984b, 1985)		•			

years (Lilley *et al.* 1994:431). Age assignation of the material from St Nicholas Shambles (White 1988:28), Wharram Percy and Ipswich (Mays unpub.:9) was mainly reliant on dental attrition, although closure of the skull sutures and morphological changes at the pubic symphysis were taken into consideration when attributing the probable minimum and maximum age of an individual. In addition to these indicators, changes to the auricular surface of the ilium contributed to the assessment of the Abingdon and Fishergate remains, and a further indicator, sternal rib end morphology, was included in the Fishergate estimates (Stroud and Kemp 1993:168-170).

Aside from the sheer variety of the ageing methods applied, the problem of how to classify the data for the purposes of analysis was further complicated by the widely held concerns and debate over the reliability of the methods. It has long been suspected that the standard techniques for ageing adult skeletons yield unreliable estimates (Mays 1998:49-57), and this has been confirmed by recent studies which have applied them to archaeological samples of documented age. Saunders and co-workers (1992) tested four methods using skeletons derived from a nineteenth century Canadian cemetery, the ages of which were known from coffin plates and parish registers. The methods relied on cranial suture closure (Meindl and Lovejoy 1985) and morphological changes to the pubic symphysis (Suchey *et al.* unpub.), sternal rib end (Iscan *et al.* 1984a, 1984b, 1985), and auricular surface (Lovejoy *et al.* 1985a). Various problems were encountered in the application of all the indicators, the most common being increasing inaccuracy and bias with increasing age, with a tendency to under-age older skeletons. Molleson and Cox (1993:167-179) investigated the efficacy of the 'Complex Method' on a large sample of skeletons retrieved from the crypt of Christ Church in Spitalfields, London, the ages of which were known from coffin plates. The Complex Method, devised by Acsádi and Nemeskéri (1970), was recommended by a commission of European physical anthropologists as being the most reliable procedure for determining adult age at death (Workshop of European Anthropologists 1980). It utilises a combination of at least two out of the following four ageing criteria to produce an estimate, which is purported to be within five years of the actual age: pubic symphysial morphology, obliteration of the cranial sutures, the trabecular bone structure of the femoral head, and the trabecular bone structure of the humeral head. However, Molleson and Cox found that when all four characteristics were used, less than 30% of the Spitalfields sample were aged to within five years of the known age; although half the sample were estimated to within ten years, and three-quarters to within fifteen years of the known age. A systematic error was also identified whereby younger individuals (under about 40 years) tended to be over-aged, and older individuals (over about 70 years) tended to be under-aged.

Various reasons have been proposed to explain the apparent inaccuracy and bias of these osteological ageing methods. A major weakness lies in their reliance on what may be described as 'degenerative' changes, because different individuals degenerate at different rates, so their biological age may not correspond to their chronological age. Molleson and Cox (1993:214) have suggested that the pattern of bias observed in the Spitalfields study may indicate that there is an association between the ageing process and age at death. Those who died from natural causes at a comparatively young age tended to have bones which had aged prematurely. They concluded that 'As a result of the findings from Spitalfields it would be incautious to attempt to age an adult more precisely than as biologically young adult, middle-aged or old' (Molleson and Cox 1993:214). Mays (1998:55) also points out that the causes for the morphological changes which take place in bone, and the extrinsic factors which may influence the relationship between their manifestation and chronological age, are ill-understood. It is therefore not possible to know whether the techniques are appropriate for use on archaeological assemblages because the standards have been generated from modern reference collections which are comprised of individuals who would have experienced a different diet, health status and lifestyle. Further limitations lie in the reference collections themselves. Most consist of dissecting-room cadavers, but doubts have been raised over the reliability of their age documentation. Many are also biased in their demographic structure, towards a particular age class, sex or socio-economic group, and this has impaired the development, evaluation and application of the techniques (Mays 1998:53-55).

Mays (1998:57-66) has argued that methods based on dental attrition are largely free from these problems. He cites a study by Lovejoy and co-workers (1985b in Mays 1988:57) which found that compared with a range of other osteological indicators, tooth wear provided the best correlation with documented age when applied to a reference collection. Mays also highlights studies which have shown dental attrition to be a fairly reliable method by testing its performance on living Aboriginal (Richards and Miller

1991 in Mays 1998:57) and Eskimo (Tomenchuk and Mayhall 1979 in Mays 1998:57) populations of known age; a test of technique which is not practicable for most other age indicators (Mays *et al.* 1995). Unlike osteological methods, the causes and development of attrition are understood, and the rate of wear can be calibrated for the population under study, rather than being dependent on standards derived from modern reference collections. This is achieved by examining the relative difference in wear between the first, second and third molars in a sample of reliably aged immature skulls from the assemblage, and using the known differences in eruption timings between the three molars to determine the rate of attrition (Miles 1962, 1963). The results can then be extrapolated to estimate the functional age of teeth in a more advanced stage of attrition. As with osteological indicators, variability between individuals poses a limitation. However, Mays, de la Rua and Molleson (1995) found little variation in wear rates between individuals in a sample of child skeletons from the Romano-British cemetery at Poundbury, Dorset. Neither were pronounced differences identified between populations across an extended time period, according to research by Brothwell (1963) which examined child skeletons dating from the Neolithic to the sixteenth century. Another limitation may stem from the underlying assumption that the rate of wear in children provides a suitable indication of that which occurs in adults. It is likely that wear rates between individuals become more variable with advancing age, and coupled with the problem of ante-mortem tooth loss, the method becomes less accurate among older skeletons (Mays 1998:62-66; Mays *et al.*1995). However, this problem is common to most other methods.

In a recent demographic study of the Wharram Percy cemetery, Mays (1998:71) favoured tooth wear as the sole ageing indicator. This approach contrasts with the 'multimethod' strategy advocated by many authors, such as Roberts and Manchester (1995:23), and Saunders and co-workers (1992), where as many criteria as possible are taken into consideration in order to attribute a diagnosis. Despite the recognised shortcomings of the dental attrition technique, Mays explained that he 'resisted the temptation to use several age indicators' because he 'felt that this would simply risk contaminating the data which there is reason to suppose are reasonably reliable (dental wear ages) with those which, as far as archaeological populations are concerned, are of completely unknown reliability'(p.71).

Since Brothwell's dental attrition scheme had been applied to all the medieval cemeteries included in this study, and given the relatively greater confidence which has been placed in the technique compared with the other methods applied to the material, the decision was taken to use it as the basis on which to categorise the data for the purposes of statistical analysis. Its widespread application enhanced the comparability of data between the cemeteries, and as more skeletons had been aged using this procedure than any other it simplified the process of allocation. Two slight modifications were made to Brothwell's categories: the youngest age group was altered from '17-25' to '18-25', simply because this study was specifically focusing on comparisons between males and females and eighteen is typically the age at which sex assignation becomes feasible by conventional methods; and an additional grade, 'adult', was added to include the minority of sexed individuals for which no estimate of age could be attributed, beyond that they were skeletally mature. While precedence was given to the age classification attributed using Brothwell's method, in practice this did not negate the use of other indicators. Brothwell's categories are fairly broad and assessments based on other methods, especially composite estimates produced by taking several criteria into consideration, tended to support the classification attributed using dental wear; although it might be argued that in cases where a single observer had been responsible for assessing all the ageing criteria in a given skeleton, an element of unconcious bias could have operated to produce a similar result using different methods (Wakely pers. comm.). Discretion was used on an individual basis as to the most appropriate category in which to place skeletons for which no assessment of tooth wear could be undertaken, such as those lacking crania. In the majority of cases, the age range which had been assigned using other methods clearly coincided with one particular category over any other. Following Mays (1998:71) opinion, it could be argued that perhaps these individuals should have been excluded from the analysis, for risk of 'contaminating' the data. However, it seemed rash to reduce the sample size solely on these grounds, especially as so many judgements in palaeopathology are made on a subjective basis. As Maples (1989:323 in Roberts and Manchester 1995:23) has remarked, 'age determination is ultimately an art, not a precise science'. In view of recent findings, it could also be argued that categorising the data into ten year age bands is too refined a system, although some authors do recommend this stratification, such as Waldron (1994:88) who is more optimistic about the reliability of ageing methods. However, the boundaries to the categories should be viewed as fairly fluid, and furthermore, it is important to emphasise that the strata really represent relative differences in biological age. They should not necessarily be taken as a reflection of chronological age as the use of numerical labelling, convenient though it is, may imply.

Ageing of the subadult material from Abingdon and Fishergate which had been sexed using the tooth measurement technique discussed in chapter 3, had been undertaken using established methods: dental eruption, epiphyseal fusion and long bone measurement (table 5.3). Unlike adult ageing techniques, these are considered to provide fairly accurate, reliable estimates as they are dependent on developmental changes which are closely associated with chronological age (Mays 1998:42; Roberts and Manchester 1995:23)

Table 5.3 Criteria used for subadult ageing

	Abingdon	Fishergate	Ipswich/ Wharram	Jewbury	St Nicholas
Dental eruption (Ubelaker 1978: figure 62)	•	•	•	•	•
Epiphyseal fusion (Workshop of European Anthropologists 1980: figure 6)	•	•	•	•	•
Long bone measurement (Maresh 1955; Scheuer *et al.* 1980)	•	•	•		•

To provide a visual representation of the proportion of adults allotted to each sex classification, pie charts were constructed for each cemetery sample (figure 5.1a-g). The data for skeletons which had been sexed with less confidence were then combined with those that had been sexed more securely (i.e. 'probable males' were pooled with 'males', and 'probable females' with 'females'), and the frequency and percentage of individuals attributed to each sex were tabulated (table 5.5). The sex ratio of each sample was computed, defined as the number of males present for every female, and chi-square tests were applied to determine whether the difference in the frequency of males and females was statistically significant (table 5.5). In order to identify whether there were any differences in the proportion of males to females among the respective age categories, these statistics were repeated for each of the four adult age groups, and the combined data from the two youngest (18-35 years) and eldest (>35 years) groups, as it was envisaged that amalgamating the data in such a way may clarify any differences between 'younger' and 'older' groups by reducing the number of categories and increasing the sample sizes (table 5.7 and 5.8).

Studies on skeletal samples of known sex have estimated that the accuracy rates for skeletal sexing methods may be as high as 98% when the pelvis and skull are available for examination, 95% when the pelvis alone is considered, 90% for the lone cranium and between 80-90% when metrical criteria are used (Workshop of European Anthropologists 1980; Meindl *et al.* 1985; Molleson and Cox 1993:23, 206). However, when dealing with samples of unknown sex, the reliability of any diagnosis is almost impossible to quantify definitively because it is dependent upon a variety of factors, such as the extent of sexual dimorphism exhibited by the population sample under study; the preservation or manifestation of sexually dimorphic traits in an individual; and ultimately, the perception of such traits by those who examine the material. This raised the question of whether it was appropriate to combine the individuals which had been sexed less securely with those that had been sexed with greater confidence for the purposes of data analysis, particularly as the study was specifically aiming to compare the sexes. Combining the data in such a way might bias results by introducing individuals with a higher probability of being incorrectly sexed. Theoretically, an even more refined system than the original four grade classification could have been applied, as even within these divisions individual skeletons were considered to display varying degrees of 'masculine' or 'feminine' traits (Workshop of European Anthropologists 1980). However, such a system would have been impractical to implement as it would have fragmented the samples into numerous, small divisions to provide results that would have been difficult to interpret. For this reason, the system of combining individuals of 'probable' sex with those that had been sexed more assuredly was retained for all analyses of pathological data in the subsequent chapters, as it was anticipated that any potential bias introduced through including these individuals was likely to have been offset by the advantage of increased sample size. However, it was felt that the issue of accuracy in sex assignation was an important one to address in relation to the computation of sex ratios, as one hypothesis put forward to explain the consistent over-representation of males in skeletal assemblages is that there is a systematic bias by anthropologists to mis-sex female skeletons as male in their application of skeletal sexing methods.

It was Weiss (1972) who first proposed this theory, estimating the error rate to be about 10-15%. He suggested that the potential for inaccuracy lay in the use of sexually diagnostic traits which are graded as being 'larger' or 'smaller' in nature, such as the characteristics on the skull, bone rugosity or femoral head size; rather than those which are recorded as being 'present' or 'absent', such as the pre-auricular sulcus on the pelvis. He states that the use of subjective morphological characteristics may result in 'an irresistible temptation' (p.240) to designate doubtful specimens, with traits of intermediate size, as male, and only those in which the traits are absent as female, resulting in an overall bias toward male classification. Roberts and Manchester (1995) also warn against the danger of using 'robusticity' as an indicator of skeletal sex: 'The expression of many of the cranial traits and metrical data used relate to the robusticity of the person in life, so that, in theory, males will be more robust than females; this does not always apply, because some females may have very strenuous occupations leading to the development of a robust skeleton' (p.23). In addition, 'older people develop skeletal structures which are more robust, and a skeleton may be attributed mistakenly for a male rather than a female' (p.25). With reference to these types of skeletal indicators, St Hoyme and Iscan (1989) highlight the influence of the preconceptions which may be held by anthropologists when making diagnostic judgements, that probably originate from 'our Victorian predecessors (who) valued "delicacy" and "refinement". For them, a proper lady was delicate, enjoying poor health' (p.66). 'They were undoubtedly thinking of ladies - their wives or sweethearts or other imaginary females - rather than the maids, hired girls, and other hardworking women in the real world' (p.68), but such a perception may have manifest itself in a source of skeletal sexing bias in the present day. However, it could be argued that the converse situation might also lead to an incorrect classification, with slightly built males being classified as female.

To give an indication of whether a systematic sexing bias was in operation with respect to the material included in this study, the sex ratios and chi-square tests were re-computed for the total samples, but this time excluding those deemed to be of 'probable' sex, on the assumption that these individuals would be most susceptible to any systematic bias in sexing methodology as they tended to be less complete or have ambiguous sex characteristics (table 5.6). If the hypothesis was correct, the proportion designated as male would be expected to fall in conjunction with a relative rise in the proportion of females, resulting in an overall reduction in sex ratios. These statistics were not repeated for the respective age categories as the proportion classified as being of 'probable' sex was comparatively small, and their removal would not have had a great impact on the figures once divided further by age category.

An alternative hypothesis often put forward to explain the excess of males so often observed in skeletal assemblages is that the bones of gracile females disintegrate more rapidly, resulting in a lower recovery rate at excavation (Bennike 1985:34; Walker *et al.* 1988). Walker and co-workers (1988) investigated this theory by comparing the demographic profile of a skeletal assemblage recovered from the Purisma Mission Cemetery, California, with burial records kept by the Franciscan priests who operated the cemetery. However, no statistically significant difference was found between the sex ratio of the skeletal assemblage and the burial records. Indices of skeletal completeness were also computed for each skeleton and these revealed that males and females were equally well preserved. The authors then carried out a similar evaluation of skeletal completeness on a collection of skeletons excavated from a Californian prehistoric site, Ca-Ven-110. Again, there was no significant difference in preservation between the sexes. However, skeletal age was found to be a significant factor in preservation bias. The burial records from the Purisma cemetery showed that the majority of interments were elderly adults (>45 years), children and infants, yet young and middle-aged adults (18-45 years) predominated in the skeletal assemblage. In addition, the indices of skeletal completeness from both the mission cemetery and Ca-Ven-110 demonstrated that the remains of elderly individuals and juveniles were less complete and more fragmented. The inferior preservation of juvenile skeletons was attributed to the relatively rapid disintegration of their incompletely calcified bones, and the relatively poor preservation of the elderly was ascribed to the accelerated loss of bone calcium in old age. In the light of these findings, it could be argued that elderly females may be at greater risk of being lost from the skeletal record than elderly males because reduced oestrogen levels post-menopause may result in an increased susceptibility to osteoporosis. Unfortunately, Walker and colleagues did not present cross-tabulated data relating age and sex preservation, so no inferences could be drawn in relation to the Californian samples. However, Mays (1996) recently carried out a study of cortical bone mass in a sample of individuals from Wharram Percy and did identify a significant loss of bone among elderly females (>50 years) compared with their younger counterparts (18-29 years) which was not paralleled among the males in the sample. Bennike (1985:35-36) has suggested a further process which might, theoretically, result in a superior level of preservation among male skeletons, and this could be 'due to men being buried with greater care than women and thus being better preserved in the soil'. However, as discussed in chapter 2, although vague sex differences in burial practice were occasionally inferred among some of the cemeteries, the available evidence did not suggest that males were customarily given preferential treatment in burial.

To give an indication of whether the sex composition of any of the samples included in this project could have been influenced by a sex bias in preservation, a study of skeletal completeness was carried out using a method which was similar to that employed by Walker and colleagues (1988), based on the survival of 14 long bones: clavicles, humeri, radii, ulnae, femora, tibiae and fibulae. The number of long bones represented in each individual was tallied according to sex and age category, then expressed as a percentage of the total number of long bones which would be expected to be present if all 14 were represented in each individual. The method took no account of long bone degradation, merely the presence or absence of each element. Chi-square tests were applied to determine whether there were any statistically significant differences between the sexes in the proportion of long bones represented (table 5.9). The Jewbury cemetery was excluded from this analysis as the time limits imposed on the examination of the assemblage precluded the recording of skeletal inventories.

The age at death profiles for the entire cemetery samples have been presented graphically in figure 5.2a-g. The frequency and percentage of individuals allotted to the four adult age groups were then tabulated for males and females respectively, in order to compare their age at death distribution (table 5.10). Chi-square tests were applied to the cross-tabulated frequencies to determine whether there was any statistical association between sex and age at death (table 5.10). These statistics were repeated after pooling the data from the two youngest ('18-25' with '25-35') and eldest ('35-45' with '>45') age groups (table 5.11). It is widely asserted that female fecundity tends to diminish markedly after the age of about 35 (Henry 1957 in Wells 1975:1244), so it was envisaged that combining the data in this way might emphasise any sex differences in age at death which may be associated with childbearing. The age at death profiles for adult males and females were also contrasted graphically, to provide a visual representation of results (figure 5.3a-h and 5.4a-h).

5.3 Results and Discussion

The consistent preponderance of males among the skeletal collections was clearly visible from the pie charts presented in figure 5.1a-g. These also highlighted the considerable variation in the extent of this bias between sites. The results presented in table 5.5, detailing the proportion of males and females in the samples (individuals of 'probable' sex incorporated into the figures), revealed that the highest sex ratios were evident in the two monastic assemblages, with more than twice as many males as females among the Ipswich collection, and more than three times as many males in the Fishergate 6 group, the sex difference in frequency being statistically significant at the 1% level for both sites. Among the lay cemeteries, the rural site of Wharram Percy displayed the greatest sex imbalance. Sixty-two per cent of the sample was male, the sex difference in frequency being statistically significant at the 1% level. The sex difference among the Abingdon collection was also significant at the 1% level, with male skeletons comprising 57% of the sample. Although the sex ratios for the three remaining assemblages were also skewed in favour of males, the differences were not statistically significant. Of these, Fishergate 4 was the most biased with a 59% male contingent, followed by the collection from St Nicholas Shambles which was 55% male. Of all the cemeteries, Jewbury displayed the most balanced sex ratio; 52% of the sample consisted of male skeletons. The lack of a statistically significant difference in sex frequency among the assemblages from St Nicholas Shambles and Fishergate 4 may at least partly be related to the relatively small size of the samples. When the data from all the lay cemeteries were pooled, a chi-square value of 24.267 was obtained, which was statistically significant beyond the 0.001 probability level. The consistent male bias among the lay cemeteries resulted in a pooled sex ratio of 1.318:1. In percentage terms, 56.9% of the pooled lay sample was male, and 43.2% was female (n=1,291).

When the data were broken down according to age group, as shown in table 5.7, it was clear that the strong male bias pervaded the entire monastic samples, with all four age categories displaying a statistically significant difference in the proportion of males to females ($p<0.05$). Among the lay cemeteries, there was a general inclination for the superiority in male numbers to rise with age, with the exception of the Fishergate 4 sample which tended to display the reverse trend. These patterns were most apparent when the data for the youngest and eldest age groups were pooled, as shown in table 5.8, the disparity between the sexes being greatest among those aged over 35 years in all cemeteries bar Fishergate 4 which showed the greatest excess of males among those aged under 35. The anomalous results for Fishergate 4 can be attributed to the inclusion of the weapon injury group, a collection of young males with fatal blade injuries (see section 2.3). However, the chi-square tests revealed that most of the sex differences within the respective age groups were not statistically significant, although this may have been a manifestation of the reduced sample size having split the data by age category. The exceptions to this were the eldest age groups in the Wharram Percy and Abingdon collections and the youngest age group in the Fishergate 4 sample. The sex difference in all these samples was statistically significant beyond the 1% level. More than 60% of those aged over 45 years in the Abingdon and Wharram cemeteries were male, and there were more than three times as many males than females aged below 25 in the Fishergate 4 assemblage.

When the skeletons of 'probable' sex were omitted from the analysis of cemetery sex composition, an unexpected result was obtained, as illustrated in table 5.6. In contrast to the predicted fall in the proportion of individuals designated as male, the sex ratio actually increased slightly for all the cemeteries with the exception of Wharram Percy which showed a marginal decrease in the proportion of males. This implied that the skeletons with doubtful sex characteristics were more often classified as female rather than male, so these results did not seem to support the theory that a systematic bias towards male classification was in operation. If anything, the converse appeared to be true. One explanation for this could be that with an awareness of the arguments proposed by Weiss (1972) and other authors, biological anthropologists may actually be over-compensating for any potential male bias in skeletal sex determination by inclining to designate individuals with ambiguous or inadequate sex characteristics as female. An alternative interpretation may be drawn from the results of research carried out by Meindl and co-workers (1985). This indicated that the concerns of Weiss may be unfounded, and that the predominance of males in skeletal assemblages cannot be explained by a male bias in the application of skeletal sexing methods. Two experienced observers were supplied with a sample of 100 individuals from a reference collection of documented sex, comprising 59 males and 41 females. However, the information regarding sex was withheld from them whilst they seriated the pelves and skulls on a continuum from the most android to the most gynecoid, and made an assessment as to the likely sex of each individual. When the true sex of the individuals contained in the sample was revealed, the authors found that the females had rarely been misclassified whereas males were sometimes incorrectly assigned as female. Almost all the females obtained extreme gynecoid scores on pelvic morphology, with the result that none were incorrectly sexed on the basis of the lone pelvis. Males displayed greater variability in pelvic characteristics which led to the misclassification of four individuals using pelvic criteria alone. The lack of variation in the female pelvis was attributed to the pressures of natural selection to which the male pelvis has not been subject. The distinctive anatomy of the female pelvis is thought to have evolved as a compromise, accommodating the opposing requirements of locomotion and parturition. While a broad pelvis is necessary to provide an adequate birth canal, the divergence of the hip joints is limited because a narrow pelvis is more efficient for locomotion. Cranial characteristics were found to be less sexually dimorphic, perhaps because they have not developed to fulfil a primary sex-specific role. Again, a greater proportion of males than females were incorrectly sexed on the basis of the skull alone. However, this bias was largely attributed to differences in the age structure of the male and female samples as skeletal age was found to be a significant factor in determining the reliability of skull indicators in both sexes. Facial and cranial dimensions have been observed to display a steady increase throughout adulthood, estimated to be between 2% and 4% from the age of 20 to 60 years, resulting in an increasingly masculine skull morphology with advancing age. It was suggested that this effect could potentially result in young male skulls being misclassified as female and elderly female skulls as male. The higher rate of male misclassification was ascribed to the comparatively greater proportion of young males in the sample. Following these results, the authors reiterated the need to rely primarily on pelvic indicators when making skeletal sex assessments, but stated that 'even so, anatomists who adhere to this rule will probably underestimate the proportion of adult males, while erring in very few of their assessments of true females' (p.84). Referring to the survey of population sex ratios carried out by Weiss (1972), they concluded that 'of the archaeological samples of reported high sex ratios, many may even represent *underestimates* of the excess of males' (p.84, footnote 3). A more detailed investigation into the reasons behind any potential bias or inaccuracy in skeletal sexing method was beyond the scope of this study. The method was limited by the fact that most of the sex diagnoses had been attributed using a combination of several indicators, and perhaps future research should focus on testing skeletal indicators separately, in order to elucidate whether certain traits may be inherently responsible for producing a bias toward either sex. Nevertheless, the results presented in tables 5.5 and 5.6 could lend support to the conclusions drawn by Meindl and co-workers (1985).

The results of the study of skeletal completeness, presented in table 5.9, did not reveal any consistent sex bias in long bone survival. Considering first the comparative data for the total samples, irrespective of age structure, the collections from Abingdon, Fishergate 6 and Ipswich displayed no statistically significant sex difference in the proportion of long bones represented. A greater proportion of male long bones were represented within the Fishergate 4 collection, while a greater proportion of female bones were represented among the assemblages from St Nicholas Shambles and Wharram Percy, the sex difference among all these comparisons being statistically significant at the 1% level. The results obtained when the data were broken down into the respective age categories also showed an apparently indiscriminate pattern of long bone preservation between males and females. Approximately half the age-specific comparisons revealed no statistically significant difference between the sexes. Those that did, were not confined to any particular age group across the cemeteries and neither sex was consistently preserved to a greater or lesser degree in any of the age groups. Even among the eldest age categories, in which a male bias in preservation was most expected, only the cemeteries of St Nicholas Shambles and Wharram Percy displayed a statistically significant sex difference ($p<0.01$) in long bone survival, and these were actually biased in favour of females, the reverse of the predicted pattern. So while there were some sex differences in the proportion of long bones preserved, the results seemed to imply that long bone survival among these groups was influenced by other, probably indeterminable factors, such as local soil conditions, rather than sex *per se*. The results did not support the idea that the generally less robust bones of females were more prone to decay or that the presumed reduction in bone mass among the females in the most elderly age group (>45 years) had a substantial impact on the number of female bones surviving. In fact, contrary to the expected trend, there was no consistent reduction in the percentage of bones preserved among the eldest individuals (>45 years) of either sex. Percentage survival was similar to or even greater than many of the other age groups in the respective cemeteries. Of course, that is not to say that age-dependent bone loss does not have an adverse effect on preservation. The prevalence of osteoporosis was unknown among the samples, and it is possible that the proportion of individuals affected was comparatively low. In addition, the development of osteoporosis is associated with advancing age and as current methods cannot precisely determine age at death among those over about 50 years, it was not known whether the age distribution of those in the eldest cohort were skewed toward 50 or much older, with an increased likelihood of displaying osteoporosis.

What the study of skeletal completeness did highlight though was the differences in preservation between cemeteries. The material from St Nicholas Shambles was the least well preserved with only about 50% of adult long bones surviving. This was followed by Wharram Percy, in which 60-70% of the total number of potential long bones were present. Approximately 70-80% of long bones were represented among the Abingdon and Fishergate assemblages. Ipswich was the most well preserved collection, with more than 80% of all long bones surviving. This result emphasised the importance of taking preservation differences into account when comparing prevalence figures for the various pathological conditions between sites, as discussed in section 6.5.2.

A further factor which cannot be ruled out as having a possible influence on skeletal sex ratios is potential bias introduced through site sampling (Eley and Bayley unpub.). As discussed in chapter 2, none of the cemeteries were excavated in their entirety and although male and female burials were generally intermixed, at least with regard to the lay cemeteries, there were areas where single sex clusters were observed. Therefore, it is feasible that sex biases could have arisen in the samples retrieved, depending on the areas that were excavated. However, it is difficult to reconcile how this would explain why the sex bias should fall so regularly in favour of males in these, and the majority of other skeletal assemblages.

On a similar theme, rather than differential retrieval of male and female bones during modern excavations, Hanawalt (1986:102) has even suggested the possibility that during the Middle Ages, when the sites were still in use, female rather than male bones may have been unearthed and scattered as graveyards were cleared for new occupants. However, this would seem improbable in a period when named gravemarkers were not generally used and so the sex of a burial could not have been easily identified (Wakely pers. comm.).

Since the results of this study did not appear to provide convincing support for the first two lines of argument proposed to explain the skewed sex ratios among the skeletal assemblages, it was necessary to consider the third set of ideas outlined in the introduction, concerning the possible demographic or cultural factors which may have had an influence on the sex ratios interred. These primarily focus on the potential effects of migration, infanticide, and contemporary attitudes towards raising male and female children.

In the 1960's, Thrupp (1965-6) argued that the male bias observed in a series of European cemeteries may have arisen through population movements, brought about by factors such as colonisation, war, and economic circumstances, including the gender-specific demand for labour. This is a view which has since been echoed by Grauer (1991) and Mays (1997; 1998:72) in relation to the British medieval cemeteries of St Helen-on-the-Walls and Wharram Percy. As demonstrated above, the Wharram Percy collection, derived from a rural Yorkshire community, is heavily weighted in favour of males. By contrast, the cemetery of St Helen-on-the-Walls, which served the particularly poor parish of Aldwark in the city of York, displayed an unusually low sex ratio of 0.86 (Dawes and Magilton 1980). It contained 394 adult females and only 338 males, a difference which was statistically significant ($p<0.05$). Grauer and Mays have both suggested that the skewed sex ratios in these cemeteries may, at least in part, be best understood historically in terms of migration patterns. To provide support for their hypotheses, they have each drawn analogies with observations made on the poll tax returns of 1377, a tax which was levied on all persons over the age of thirteen (Russell 1966).

Independent analyses of the poll tax listings by Russell (1948:150-151) and Goldberg (1986; 1992:280-304, 368-375) have identified a tendency for there to be an inverse relationship between sex ratio and settlement size. Russell (1948:151) writes, 'if one examines the ratio of men to women it seems that as the proportion of men to women decreases the size of the places increases'. Goldberg's study indicates that in some urban centres there were only around 90 males for every 100 females, placing the sex ratio of York at 90.5, Hull at 86.1 and Carlisle at just 85.4 for example. In rural districts, the sex ratio often exceeded 100, surpassing 140 in a minority of villages such as Normanton in Rutland and Golding in Oxfordshire. Goldberg (1992:369) believes that 'this suggests that the adult population of later medieval English towns were characterized by a preponderance of females, but that the reverse is true of the countryside'. Both Russell and Goldberg attributed this to a disproportionately high level of female migration into towns from the rural hinterlands. Goldberg favours the idea of female-led migration into towns over a net emigration of males to the countryside in view of the generally high level of urban immigration, which in turn enabled many towns to sustain population levels despite the overall massive decline in numbers in the aftermath of the Black Death (Unwin 1990:127). Goldberg also cites female emigration, particularly that of young women, as a possible factor which contributed to the decline and eventual desertion of some villages in the later medieval period, as it may have diminished the capacity of rural communities to reproduce themselves.

Goldberg suggests that the principal reason behind the proposed female rural exodus was the contraction of labour-intensive arable cultivation upon the reduced demand for grain in the post-plague period, in conjunction with the relative prosperity being enjoyed by towns at a time when rising wages created a demand for manufactured goods and services (see below). Women may have been more vulnerable in a depressed rural labour market whereas the labour-starved towns offered them employment opportunities, particularly in service and in the emergent industries such as weaving. Using biographical data recorded about deponents to the Church Court of York during the fourteenth and fifteenth centuries, Goldberg (1997) has demonstrated that it was predominantly unmarried adolescents and young adults who were the most conspicuous among those known to have migrated, many of whom subsequently found partners and settled permanently. He therefore suggests that a further attraction of towns to female migrants may have been that they provided the opportunity to socialise and engage in courtship in the absence of parental supervision.

Topographical examination of the poll tax data has also revealed a propensity for females to reside in high concentrations within specific localities of towns, a phenomenon which Hufton (1984) has termed 'spinster clustering'. Rental evidence indicates that these congregations were frequently in the poorer suburbs, and Goldberg connects this with the immigration of women who, at least initially, may have been driven to take accommodation in cheap tenements outside the more prosperous central areas. One such area identified in York, was Aldwark. Grauer therefore suggests that the over-representation of females in the cemetery of St Helen-on-the-Walls may be a direct reflection of this pattern of female immigration and residence. The age structure of the assemblage may provide further evidence to support this contention, with the excess of females in the total sex ratio being largely accounted for among those aged under 35. Grauer suggests that if young females comprised a significant proportion of rural immigrants, then the overall mortality among young females may have been increased upon the exposure of incoming females to the urban pathogenic environment. They may have succumbed to new diseases to which they had no immunity, a threat which was compounded by the maternal stressors facing this cohort.

Using non-ambiguous place-name surname evidence, McClure (1979) has demonstrated that most migrants to York were typically drawn from a 20 mile radius of the city. The village of Wharram Percy is located at approximately this distance from York (see section 2.6), and Mays (1997:124) suggests that the elevated sex ratio of the skeletal assemblage from the site may be reflecting 'the other side of the coin as far as migration patterns are concerned', with female emigration to York and other urban centres such as Hull leaving a rural population dominated by males. Again, the age structure of the sample would seem to support this theory. As tables 5.7 and 5.8 indicated, the surplus of males was greatest amongst the most elderly, with a sex difference in frequency which was statistically significant beyond the 1% level. Perhaps this is indicative of a pattern of migration in which females emigrated whilst young and without family ties, leaving a greater proportion of males to grow old in their natal community. Following Goldberg's proposition, such a depletion in young females could even be implicated in the eventual depopulation of the village (see section 2.6).

If the inferences made by Grauer and Mays are correct, it implies that rather than making general interpretations about the collective sex ratios of skeletal assemblages, it may be more appropriate to interpret the sex composition of cemeteries individually, with reference to the socio-economic context of the communities they served. Although males predominated in all the collections included in this study, it is notable that the magnitude of bias in the lay cemeteries seems to follow the general pattern identified by Russell and Goldberg from the 1377 poll tax returns. The assemblage derived from the smallest settlement, Wharram Percy, displayed the highest sex ratio. The collection associated with the market town of Abingdon displayed the next highest superiority in male numbers, a sex difference which like Wharram, was statistically significant beyond the 1% level. The collections derived from London and York, two of the wealthiest and most populated cities in medieval England, contained proportions of males and females which were more comparable in number, and not statistically significantly different.

The cemetery of Abingdon Vineyard not only served the population of Abingdon itself, but also the surrounding rural parishes. So perhaps the high sex ratio observed in the cemetery collection was a product of this rural element, dominated by males as a result of female-led migration away from the countryside. Toponymic studies by McClure (1979) and Penn (1983) have demonstrated that the distances travelled by migrants into towns bore a general correspondence to the size of population. The dates of their sources ranged from the late twelfth to the early fourteenth centuries. Most migrants to villages and small to medium-sized market towns were drawn from within an 8 mile radius, whereas larger urban centres such as Nottingham or Leicester typically attracted migrants from within 15 miles. A substantial proportion of Bristol's immigrants were drawn from distances exceeding 40 miles, reflecting the town's regional economic dominance, and the catchment area of London was of a different order altogether, attracting people from throughout the country. This implies that the attractiveness of a town depended on its economic prosperity and the opportunities it offered. Furthermore, from a study of servants who had migrated to Hull, Goldberg (1986) found that females had travelled longer distances and in greater numbers than their male peers. Therefore, although Abingdon was an established market town, it may not have exerted the same pull on migrant female labour as perhaps other, larger towns in the vicinity such as Oxford, or even Bristol and London further afield. This may have been another factor which served to reduce the female component in the skeletal assemblage. Like Wharram Percy, the greatest excess in males was seen among the most elderly (table 5.7 and 5.8), a disparity between the sexes which was statistically significant beyond the 1% level. This could represent further evidence to support the idea of a comparatively high level of migration among young females away from the area leaving an elderly population dominated by males.

The migration theory might also be used to speculate on the factors contributing to the male bias in the cemeteries of St Nicholas Shambles and Fishergate 4. It is known that the importance and prosperity of London generated a pattern of mobility which was quite distinct from other urban centres, and it held opportunities which drew people from a diverse range of backgrounds. However, the parish of St Nicholas Shambles was a quarter of London which specialised in butchery (see section 2.2), and various documentary sources indicate that although women sometimes assisted in the industry, butchery was almost the sole preserve of men (Goldberg 1992:108-109,190; Graham 1997:130-131; Kowaleski 1986:148). It might therefore be speculated that the industry attracted a disproportionately high level of men into the area. It is feasible that a small number of intrusive monastic burials contributed to the male bias within the Fishergate 4 assemblage. However, the cemetery's sex ratio was also skewed by the group of young males with fatal weapon injuries, that may have been casualties of a battle (see section 2.3). Without these, the sex composition would resemble that of St Helen-on-the-Walls in Aldwark, York. Like Aldwark, the district of Fishergate was situated on the periphery of the city, and it is tempting to surmise that it may have attracted a similar pattern of female immigration.

Of all the cemeteries, Jewbury displayed the sex ratio which was closest to unity. Given the large size of the collection, containing over 300 sexed individuals, it is likely that the lack of any statistically significant difference in the proportion of males to females reflects a real similarity in sex ratio. Dobson (1974) has reviewed documentary evidence for the pattern of Jewish settlement in England during the Middle Ages, and concluded that prior to the mid-twelfth century, the Jewish population in England was confined to London. He believes that it was the expansion of the Jewish finance business which instigated the later establishment of Jewish communities in some of the larger provincial towns. By the latter half of the twelfth century, Jews had replaced Christians as the chief creditors to the English aristocracy. Dobson asserts that this transition occurred because Jewish financiers 'performed a well-established service more efficiently than their Christian competitors. In particular, the Jews resident in Angevin England enjoyed the inestimable advantage, for the purposes of money-lending, of forming a closely integrated minority group ideally qualified for mutual co-operation and organisation in business as well as religious matters' (Dobson 1974:9-10). A small number of extremely wealthy patriarchs dominated the syndicate. 'Like the great capitalist enterprises of the twentieth century, the financial dealings of the medieval English Jews defy understanding until it is appreciated that they operated at a national rather than local level: the history of any one community, York not excepted, can never be studied in isolation' (Dobson 1974:44). The York Jewry probably originated as an outlying business agency and Hebrew families were induced to settle through 'the backing and often direct sponsorship of their compatriots in the south' (Dobson 1974:10). There is little evidence to indicate that individual Jews dispersed away from the main settlement in York to become permanently resident in other smaller towns in the north, even though some business transactions did involve travel away from the city. This solidarity in residence, also observed elsewhere in the country, was probably judicious for economic and social reasons, not least the threat of anti-Semitic persecution, as testified by the York massacre in 1190. The greater social cohesion of the Jewish community may have a bearing on why the sample from the Jewbury cemetery displayed a sex ratio which was close to unity. Young Jews were not attracted away from their communities by the same employment and cultural circumstances which were presented to their Christian counterparts, and so not subject to the same forces of migration which may have come to influence the sex ratios of the Christian cemeteries. A further explanation may simply lie in the fact that only one Jewish cemetery existed in York, and this was one of only ten known to have existed in the whole of medieval England (Lilley 1994:361). It was not until 1177 that the Crown permitted Jews to bury their dead in provincial Jewish cemeteries. Communities which did not possess their own cemeteries transported their dead elsewhere for burial. So even if a disproportionately high number of either male or female members of the Jewish community did migrate during life, distorting the sex ratio of the living population, the limited number of sites available for interment could theoretically have restored the sex ratio upon death, presuming that segregation of the sexes in burial was not generally practised.

The above discussion illustrates how the notion of 'population movements' can be used to provide seemingly adequate interpretations for the demographic composition of skeletal samples. However, it will also be apparent that it is an approach which can produce somewhat convenient or superficial explanations for the patterns observed. Mays (1997:124) underlines the arguments used to explain the skewed sex ratios of Wharram Percy and St Helen-on-the-Walls with the caution that 'we should be wary of making simplistic connections between historical and archaeological data'. Thrupp (1965-6:475) also questions whether 'we should accept burials scattered chronologically over several centuries as valid aggregative data'. As discussed in section 2.8, all the lay cemeteries included in this study were in use for a prolonged period, each spanning at least a century, through different phases of the Middle Ages. During this time a dynamic complex of economic and social changes took place, not just on a national scale but on an intensely local and regional basis, which undoubtedly had a similarly complex bearing on medieval population movements. To illustrate this point, it is appropriate at this juncture to summarise some of the key features of medieval chronology, and its association with population mobility.

The Middle Ages can be viewed as broadly tripartite. The initial phase was characterised by a prolonged period of buoyant expansion. This was halted by crisis in the first half of the fourteenth century and followed by a period of contraction and reorientation (Campbell 1990; Platt 1978; Unwin 1990). Domesday Book indicates that late-eleventh century England was sparsely populated, with estimates for the total population ranging from between 1.1 and 2.25 million (Campbell 1990:70-71; Darby 1973:40). The social order was feudal, with the majority of the population, the peasantry, being subordinate to a land-controlling lordly class to whom they were obliged to give labour services, fines and taxes in exchange for their occupation of subsistence holdings. Most peasants were literally 'tied to the soil', legally unfree and prohibited from occupational and personal mobility. However, during the succeeding two centuries, the feudal structure began to dissolve as the established relationship between authority, labour and land was considerably modified.

The prevailing demographic trend for the first phase of the medieval period was one of vigorous population growth. For economic, ecological and institutional reasons, the rate of increase varied geographically, but it is estimated that by the close of the thirteenth century the total population had multiplied at least threefold (Beresford 1973:82; Campbell 1990:71). This was expressed in the widespread extension of cultivation and settlement (Beresford 1973; Campbell 1990; Platt 1978:39-44). New and abandoned lands were colonized, which promoted a rise in the proportion of free tenures as landowners enticed new settlers with generous holdings that were relatively unencumbered with feudal ties. A situation of labour surplus had replaced that of labour shortage and many landlords, who were no longer dependent on forced labour to work their land, preferred to commute customary services for hired labour and take rents in cash rather than kind. The self-sufficiency of the eleventh century gave way to an increasingly specialised agrarian economy based on production for exchange and profit rather than for use. Associated with the growth in productivity was a proliferation in marketing (Beresford 1973; Fox 1973; Platt 1978:30-36; Unwin 1990). Established towns grew rapidly and numerous new towns were founded during the thirteenth century. The excessive increase in population meant that there was no shortage of rural emigrants who had succeeded in freeing themselves to feed this unprecedented phase of urban expansion.

However, towards the end of the thirteenth century the rate of economic expansion was becoming insufficient to support the even greater climb in population (Campbell 1990; Goldberg 1992:282-283; Platt 1978:91-93). Reserves of colonizable land were reaching exhaustion. Land inheritance customs and the intense competition for land generated by the density of population resulted in holdings being subdivided further and further until fragmented to such a reduced size that they could no longer support the families dependent on them. Many were forced to take paid labour, but the pressure of numbers meant that the available labour was outstripping demand and wage rates had fallen substantially. The opening decades of the fourteenth century then delivered a succession of extreme blows (Beresford 1973; Campbell 1990; Goldberg 1992:282-283; Platt 1978:95-102). Torrential rain in 1315 caused widespread crop failure. Grain prices rose dramatically and the country plunged into a state of famine. This was accompanied by a virulent epidemic, possibly typhoid. The following harvest was equally disastrous and in 1319-20 cattle stocks were devastated by an outbreak of murrain. This depleted plough teams and the capacity to till the land, causing further harvest failure in the following season. For the remaining half of the century, episodes of bad harvests were compounded by heavy taxes levied to fund the war against France. There was growing polarization between rich and poor. Only the wealthiest with large viable holdings were able to make this period of teeming population and constrained resources work to their advantage. They benefited from low labour costs, and profited from high grain prices reaped from surplus stocks that were produced during intermittent years of good harvest. Those with small holdings were driven to sell land in order to buy food, but they sold land in bad years when it was a buyer's market and purchased grain at seller's prices, leading to an ever deteriorating predicament (Razi 1980:87-88). The living standards of the majority of the population had sunk to an absolute nadir. Landlessness, unemployment and destitution in the countryside led to an influx of the poor and needy to towns in search of work and charity. Hilton (1982 in Goldberg 1992:283) has suggested that females were particularly numerous among the 'flood of recruits' into towns at this time, an assertion drawn from the high number of pledges made to the borough court of Halesowen guaranteeing the good conduct of women seeking accommodation in the area. However, Goldberg (1992:288) does refute this idea, instead suggesting that the pledges were required because the unsupervised woman was seen as a trouble-maker, and that 'the evidence more readily reflects the marginal economic status of women in towns before the plague, a status that forced many the wrong side of the law simply to survive, rather than any underlying preponderance of females'.

The events of the early fourteenth century had exacted a heavy toll on the population, but the years 1348-9 witnessed a catastrophe of epic proportions. The onslaught of the Black Death culled an estimated third, or possibly one half, of the country's population, eradicating most of the increment accumulated in the preceding centuries (Beresford 1973:86; Campbell 1990:101; Goldberg 1992:288). Plague remained endemic for the rest of the medieval period and subsequent visitations of plague and other pestilence contributed to further demographic recession far into the fifteenth century (Hatcher 1977:11-30), such that Thrupp (1965 in Campbell 1990:104) has dubbed the fifteenth century 'the golden age of bacteria'. Rawcliffe (1995:3) also paints an evocative picture: 'It is impossible for modern readers truly to comprehend the shock and terror generated across Europe by the plague of 1348-9. Nor can we assume that subsequent epidemics caused any less panic and despair: a further twelve occurred throughout England between then and 1485, as well as numerous regional outbreaks which, cumulatively, did far more to hasten demographic decline. Intestinal and pulmonary infections, typhus, measles and sickness arising from malnutrition were all endemic, often hitting local communities in waves, one after another'. The ubiquity of death is reflected in the macabre nature of much of late medieval imagery and literature (Platt 1978:138-147).

Nevertheless, there were positive repercussions to the decline in population for those surviving (Campbell 1990; Goldberg 1992:289-290). The economic climate of the later Middle Ages was in many respects the opposite of the pre-plague era. Wage rates soared as employers competed for the scarce labour supply, and women in particular benefited from this development. Grain prices collapsed due to the fall in demand, and living standards rose to an all time high. Towns remained fundamental to the commercial economy and many retained their vitality during the later Middle Ages (Unwin 1990:132), so encouraging immigration. In the countryside, high wage rates combined with the low demand and price of grain, forced a contraction in labour-intensive arable farming. The rise in incomes created a demand for meat and animal products producing a shift toward less labour-intensive pastoral husbandry. There was a retraction in the area under cultivation, particularly on marginal soils, and many settlements shrank or were abandoned (Beresford 1973). Land became abundant and the small parcels of land which had been divided under the pressure of population in the pre-plague period were gradually consolidated into larger holdings and into fewer hands. There was a demise in the traditional method of landlord managed demesnes in favour of leasehold tenures. This, along with demographic disruption in the aftermath of the plague, contributed to the eventual demise of feudalism and the emergence of a new social order. Associated with these changes was a considerable increase in the rate of mobility. Freedom and opportunity encouraged peasants to improve their circumstances through migration, and various reconstitution studies have illustrated how previously servile families were able to rise to prominence through land acquisition and commercial enterprise (Campbell 1990:111; Raftis 1964:139-182; Razi 1980:117-118).

The ability to trace migration patterns through this intricate extended chronology, both regionally and nationally, is notoriously difficult and is an area of study which is still really in its infancy. Many sources are yet to be utilised and Fox (1973:78) describes those which are available as often 'fragmentary and intractable'. Goldberg (1992:280) complains that they 'tend to raise almost as many questions as they answer'. A further problem is that the nature of many sources, such as manor court rolls and tax assessments, are primarily concerned with fines and taxes imposed on males, so they tend to record little about female population movements. The integration of skeletal data into this patchy knowledge of medieval mobility is even more problematic. The cemeteries included in this study were not only drawn from different chronological phases but from geographically disparate areas, and communities which were socially and economically distinct. The explanations for the sex biases observed in the cemeteries of St Helen-on-the-Walls and Wharram Percy are simply founded on deductions associated with the skewed sex ratios noted in the surviving poll tax listings of 1377. Even if sound, the pattern of mobility interpreted from this source may only be specifically applicable to the conditions which prevailed during the post-plague period, yet both cemeteries were in use for the duration of the Middle Ages. The interpretations proposed for the remaining cemeteries in this study were made with a similar pattern of migration in mind, yet only the collection derived from Abingdon contained material which even encompassed this period, the rest pre-date this phase. It is clear that if any advances are to be made in this field of research, emphasis must be placed on the accurate stratigraphic phasing of burials within medieval cemeteries. Further comparisons between the sex ratios of urban and rural assemblages might help to elucidate whether there is any real connection with patterns observed in the historical data. Even so, our sheer ignorance of what cemetery population samples actually represent in relation to the diversity of factors which may have determined their composition (discussed in section 2.8), may ultimately prohibit the possibility of evaluating the effect of migration on skeletal populations. As Molleson and Cox (1993:213) have stated, 'it is extremely dangerous to make assumptions about populations from skeletal samples about whom nothing is known except that they represent all that remains of dead human beings'. At present, it is safest to conclude that the influence of medieval population movements on skeletal sex ratios can only be viewed as a theoretical association.

A final approach to explaining the male bias to adult skeletal assemblages is that there could be an excess of females among those aged under *c.*18 years which would serve to balance the sex ratio. The proportion of subadults designated to each sex from Abingdon and Fishergate using the tooth measurement technique (discussed in chapter 3), does not provide immediate support for this hypothesis. Although there was no statistically significant difference in the number allotted to each sex, both samples contained a marginally higher frequency of male classifications. However, the samples were so small, it would be inappropriate to draw any general conclusions on the basis of these results. Furthermore, the method could not be used to sex young children with undeveloped permanent teeth. Future developments in sub-adult sexing methodology may confirm whether there is any foundation to this theory. At present, it may be helpful to turn to documentary sources to evaluate whether there is any historical evidence to suggest that there was a higher death rate among sub-adult females.

It has been asserted that pregnancy and childbirth carried a significant mortality risk, so perhaps childbearing served to elevate the death rate among females under the age of 18, depending of course on the typical age at which females embarked on motherhood. This might be inferred by examining the evidence for the typical age at first marriage. Puberty was stipulated to be the minimum age for matrimony under canon law, defined as 12 years for girls and 14 for boys. However, the general consensus is that marriage in the early teenage years was mainly confined to the aristocracy, who often betrothed their children, especially their daughters, at an even earlier age (Hanawalt 1986:97-100; Shahar 1983:134-138; 1992:223-224). Opinions differ as to what the typical marriage age was for the majority of the population, partly due to limitations with the available evidence (Bennett 1987:71), and also because it varied with time and locality. Nevertheless, Razi (1980:50-64,135-137) was able to estimate the average age at first marriage among the parishioners of early fourteenth century Halesowen using court roll evidence, and placed it at between 18 and 22 years for both sexes. Poorer peasants married later than their wealthier counterparts and some never married, which Razi associates with an inability to secure land or dowries during a period of low wage rates and land shortage. In the post-plague period, Razi detected a slight drop in marriage age, especially among females, with at least 13% of the sample of 119 females marrying between the ages of 12 and 19. He attributed this to the higher wage rates and abundance of land in the post-plague era which enabled poorer peasants to enter into wedlock sooner. Hanawalt (1986:96) cites evidence from the 1381 Suffolk poll tax returns which concords with Razi's estimates, and similarly Bennett (1987:72-73) has examined the limited evidence available from rural Brigstock before the plague and tentatively concluded that most villagers probably married by their early twenties.

Goldberg (1986; 1992:225-232; 1997:1-15) however, rejects the argument for a comparatively early marriage regime. Using deposition evidence from York ecclesiastical court, dating to the later fourteenth and fifteenth centuries, he contends that young people often remained single into their early or mid-twenties and that marriage rarely occurred in the late teens. He proposes that the auspicious employment opportunities in the post-plague period, particularly for women, enabled young people to remain independent and so postpone marriage. Delayed nuptiality has also been cited as a factor which may have contributed to the demographic recession that persisted after the plague, through the fifteenth century (Campbell 1990:104; Hanawalt 1986:96). Similar views are shared by Smith (1979 in Campbell 1990:104-105; 1983 in Goldberg 1992:232) who identified a relatively late age at marriage in an earlier study of 1377 and 1381 poll tax data. Nevertheless, from the evidence provided by a small sample of rural deponents to the church court of York, Goldberg cautiously suggested that the average marriage age in the countryside may have been younger than it was in urban society, perhaps in the late teens or early twenties.

It is possible that the average age at first birth was actually lower than that at first marriage. Birth outside wedlock was a common occurrence in all social classes, and pregnancy was often a prelude to marriage (Hanawalt 1986:195-196; Shahar 1983:113-120). Although Goldberg contends that women frequently deferred marriage into their twenties, he believes that this 'need not imply that they were necessarily sexually inexperienced prior to their marriage' (Goldberg 1992:232), an opinion shared by Hanawalt (1986:195-196). Using court fine data from pre-plague Halesowen, Razi (1980:64-65) estimated that one woman gave birth outside marriage for every 1.9 women who married, and found that birth outside wedlock was most common among the poorest peasants.

On balance, the evidence would suggest that an element of females probably did bear children in their mid to late teens before reaching full skeletal maturity, particularly in rural society, though this was probably not the case for the majority. It is therefore feasible that a slight excess of females exist among those whose sex characteristics were insufficiently developed to permit a sex diagnosis, which may go some way toward balancing the sex ratios evident within the adult portion of the skeletal samples. However, figure 5.2a-g also indicates that the age cohort 13 to 17 years contained a comparatively small number of individuals, suggestive of a generally low level of mortality among this age group, so this line of argument is unlikely to be the entire explanation.

As figure 5.2a-g illustrates, most subadult deaths occurred during infancy and in the pre-teen years. Female infanticide and the inferior care of female children have been suggested as possible causes for a higher mortality rate among females in this age group. Historical records suggest that infanticide, primarily through exposure, was an accepted practice in the ancient Greek and Roman world, justified as a means of controlling family size. This may seem a difficult concept to understand in a modern western culture, but as Mays (1995a:8) explains, the newborn infant was not considered to be 'a fully-fledged member of human society'. Mays draws an analogy with the 'modern justifications for abortion before the foetus is "viable" at 24 weeks' (p.8). Baby girls were more frequently the victims, resulting in an abnormally high sex ratio in the surviving population (Langer 1974a; 1974b; Mays 1993; 1995a). However, the arrival of Christianity to Europe was concomitant with a change in attitude. Christian ethics held that that all human life was sacrosanct, and infanticide was outlawed in all Christian countries. Despite this prohibition, the practice undoubtedly continued. Shahar (1992:127) and Mays (1995a) believe that the fact that the church and medical writers felt the need to repeatedly condemn the practice throughout the Middle Ages, indirectly testifies to its existence. Foundling's homes were also established across medieval

Europe as an incentive to prevent infanticide and the abandonment of unwanted children. Helmholz (1975) and Kellum (1974) have each provided direct support for its existence in medieval England with examples of court prosecutions, and further indirect testimony comes from folklore and superstitious beliefs which recount cases of infant murder and abandonment (Kellum 1974; Shahar 1992:132-139).

In a prelude to Kellum's paper, it is contested that 'a widespread infanticidal component was present in the medieval personality'. However, while the existence of infanticide is not disputed, whether it was restricted to isolated incidents or was a common practice is unknown, owing to the covert nature of the act (Helmholz 1975; Shahar 1992:127). It was often impossible to distinguish between disguised murder and accidental deaths resulting from suffocation by overlaying in bed, drowning, fire, or even still births. Mays (1993; 1995a) has attempted to use skeletal evidence as a method for indicating the prevalence of infanticide. He took long bone measurements to determine the age at death of perinatal infants from six Romano-British sites and the large medieval assemblage from Wharram Percy. The age distribution of infants from the Roman sites displayed a sharp peak in deaths around full-term, a pattern which may be suggestive of widespread infanticide. The distribution from Wharram Percy was much flatter with no pronounced peak at full term, a pattern which is characteristic of still births and deaths from natural causes in the immediate post-natal period. Mays (1995a:8) suggested that the infanticide of predominantly female babies in the Roman period could explain the 'long-standing conundrum' of high sex ratios in Romano-British cemeteries. However, he contends that the pattern of perinatal deaths from Wharram Percy does not necessarily indicate that infanticide was rarely practised in the medieval period. It may simply reflect how easily the crime could have been concealed. Victims may have been buried surreptitiously away from the churchyard. Infant burials may also exist in areas of the cemetery which were not excavated, especially as the unbaptised were often segregated outside the main burial area (Kellum 1974; Shahar 1992:50-52). Herlihy (1995:225) infers the possibility of concealment in a reference to fifteenth century preachers who claimed that 'the streams and cesspools of Europe echoed with the cries of abandoned babies'.

Russell (1948) and Coleman (1976) have both argued the case for mass female infanticide on the basis of sex ratio data derived from documentary sources. Russell asserts that any marked disparity in the proportion males to females 'causes suspicion that some tampering with human life has occurred' (p.49). He identified a ratio of four males to three females among the heirs of landholding class recorded in the Inquisitions Post Mortem during the periods preceding and following the Black Death, and suggested that this may have been the 'result of elimination of female babies at birth' (p.49). He also detected 'an unmistakable deficiency in the number of female children' listed among the serf families who occupied lands owned by John of Hastings in 1391-2. Seventy-eight boys were listed compared with 46 girls, a deficiency which Russell suggests may have arisen through the 'liquidation' (p.167) of females. Coleman analysed manorial census data pertaining to the peasants from Saint Germain-des-Prés, in an albeit earlier period, dating to the ninth century. She identified an inverse relationship between family size and sex ratio, whereby the proportion of females declined with increased family size. Coleman suggests that daughters may have been perceived as a financial drain and their numbers may have been regulated through infanticide. She concludes that it is 'probably fair to wonder if the answer to many a hard-pressed peasant's prayer came in the form of death, primarily of female babies'. However, both authors acknowledge that the discrepancies in sex ratios could have arisen for other reasons, such as the under-enumeration of females by those who recorded the data, an interpretation supported by Herlihy (1995).

Hanawalt (1977) has investigated the proposal that female babies were the more likely victims of infanticide by comparing the number of male and female infant deaths that were recorded as 'accidental' in fourteenth century Northamptonshire coroners' inquests, on the premise that accidental deaths may actually contain a proportion of disguised cases of infanticide. However, of those aged below one year, 28 boys were recorded compared with only 20 girls, a pattern which is not consistent with the idea of widespread female infanticide.

Herlihy (1995) has asserted that the chief difference between the infanticide which was practised in the ancient world and that which was practised in the Middle Ages was the motive behind the act. Scrimshaw (1984) has collated a host of reasons for practising infanticide using a range of modern and historical sources, and no doubt these also applied during the medieval period (Coleman 1976), but the most common motives appear to have been poverty and moreover, birth outside wedlock (Herlihy 1995; Shahar

1992:127-129). Herlihy (1995:226) believes that 'the killing or abandonment of babies in medieval society was the characteristic resort of the fallen, the poor, the desperate. In the ancient world, infanticide had been accepted practice, even among social elites'. Poverty may have led to a greater extermination of female babies if they were considered a greater financial burden, but as Hanawalt (1977) points out, infant mortality was so high, estimated to be between 30-50%, infanticide may have been unnecessary. Brissaud (1972 in Shahar 1983:118-120; Shahar 1992:127-128) has examined letters of remission of punishment granted by French officials to peasant women who had killed their babies after birth, and without exception, the women had given birth outside wedlock. None had defended their conduct on the grounds of poverty, but rather they had pleaded 'fear and shame' as the reason behind their actions. However, if the stigma of illegitimacy was a primary motive for infanticide, it seems reasonable to argue that the sex of the child would have been immaterial. The chief anxiety of the mother would surely have been to eliminate the child, regardless of its sex. Furthermore, Razi (1980) has argued that birth outside wedlock was not necessarily stigmatised in medieval England. Not only was it a common occurrence among the peasants of Halesowen, but many women 'subsequently married - and not below their station' (p.65), so even this factor may not have been responsible for triggering infanticidal behaviour on a widespread scale.

Kellum (1974) and Hanawalt (1977) have pointed out that the lack of direct evidence for widespread infanticide in the Middle Ages may be significant, perhaps indicative of a 'conspiracy of silence'. However, as Kroll and Bachrach (1986), DeMaitre (1976-7), and Hanawalt (1986:102) have also noted, there is considerable evidence to suggest that efforts were taken to secure the well-being of children, including the care and help sought by parents whose children were sick or disabled. These authors argue that if infanticide was widely practised, such children would probably have been the most likely targets, more so than female babies, and so they have dismissed the argument that the absence of positive evidence for prevalent infanticide is in any way meaningful. This view is concordant with Johansson's (1984:471) opinion that 'until the sixteenth century, demographic documentation is so uneven and its interpretation so fraught with problems that the existence of female infanticide in Europe remains doubtful'. Overall, it may be said that although there is evidence to indicate that infanticide was practised in the Middle Ages, no direct evidence exists to suggest that it was a widespread phenomenon, or that females were more often the victims. However, the lack of evidence should not necessarily be taken as a categorical denial of its widespread existence, owing to the potential secrecy which could have surrounded the practice.

Evidence to support the differential treatment of male and female children is also lacking. As Orme points out, when contemporary authors write about children it is usually boys that they are referring to and this could act to 'hide a gender bias' (1995:51). In some developing countries today, such as parts of India and Bangladesh, there is a higher childhood mortality rate among females due to the preferential treatment of males. Boys are more likely to receive medical attention when unwell and to be fed a more nutritionally adequate diet than girls (Stinson 1985). However, using ethnographic and historical data, Johansson (1986) has identified an association between excess female mortality in childhood and the stage of a society's economic development. She argues that excess female mortality is most extreme in societies which are in the process of undergoing economic modernisation, particularly in agriculture, where specific cash values are placed on particular aspects of farm production. In this situation, women and girls are perceived as less valuable to the family economy because they tend to be involved in production for household consumption, work which is outside the cash economy, whereas men and boys can command wages for their involvement in production for the market, thereby encouraging greater investment in male children. By contrast, Johansson believes that in traditional agrarian societies in which the female role is perceived as active and important, females do not experience excess mortality in childhood. Similarly, once developing countries have made the transition to industrialisation and urbanism, excess female mortality in childhood ceases due to the abundance of paid labour for young girls, and ultimately the abolition of child labour. Parallels can be drawn between Johansson's model and the socio-economic history of medieval England, from which it might be argued that the conditions prevailing throughout much of the period would have served to minimise excess female mortality during childhood. For example, in the early stages of feudalism, before landlords had taken to commuting customary services for paid labour, esteem may have been placed in the work of females resulting in a low vulnerability to childhood mortality through inferior treatment. Females may potentially have been more susceptible to excess mortality during the economic crises of the later thirteenth and early fourteenth centuries, when limited employment opportunities in agriculture reduced the demand for female labour, and when grain was at a premium and so least available to the poorest and perhaps least valued members of society. The economic opportunities available to females in the post plague period, particularly in urban centres, may be viewed as being analogous to the final phase in Johannson's model, and so again females may have been held in higher esteem. This may have served to reduce female mortality, in conjunction with the greater availability of resources and overall improvement in living standards. Unfortunately, this cannot be verified from historical sources due to the scarcity of evidence, although it does illustrate how status according to gender may have varied throughout the duration of the Middle Ages.

Some authors of medical and didactic works do reveal their attitudes towards the ideal feeding practices for boys and girls which could have had a different impact on their mortality rates. It is thought that delayed weaning confers a protective effect on the child through the transfer of immunological components from the mother (Fildes 1995; Hühne-Osterloh and Grupe 1989; Katzenberg *et al.* 1996), and large sex differences in morbidity and mortality have been identified among children in cultures which practice preferential and longer duration breastfeeding for boys (Stuart-Macadam 1995). Most medieval authors recommended that weaning should take place at about two years, but one author, believed to be Arnold of Villanova, wrote that some believed males should be weaned later than females because males have 'more strength, courage and reason' (Shahar 1992:81). Michele Savonarola was of the opinion that because males lived longer than females, boys should be weaned six months later than girls, at around the age of three; and Bernard de Gordon wrote that boys should be weaned later because 'woman is only the guardian of the house, as Galen says, and therefore she needs less strength than man' (DeMaitre 1976-7:474). With regard to older children, Konrad of Megenberg and Paolo of Certaldo believed that girls required less food because they were less active as a consequence of their biological inferiority. Paolo of Certaldo explains that this should not be taken to incite prejudice against girls as parents should love all their children equally, but rather encourage a different method of nurturing as a result of the biological difference between the sexes. 'Hence', he writes, 'nourish the sons well. How you nourish the daughter does not matter as long as you keep her alive.

Do not allow her to wax too fat' (Shahar 1992:81). It might be argued that these assertions could have acted as a self-fulfilling prophecy. Perhaps if inferior nutrition was afforded to female children it may have manifest itself in inferior strength, health, and longevity, which in turn gave grounds to the beliefs on which they were founded. However, as Shahar (1992:81) has pointed out, there is no evidence to suggest whether or not the advice offered by contemporary authors was actually heeded in the parental home.

Shahar (1992:82-83) presents evidence to suggest that some parents did display favouritism towards certain children, in terms of affection and concern, but these were not necessarily their sons. Nevertheless, she does cite evidence from fifteenth century Florence which indicates that more girls than boys were handed over to wetnurses or placed in foundlings' homes, which enhanced the risk of mortality (Stuart-Macadam 1995). Furthermore, boys who were wetnursed were better fed than girls, resulting in a lower mortality rate; and more fathers of boys than girls placed in foundlings' homes vowed to one day return and retrieve their infant, so boys tended to be raised and nurtured within the foundlings' homes, whereas girls were more likely to be sent to cheap wetnurses in the country where they perished through inadequate care. However, whether this sort of discrimination against female children occurred in medieval England is not known due to the scarcity of historical sources.

With reference to the English medieval peasantry, Bennett (1987:68) acknowledges the inability to determine childhood mortality rates from documentary sources, but surmises 'it is possible that the odds worked against the survival of female children'. Although parents probably loved their daughters, Bennett contends they may have favoured their sons because they were the preferred heirs to whom the family name and lands would pass. Such partiality might have placed females at greater risk during times of difficult circumstances. The greater value that inheritance customs gave to male offspring is evident from the naming practices employed by the peasantry. The forenames of sons were picked from a limited range and were often repeated in successive generations, emphasising their importance to the family's past and future. Female names were far more varied and carried no familial importance.

Hanawalt (1986:184-185) has suggested the possibility that fathers may have taken a keener interest in the welfare of their sons than their daughters. From a study of

English coroner's inquests which divulged the person who first discovered the bodies of children who had died from accidents, Hanawalt found that 43% of male children were discovered by their fathers and 45% were discovered by their mothers. This compared with 33% of female victims being found by their fathers and 59% by their mothers. The proportion of daughters found by their mothers was even greater among those under three years, whereas the age of the son made no difference to which parent discovered the body. However, Hanawalt does offer an alternative interpretation, that mothers and fathers showed equal concern over their sons whereas mothers displayed a greater concern for their daughters.

Although the lack of a routine method for subadult skeletal sexing prohibits the ability to gauge whether there was a higher mortality rate among subadult females, adult remains can display retrospective evidence of childhood morbidity and general health. From this, sex differences in childhood mortality might be inferred. The following chapter therefore concentrates on indicators of skeletal stress among adults, in addition to the small sample of subadults sexed using the tooth measurement technique (discussed in chapter 3).

The comparison of male and female age at death profiles did provide some, though not overwhelming evidence to support the idea that females tended to experience an earlier age at death than males among the skeletally mature. The results were most decisive when the data were aggregated into two categories, grouping those aged above and below *c.*35 years, as presented in table 5.11 and figure 5.4a-h. A greater percentage of females were attributed to the younger group, and thus a greater percentage of males were attributed to the older group, within five of the cemeteries: Wharram, Abingdon, Jewbury, St Nicholas Shambles and Ipswich. Only the assemblages from Fishergate displayed the converse pattern, the group of young males with fatal weapon injuries largely contributing to the predominance of males among those aged under *c.*35 within the pre-monastic phase.

Since the percentage of females aged below *c.*35 exceeded the percentage of males in the majority of samples, it is tempting to interpret the results as evidence for a shorter average lifespan among females, perhaps as a consequence of the process of childbearing. However, the percentage difference was mostly of a small magnitude, and chi-square tests revealed that none of the cemeteries actually displayed a statistically significant association between sex and age at death, indicating that the perceived sex differences in the data could have arisen through pure chance.

Given the fairly consistent bias observed, a statistical association might have been attained had the samples been larger. There is some evidence to support this as when the data from all the cemeteries were combined, totalling almost 1,500 individuals, the value of chi-square approached a statistically significant level (χ^2= 3.335 p=0.068). However, even within this large sample, an unequivocal level of significance was not achieved. In percentage terms, 48.1% of all females were aged below *c*.35 years compared with 43.3% of males; leaving 51.9% of all females in the older category compared with 56.7% of all males.

These results indicated that the overall disparity in male and female age at death was probably of a fairly low magnitude, and really only discernible among large scale samples. Since no statistical association between sex and age at death was identified, the results could also suggest that too much emphasis has traditionally been placed on the idea that childbearing had an expressly detrimental impact on female lifespan. World Health Organisation (1987 in Ortner 1998:81) figures do support the idea that pregnancy and childbirth present a significant mortality risk in the absence of modern healthcare, indicating a maternal mortality rate of between 1:15 and 1:70 in developing countries. However, even if similar figures were applicable in medieval England, it is also important to remember that other factors could have posed a much greater threat to survival. In particular, infectious disease would have exacted a heavy toll on both sexes, perhaps overshadowing the singular importance of childbearing on female mortality. A further interpretation could be that certain factors specifically served to shorten the lifespan of males, counterbalancing the effect of childbearing in females. Possible examples might be fatal trauma or a lower resistance to environmental stress, discussed in chapters 6 and 7. As for whether an inferior health status could have contributed to the slight female tendency towards a lower age at death, or whether childbearing was primarily responsible, is difficult to infer simply from a study of age at death. In the past, it was asserted that parity status could be inferred from skeletal remains, owing to the purported 'scars of parturition' which were thought to develop on the pelvis as a result of ligament stress during pregnancy and birth (Wells 1967). However, research conducted by Cox and co-workers (Cox and Scott 1992; Molleson and Cox 1993:135-136), using material from the Spitalfields crypt with documented obstetric histories, has now invalidated this theory, which precludes the possibility of determining whether childbearing was likely to have had an important impact on female longevity on the basis of skeletal evidence. Nevertheless, it was possible to investigate whether an inferior female health status might have contributed to the slight female proclivity toward an earlier age at death, by comparing evidence for skeletal stress in males and females, and this is discussed in the following chapter.

The results were more erratic when the data were analysed using the original four age categories, as illustrated in table 5.10 and figure 5.3a-h. The age distribution of females from Abingdon, Wharram and Jewbury appeared to be skewed more towards the younger age groups by comparison to the males which tended to lean more toward the older groups, but no consistent pattern was discernible among the remaining cemeteries. None of the cemeteries displayed a statistical association between sex and age at death according to the chi-square tests, although this might partly have been related to the reduced size of the samples having split the data into four age groups, or inaccuracies in ageing methods which would tend to become more apparent with increasing refinement of the age cohorts. Nevertheless, the lack of a consistent pattern and the absence of any statistical association lends further support to the interpretation that the overall sex difference in age at death was fairly marginal.

Neither was any statistical association between sex and age at death identified when the data from all the cemeteries were pooled, although variations were observed in the male and female mortality profiles. A similar percentage of males and females were assigned to the youngest age category, *c.*18-25 years, female deaths exceeding male deaths by just 0.8%. However, while males then displayed a fairly steady rise in deaths with each successive age category (rising by approximately 3% in each cohort), there was a rise of almost 7% in female deaths among those aged *c.*25-35, which accounted for most of the excess previously observed among those aged under *c.*35. Female deaths then fell slightly in the *c.*35-45 age group (by 1.7%), which returned the sex ratio to near unity. The number of female deaths stabilised in the eldest group (rising by only 0.3%), and were exceeded by the continued rise in male deaths. This pattern indicates that a slightly greater proportion of males survived into old age, and that the shortfall in elderly females largely derived from an excess in female deaths among those aged *c.*25-35, implying that females were at a slightly elevated risk of mortality during this period. This could lend support to the interpretation that childbearing was a more important determinant on female mortality than an inferior health status, as it might be argued that the latter would tend to exert a more constant erosion on survival. Although it should be emphasised that skeletal age does not necessarily correspond to chronological age, if childbearing was primarily responsible for the slight rise in deaths among those aged *c.*25-35, it could lend support to the view that females often delayed marriage and family responsibilities into their mid-twenties. Grauer (1991) has also detected a peak in female deaths within this age cohort among the cemetery of St Helen-on-the-Walls, York, and the association between sex and age at death was statistically significant. Grauer interpreted the pattern as reflective of maternal mortality, combined by the immigration of young women into York with an inadequate immunity to survive the new pathogenic environment.

Some further patterns were noted between the age at death profiles of the various cemeteries, illustrated in figure 5.3a-h and 5.4a-h. Wharram Percy displayed the most distinctive pattern. A steady but comparatively low proportion of deaths occurred in the three youngest age groups, with a sharp rise in the proportion of those aged over *c.*45 years. Of those reaching adulthood, approximately 40% had survived to the most elderly age group upon death. The most immediate interpretation is that this supports the common assertion that life in the countryside is somehow 'healthier' (Waldron 1989), perhaps the greatest benefit being the reduced exposure to infectious diseases which tend to flourish in densely populated, urbanised areas. The profile contrasts with that obtained for Nicholas Shambles in London, which was skewed toward the younger age categories with only around 10% attaining *c.*45 years or more. Not only is this suggestive of an urban population with a heavy disease load, but perhaps also an immigrant population whereby young migrants succumbed to new diseases upon entering the urban environment. The pattern displayed by the Abingdon sample was more akin to that of Wharram Percy, though less pronounced. The lowest proportion of deaths occurred in the youngest age category, rising with increasing age. This pattern may therefore reflect the rural component in the assemblage (see section 2.5). However, the monastic phase from Fishergate displayed a similar profile to Abingdon, yet the assemblage was derived from the city of York rather than a rural settlement. Perhaps this reflects the higher standard of living that was generally enjoyed by monastic communities (Harvey 1993) and the wealthy benefactors interred in the cemetery, which tends to be conducive to increased longevity. However, the age distribution for the other monastic assemblage, Ipswich Blackfriars, was fairly evenly spread across the cohorts, which could suggest that this is not an appropriate explanation, or that the status of the interments differed between the two monastic sites.

Furthermore, these interpretations are likely to be over-simplistic as attempts to compare data between sites are clouded by a host of limitations. Aside from inter-observer variability in scoring, the respective cemetery figures represent time-averaged estimates for age at death. During the period of cemetery use, the typical lifespan probably varied considerably in response to many factors, such as epidemics, and fluctuations in birth and death rates. This impedes the ability to compare data derived from cemeteries which do not represent a discrete period in time, and are drawn from different chronological time spans and geographical areas. Nevertheless, the investigation into general health status in the following chapter helped to ascertain the validity of these interpretations, owing to the potential relationship between health and longevity.

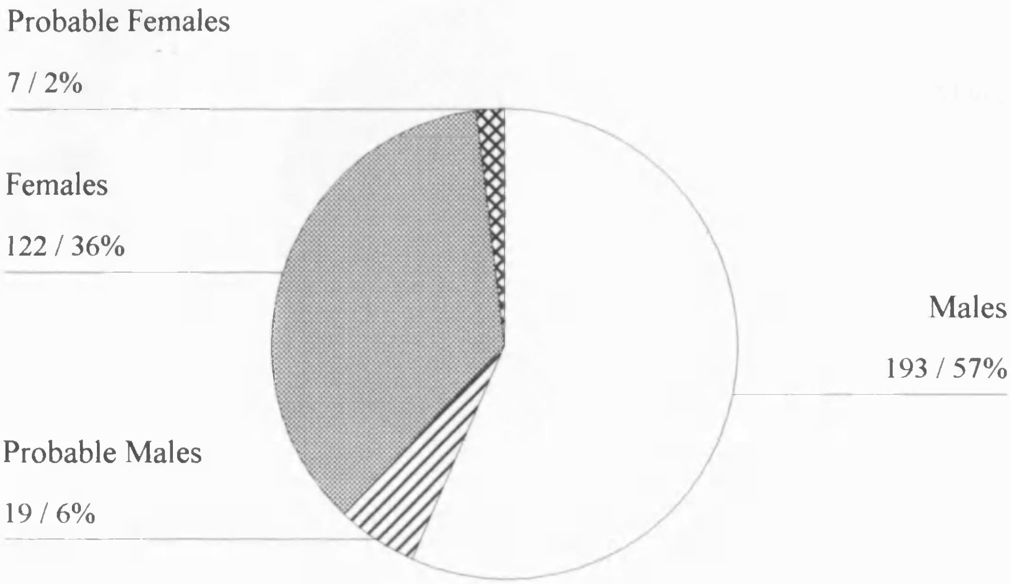
Table 5.4 Frequency of sexed and unsexed skeletons within the cemetery samples

n_m number of adult males n_f number of adult females n_s number of subadults
n_a number of unsexed adults n_t total number of individuals in the cemetery assemblage

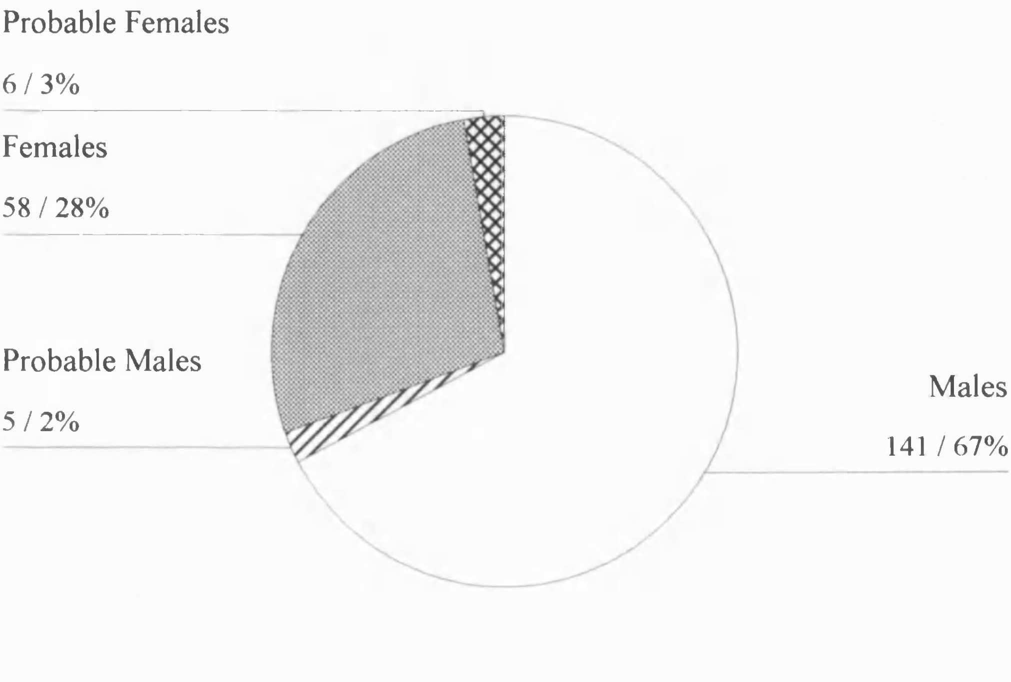
	n_m	n_f	n_s	n_a	n_t
Wharram	212	129	327	17	685
Ipswich	146	64	26	14	250
Abingdon	223	171	171	25	590
St Nicholas	91	74	52	17	234
Fishergate 4	47	33	44	4	128
Fishergate 6	176	53	39	1	269
Jewbury	161	150	132	26	469
Pooled site data	1056	674	791	104	2625

Figure 5.1a-g Pie charts illustrating the sex composition of the cemetery samples

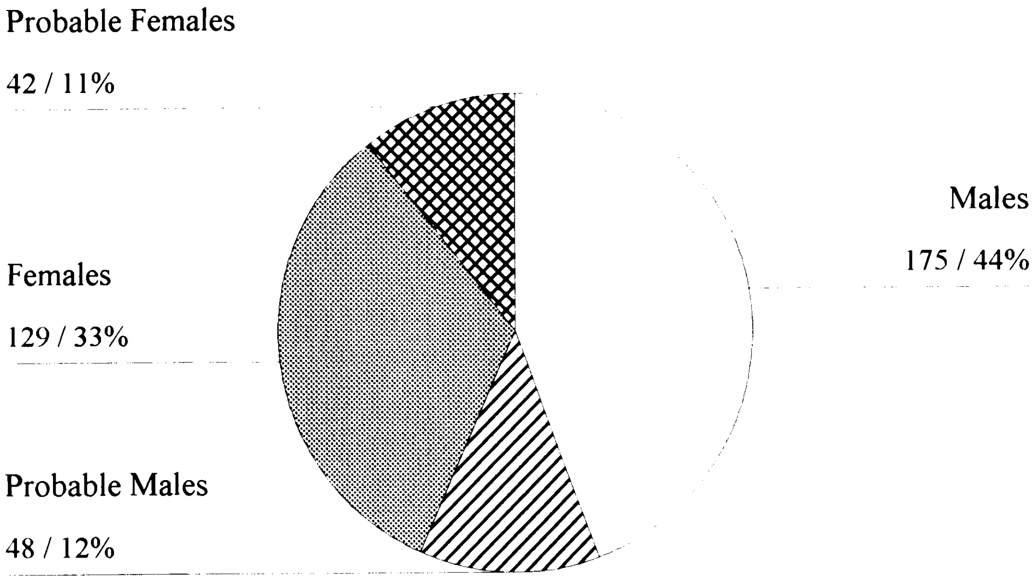
(a) Wharram Percy



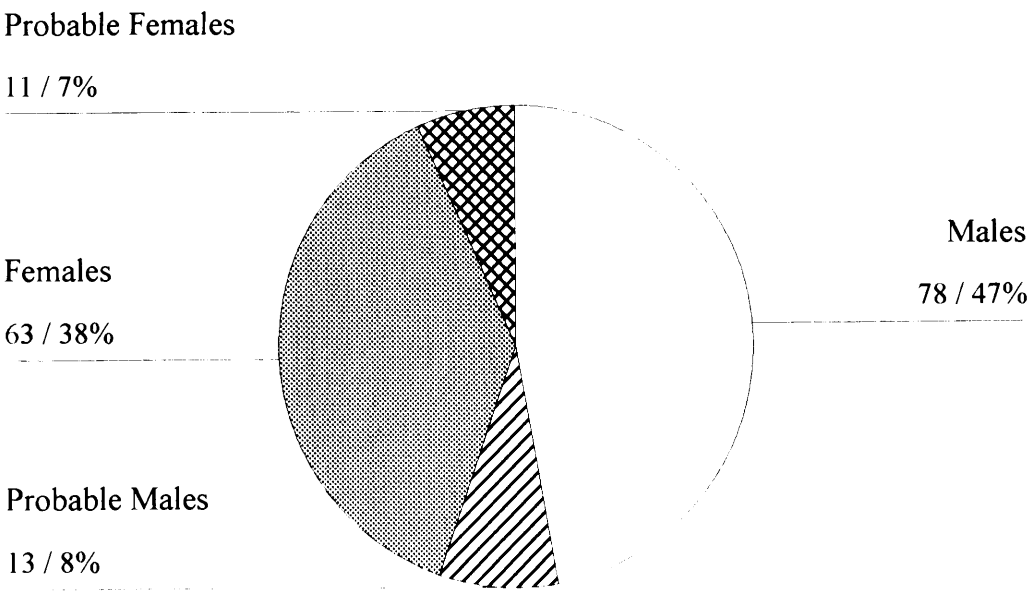
(b) Ipswich Blackfriars



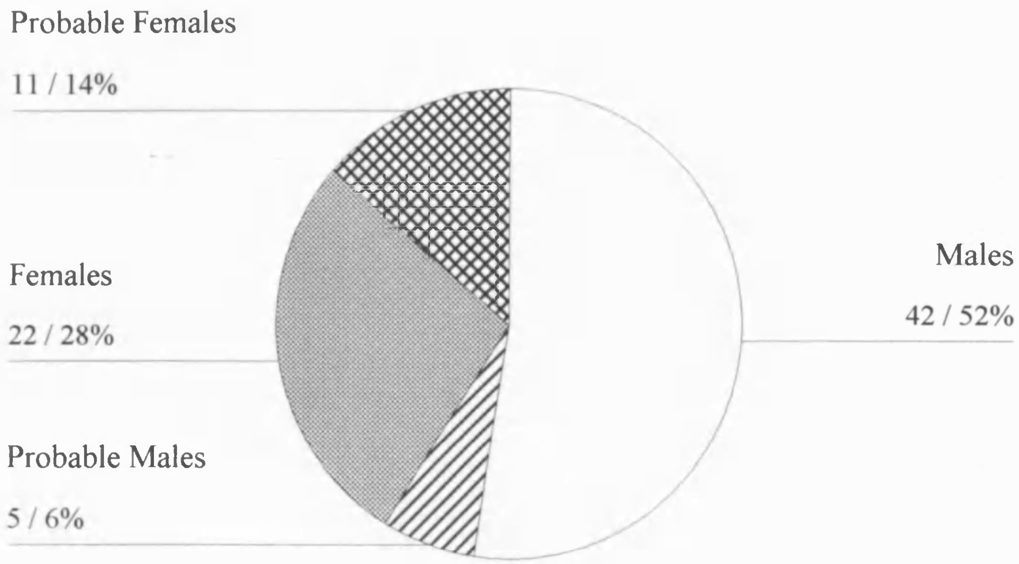
(c) Abingdon



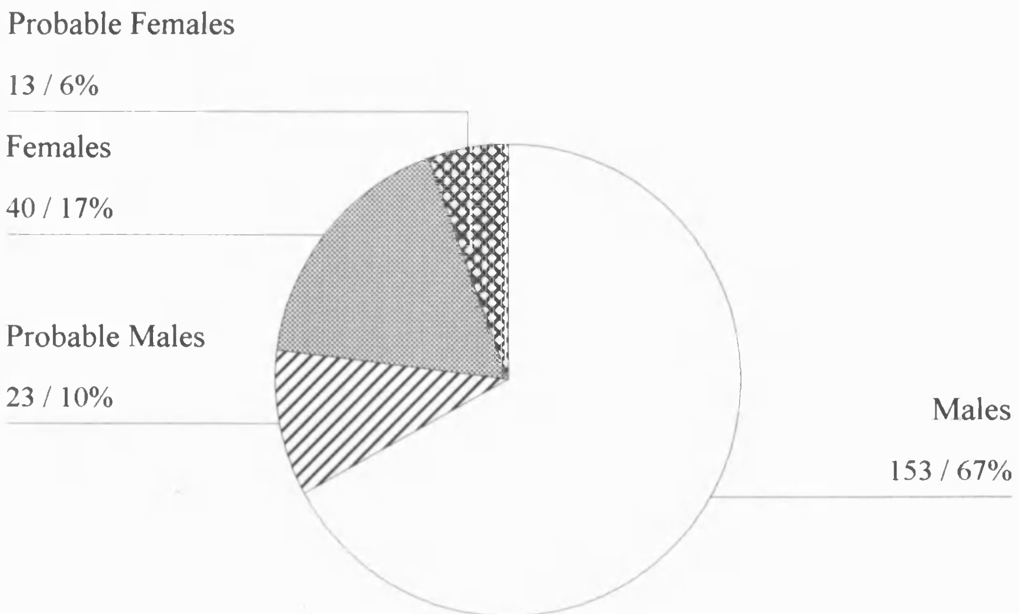
(d) St Nicholas Shambles



(e) Fishergate 4



(f) Fishergate 6



(g) Jewbury

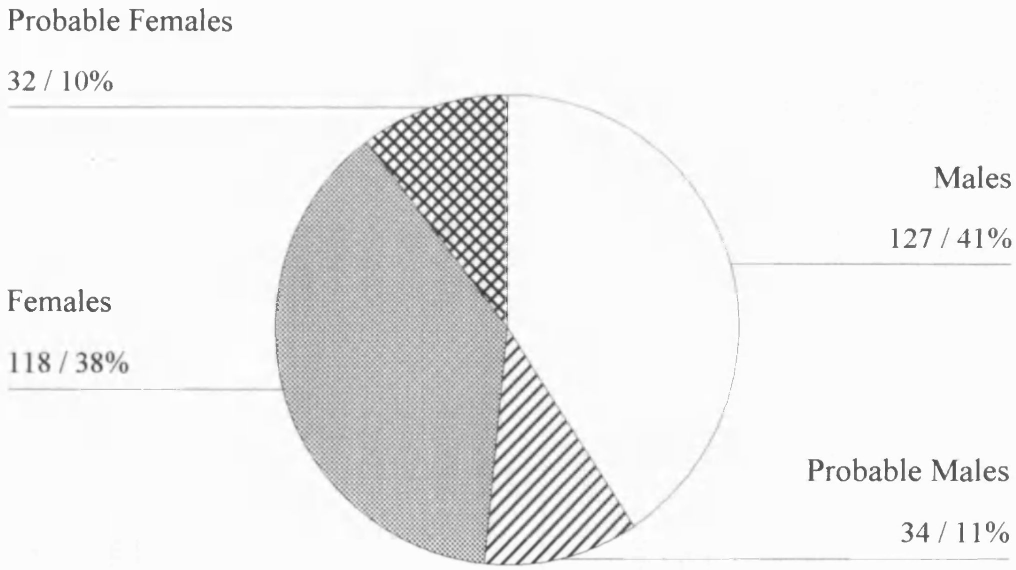

Probable Females
32 / 10%
Males
127 / 41%
Females
118 / 38%
Probable Males
34 / 11%

Table 5.5 Sex composition of the cemetery samples ('probable males' combined with 'males', and 'probable females' combined with 'females')

Sex ratio represents the number of males to every female χ^2 chi square statistic p probability

	Number in sample		Percentage of sample				
	Male	Female	Male	Female	Sex Ratio	χ^2	p
Wharram	212	129	62.2	37.8	1.643:1	20.202	.000
Ipswich	146	64	69.5	30.5	2.281:1	32.019	.000
Abingdon	223	171	56.6	43.4	1.304:1	6.863	.009
St Nicholas	91	74	55.2	44.8	1.230:1	1.752	.186
Fishergate 4	47	33	58.8	41.3	1.424:1	2.540	.118
Fishergate 6	176	53	76.9	23.1	3.321:1	66.066	.000
Jewbury	161	150	51.8	48.2	1.073:1	0.389	.533
Pooled site data	1056	674	61.0	39.0	1.567:1	84.349	.000

Table 5.6 Sex composition of the cemetery samples, excluding individuals of 'probable' sex.

Sex ratio represents the number of males to every female χ^2 chi square statistic p probability

	Number in sample		Percentage of sample				
	Male	Female	Male	Female	Sex Ratio	χ^2	p
Wharram	193	122	61.3	38.7	1.582:1	16.003	.000
Ipswich	141	58	70.9	29.1	2.431:1	34.618	.000
Abingdon	175	129	57.6	42.4	1.357:1	6.961	.008
St Nicholas	78	63	55.3	44.7	1.238:1	1.596	.207
Fishergate 4	42	22	65.6	34.4	1.909:1	6.250	.012
Fishergate 6	153	40	79.3	20.7	3.825:1	66.161	.000
Jewbury	127	118	51.8	48.2	1.076:1	0.331	.565
Pooled site data	909	552	62.2	37.8	1.647:1	87.234	.000

Table 5.7 Sex composition within in each age category of the cemetery samples (data divided into four age categories)

Sex ratio represents the number of males to every female ('probable males' combined with 'males', and 'probable females' combined with 'females')
χ^2 chi square statistic *p* probability

	Age group	Number in sample: Male	Number in sample: Female	Percentage of sample: Male	Percentage of sample: Female	Sex Ratio	χ^2	*p*
Wharram	*c.*18-25	31	24	56.4	43.6	1.292:1	.891	.345
	*c.*25-35	31	24	56.4	43.6	1.292:1	.891	.345
	*c.*35-45	35	24	59.3	40.7	1.458:1	2.051	.152
	c.>45	75	43	63.6	36.4	1.744:1	8.678	.003
Ipswich	*c.*18-25	26	11	70.3	29.7	2.364:1	6.081	.014
	*c.*25-35	36	18	66.7	33.3	2.000:1	6.000	.014
	*c.*35-45	33	8	80.5	19.5	4.125:1	15.244	.000
	c.>45	33	17	66.0	34.0	1.941:1	5.120	.024
Abingdon	*c.*18-25	28	25	52.8	47.2	1.120:1	.170	.680
	*c.*25-35	47	47	50.0	50.0	1.000:1	.000	1.000
	*c.*35-45	61	42	59.2	40.8	1.452:1	3.505	.061
	c.>45	71	43	62.3	37.7	1.651:1	6.877	.009
St Nicholas	*c.*18-25	21	12	63.6	36.4	1.750:1	2.455	.117
	*c.*25-35	21	28	42.9	57.1	0.750:1	1.000	.317
	*c.*35-45	18	17	51.4	48.6	1.059:1	.029	.866
	c.>45	8	5	61.5	38.5	1.600:1	.692	.405

Table 5.7 contd. . . /

Table 5.7 (contd.)

	Age	Number in sample		Percentage of sample				
	group	Male	Female	Male	Female	Sex Ratio	χ^2	*p*
Fishergate 4	*c.*18-25	19	6	76.0	24.0	3.167:1	6.760	.009
	*c.*25-35	12	6	66.7	33.3	2.000:1	2.000	.157
	*c.*35-45	9	10	47.4	52.6	0.900:1	.053	.819
	c.>45	4	3	57.1	42.9	1.333:1	.143	.705
Fishergate 6	*c.*18-25	24	3	88.9	11.1	8.000:1	16.333	.000
	*c.*25-35	37	13	74.0	26.0	2.846:1	11.520	.001
	*c.*35-45	43	14	75.4	24.6	3.071:1	14.754	.000
	c.>45	50	13	79.4	20.6	3.846:1	21.730	.000
Jewbury	*c.*18-25	33	39	45.8	54.2	0.846:1	.500	.480
	*c.*25-35	31	24	56.4	43.6	1.292:1	.891	.345
	*c.*35-45	40	35	53.3	46.7	1.143:1	.333	.564
	c.>45	40	28	58.8	41.2	1.429:1	2.118	.146
Pooled site data	*c.*18-25	182	120	60.3	39.7	1.517:1	12.728	.000
	*c.*25-35	215	160	57.3	42.7	1.344:1	8.067	.005
	*c.*35-45	239	150	61.4	38.6	1.593:1	20.362	.000
	c.>45	281	152	64.9	35.1	1.849:1	38.432	.000

Table 5.8 Sex composition within in each age category of the cemetery samples (data divided into two age categories)

Sex ratio represents the number of males to every female ('probable males' combined with 'males', and 'probable females' combined with 'females')
χ^2 chi square statistic   *p* probability

	Age group	Number in sample: Male	Number in sample: Female	Percentage of sample: Male	Percentage of sample: Female	Sex Ratio	χ^2	*p*
Wharram	*c.*18-35	62	48	56.4	43.6	1.292:1	1.782	.182
	c.>35	110	67	62.1	37.9	1.642:1	10.446	.001
Ipswich	*c.*18-35	62	29	68.1	31.9	2.138:1	11.967	.001
	c.>35	66	25	72.5	27.5	2.640:1	18.473	.000
Abingdon	*c.*18-35	75	72	51.0	49.0	1.042:1	.061	.805
	c.>35	132	85	60.8	39.2	1.553:1	10.180	.001
St Nicholas	*c.*18-35	42	40	51.2	48.8	1.050:1	.049	.825
	c.>35	26	22	54.2	45.8	1.182:1	.333	.564
Fishergate 4	*c.*18-35	31	12	72.1	27.9	2.583:1	8.395	.004
	c.>35	13	13	50.0	50.0	1.000:1	.000	1.000
Fishergate 6	*c.*18-35	61	16	79.2	20.8	3.813:1	26.299	.000
	c.>35	93	27	77.5	22.5	3.444:1	36.300	.000
Jewbury	*c.*18-35	64	63	50.4	49.6	1.016:1	.009	.929
	c.>35	80	63	55.9	44.1	1.270:1	2.021	.155
Pooled site data	*c.*18-35	397	280	58.6	41.4	1.418:1	20.220	.000
	c.>35	520	302	63.3	36.7	1.722:1	57.815	.000

Table 5.9 Proportion of long bones preserved in each cemetery sample

n_p number of long bones represented in sample n_t total number of long bones which could have been present if all 14 long bones in each skeleton were preserved % percentage of long bones preserved χ^2 chi-square statistic p probability

		Males		Females			
	Age group	n_p/n_t	%	n_p/n_t	%	χ^2	p
Wharram	*c.*18-25	205/434	47.2	206/336	61.3	15.075	.000
	*c.*25-35	298/434	68.7	247/336	73.5	2.152	.142
	*c.*35-45	309/490	63.1	227/336	67.6	1.770	.183
	c.>45	699/1050	66.6	488/602	81.1	39.731	.000
	Adult	286/560	51.1	115/196	58.7		
	Total	1797/2968	60.6	1283/1806	71.0	54.023	.000
Ipswich	*c.*18-25	310/364	85.2	143/154	92.9	5.835	.016
	*c.*25-35	459/504	91.1	205/252	81.3	14.857	.000
	*c.*35-45	402/462	87.0	110/112	98.2	11.739	.001
	c.>45	379/462	82.0	203/238	85.3	1.191	.275
	Adult	153/252	60.7	107/140	76.4		
	Total	1703/2044	83.3	768/896	85.7	2.670	.102
Abingdon	*c.*18-25	288/392	73.5	244/350	69.7	1.285	.257
	*c.*25-35	452/658	68.7	410/658	62.3	5.932	.015
	*c.*35-45	539/854	63.1	403/588	68.5	4.521	.033
	c.>45	812/994	81.7	477/602	79.2	1.454	.228
	Adult	56/224	25.0	70/196	35.7		
	Total	2147/3122	68.8	1604/2394	67.0	1.949	.163

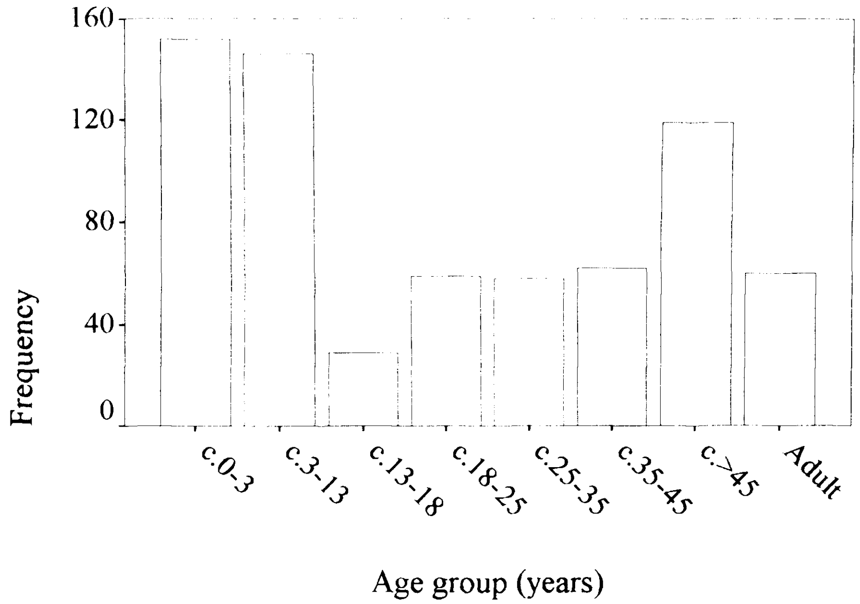
Table 5.9 contd. . . /

Table 5.9 (contd.)

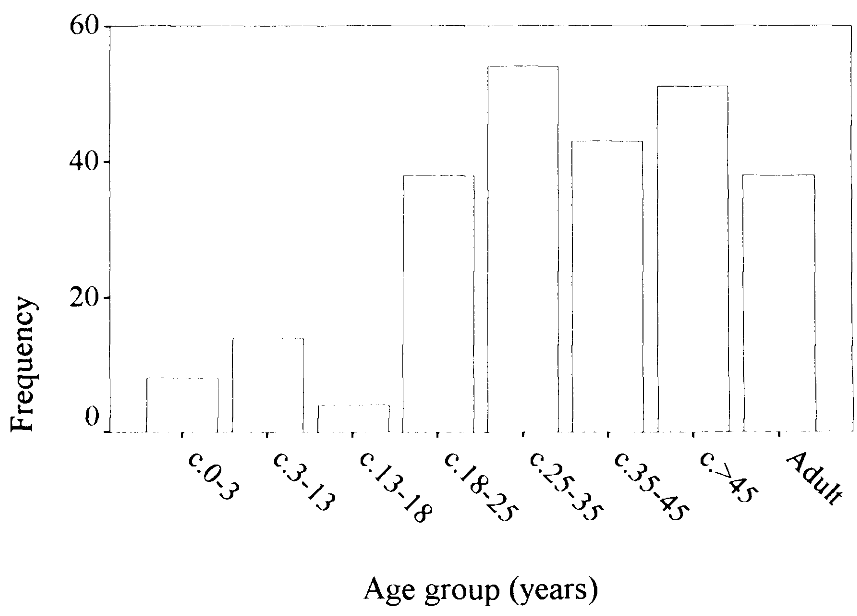
		Males		Females			
	Age group	n_p/n_t	%	n_p/n_t	%	χ^2	p
St Nicholas	*c.*18-25	145/294	49.3	64/168	38.1	5.437	.020
	*c.*25-35	145/294	49.3	221/392	56.4	3.363	.067
	*c.*35-45	146/252	57.9	146/238	61.3	.590	.442
	c.>45	40/112	35.7	46/70	65.7	15.555	.000
	Adult	113/322	35.1	67/168	39.9		
	Total	589/1274	46.2	544/1036	52.5	9.009	.003
Fishergate 4	*c.*18-25	225/266	84.6	50/84	59.5	23.817	.000
	*c.*25-35	143/168	85.1	71/84	84.5	.015	.901
	*c.*35-45	111/126	88.1	121/140	86.4	.165	.684
	c.>45	40/56	71.4	32/42	76.2	.053	.597
	Adult	19/42	45.2	43/112	38.4		
	Total	538/658	81.8	317/462	68.6	25.978	.000
Fishergate 6	*c.*18-25	266/336	79.2	37/42	88.1	1.871	.171
	*c.*25-35	399/518	77.0	172/182	94.5	27.370	.000
	*c.*35-45	502/602	83.4	150/196	76.5	4.652	.031
	c.>45	595/700	85.0	150/182	82.4	.734	.392
	Adult	128/308	41.6	51/140	36.4		
	Total	1890/2464	76.7	560/742	75.5	.481	.488

Figure 5.2a-g Bar graphs illustrating the age at death profiles for the entire cemetery samples

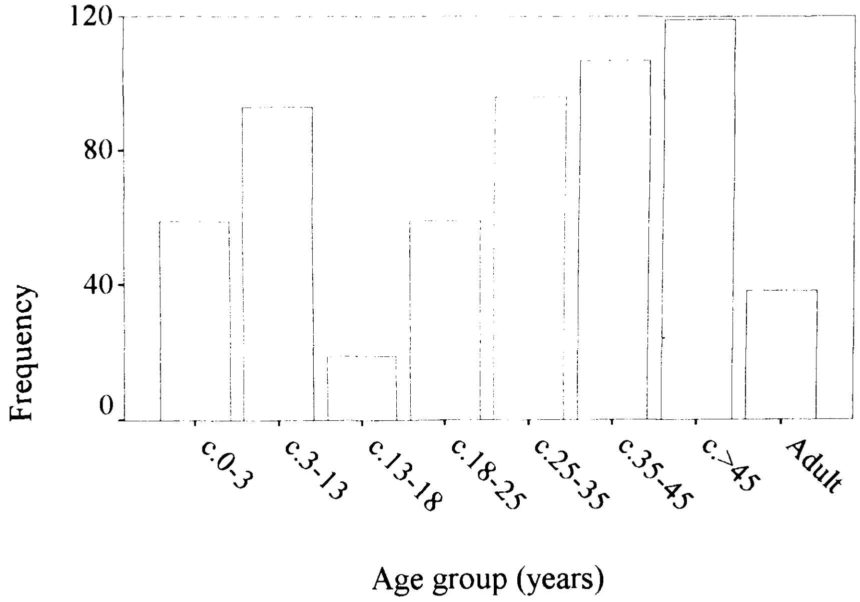
(a) Wharram Percy



(b) Ipswich Blackfriars

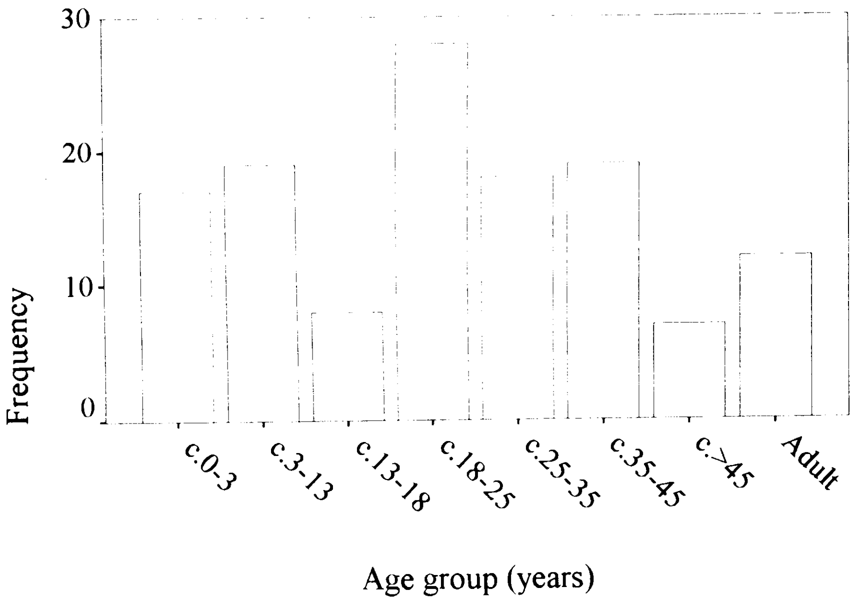


(c) Abingdon

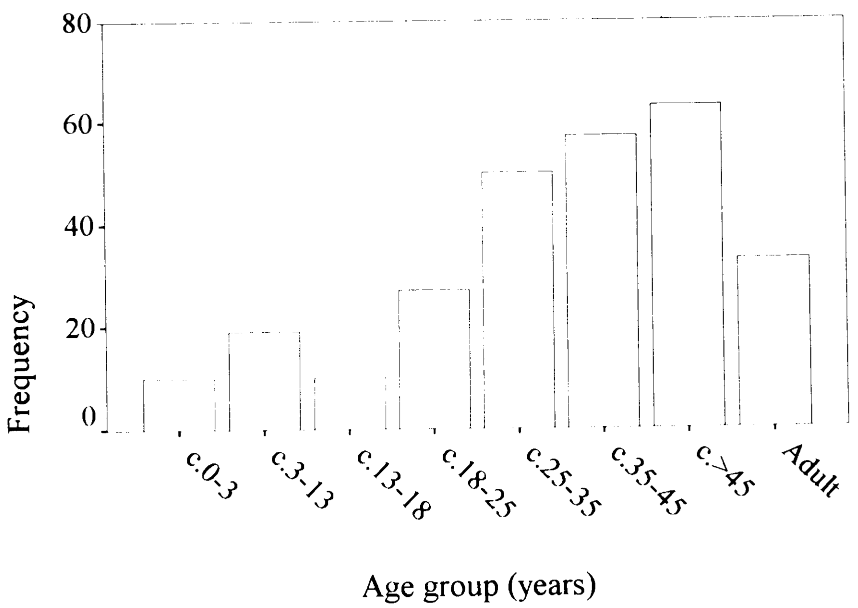


(d) St Nicholas Shambles

(e) Fishergate 4



(f) Fishergate 6



(g) Jewbury

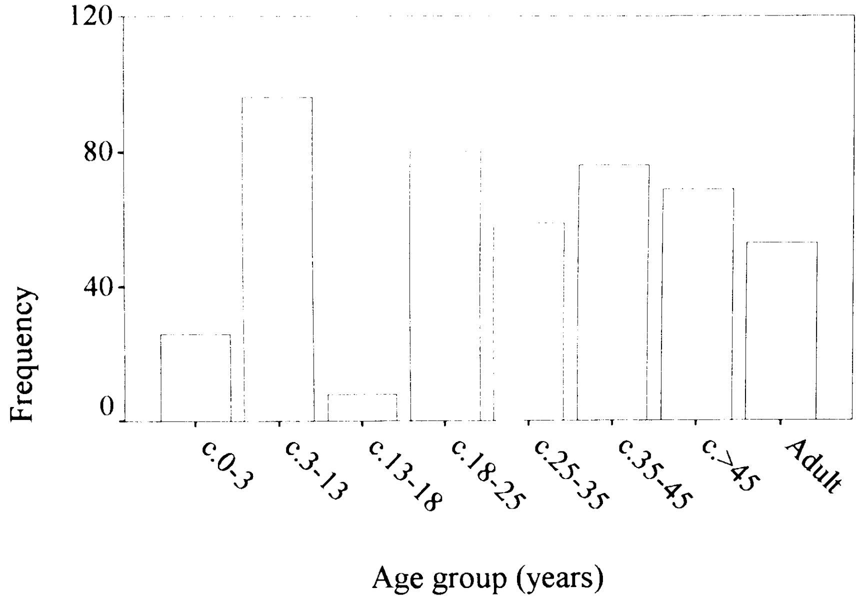

120
80
40
0
Frequency
c.0-3
c.3-13
c.13-18
c.18-25
c.25-35
c.35-45
c.>45
Adult
Age group (years)

Table 5.10 Age at death distribution for males and females (data divided into four age categories)

χ^2 chi square statistic *p* probability

	Age group	Number in sample		Percentage of sample		χ^2	*p*
		Male	Female	Male	Female		
Wharram	*c.*18-25	31	24	18.0	20.9	1.239	.744
	*c.*25-35	31	24	18.0	20.9		
	*c.*35-45	35	24	20.4	20.9		
	c.>45	75	43	43.6	37.4		
Ipswich	*c.*18-25	26	11	20.3	20.4	2.824	.420
	*c.*25-35	36	18	28.1	33.3		
	*c.*35-45	33	8	25.8	14.8		
	c.>45	33	17	25.8	31.5		
Abingdon	*c.*18-25	28	25	13.5	15.9	3.755	.289
	*c.*25-35	47	47	22.7	29.9		
	*c.*35-45	61	42	29.5	26.8		
	c.>45	71	43	34.3	27.4		
St Nicholas	*c.*18-25	21	12	30.9	19.4	3.907	.272
	*c.*25-35	21	28	30.9	45.2		
	*c.*35-45	18	17	26.5	27.4		
	c.>45	8	5	11.8	8.1		

Table 5.10 contd. . . /

Table 5.10 (contd.)

Fishergate 4	*c.*18-25	19	6	43.2	24.0	4.029	.258
	*c.*25-35	12	6	27.3	24.0		
	*c.*35-45	9	10	20.5	40.0		
	c.>45	4	3	9.1	12.0		
Fishergate 6	*c.*18-25	24	3	15.6	7.0	2.630	.452
	*c.*25-35	37	13	24.0	30.2		
	*c.*35-45	43	14	27.9	32.6		
	c.>45	50	13	32.5	30.2		
Jewbury	*c.*18-25	33	39	22.9	30.9	2.654	.448
	*c.*25-35	31	24	21.5	19.1		
	*c.*35-45	40	35	27.8	27.8		
	c.>45	40	28	27.8	22.2		
Pooled site data	*c.*18-25	182	120	19.8	20.6	4.971	.174
	*c.*25-35	215	160	23.4	27.5		
	*c.*35-45	239	150	26.1	25.8		
	c.>45	281	152	30.6	26.1		

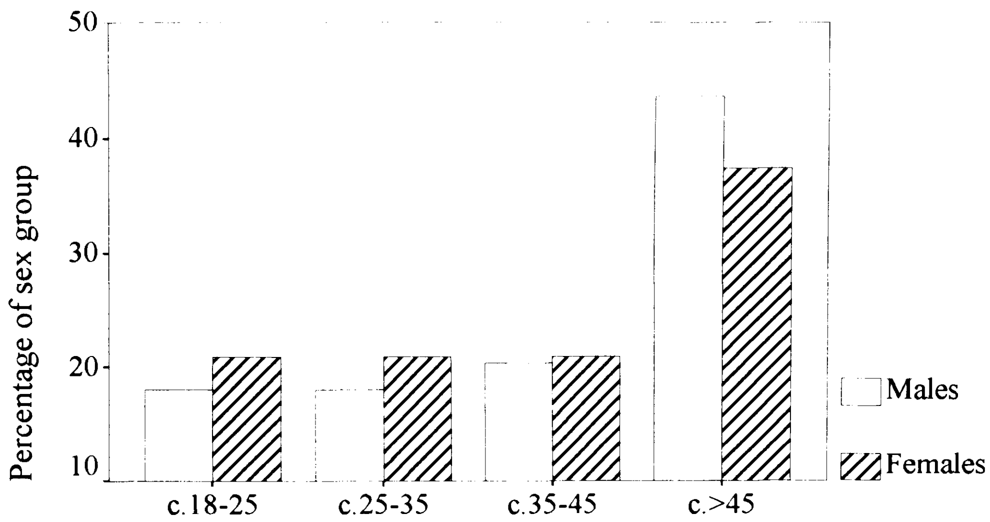
Table 5.11 Age at death distribution for males and females (data divided into two age categories)

χ^2 chi square statistic *p* probability

	Age group	Number in sample Male	Number in sample Female	Percentage of sample Male	Percentage of sample Female	χ^2	*p*
Wharram	*c.*18-35	62	48	36.1	41.7	.945	.331
	c.>35	110	67	63.9	58.3		
Ipswich	*c.*18-35	62	29	48.4	53.7	.421	.516
	c.>35	66	25	51.6	46.3		
Abingdon	*c.*18-35	75	72	36.2	45.9	3.438	.064
	c.>35	132	85	63.8	54.1		
St Nicholas	*c.*18-35	42	40	61.8	64.5	.105	.745
	c.>35	26	22	38.2	35.5		
Fishergate 4	*c.*18-25	31	12	70.5	48.0	3.423	.064
	*c.*25-35	13	13	29.5	52.0		
Fishergate 6	*c.*18-35	61	16	39.6	37.2	.081	.775
	c.>35	93	27	60.4	62.8		
Jewbury	*c.*18-35	64	63	44.4	50.0	.833	.362
	c.>35	80	63	55.6	50.0		
Pooled site data	*c.*18-35	397	280	43.3	48.1	3.335	.068
	c.>35	520	302	56.7	51.9		

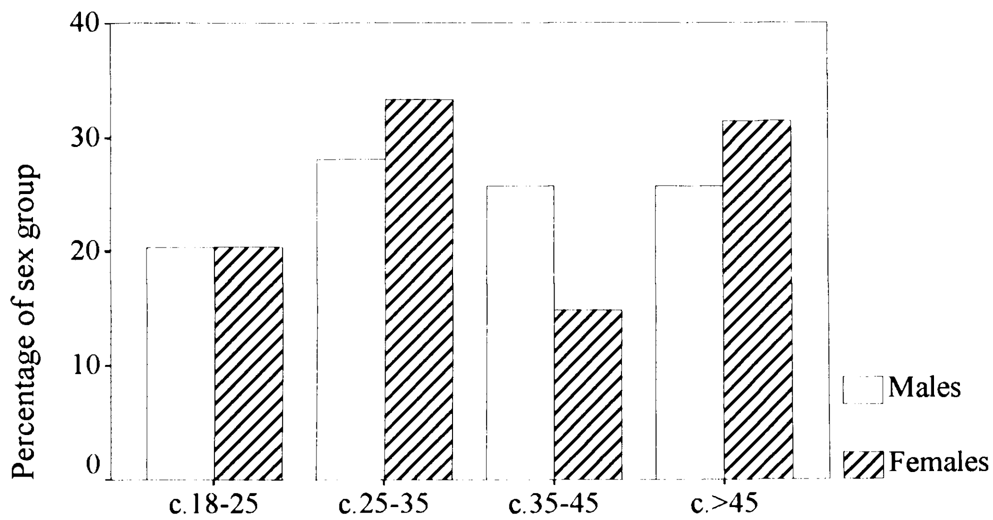
Figure 5.3a-h Bar graphs illustrating the age at death distribution for males and females (data divided into four age categories)

(a) Wharram Percy



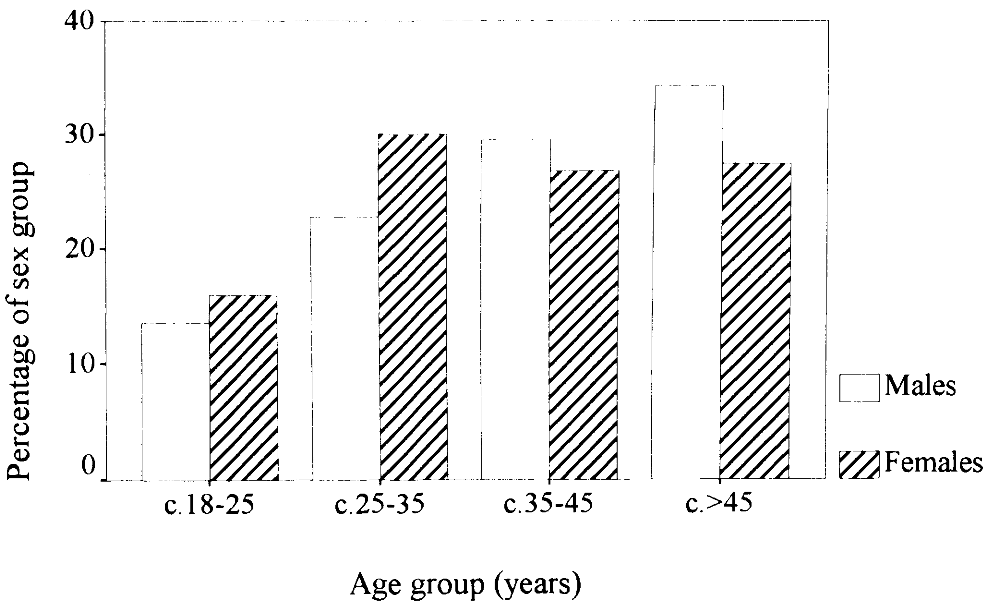
Age group (years)

(b) Ipswich Blackfriars

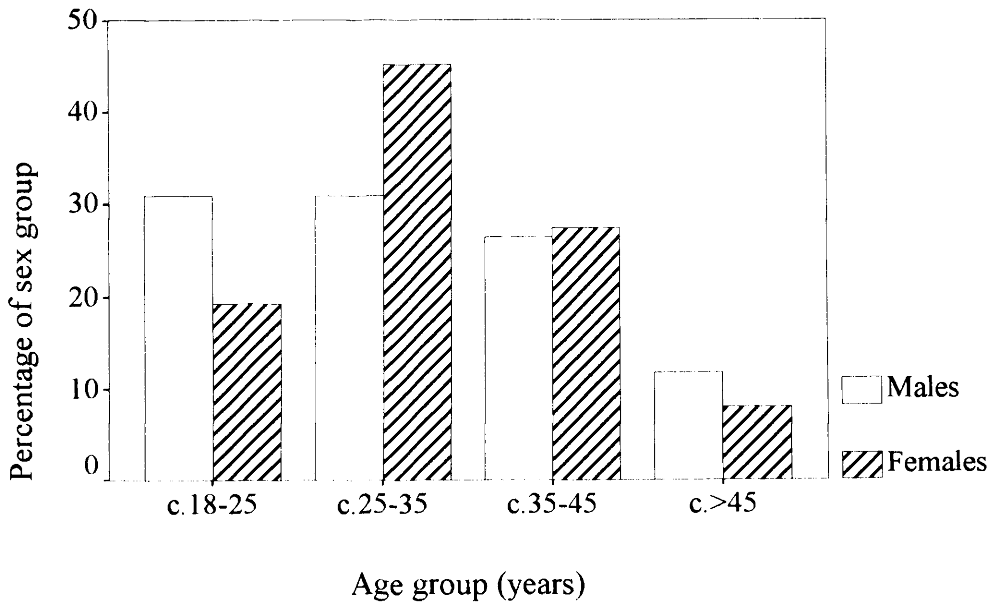


Age group (years)

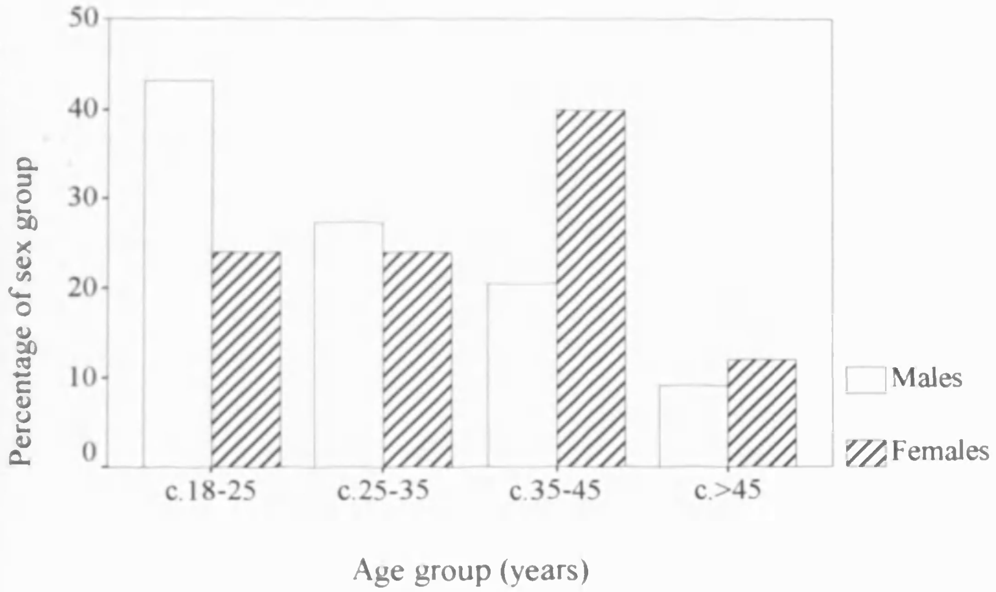
(c) Abingdon



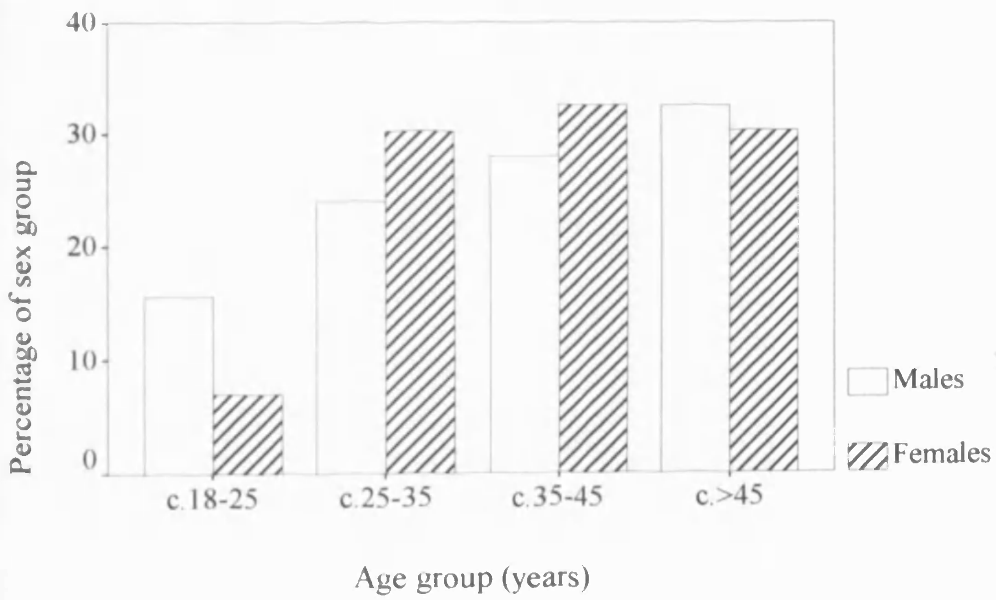
(d) St Nicholas Shambles



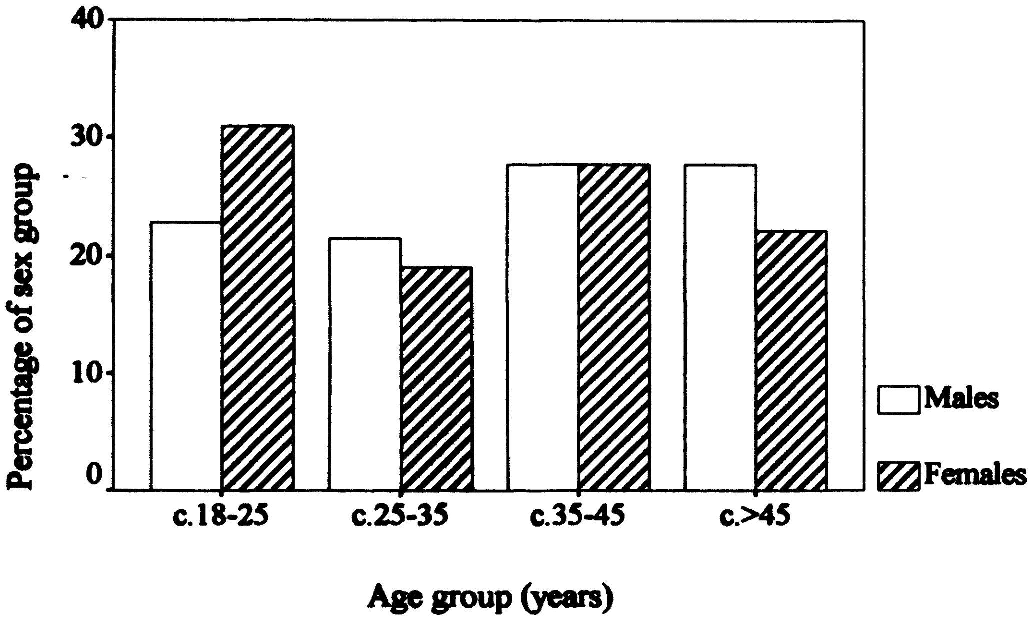
(e) Fishergate 4



(f) Fishergate 6



(g) Jewbury



(h) Pooled Site Data

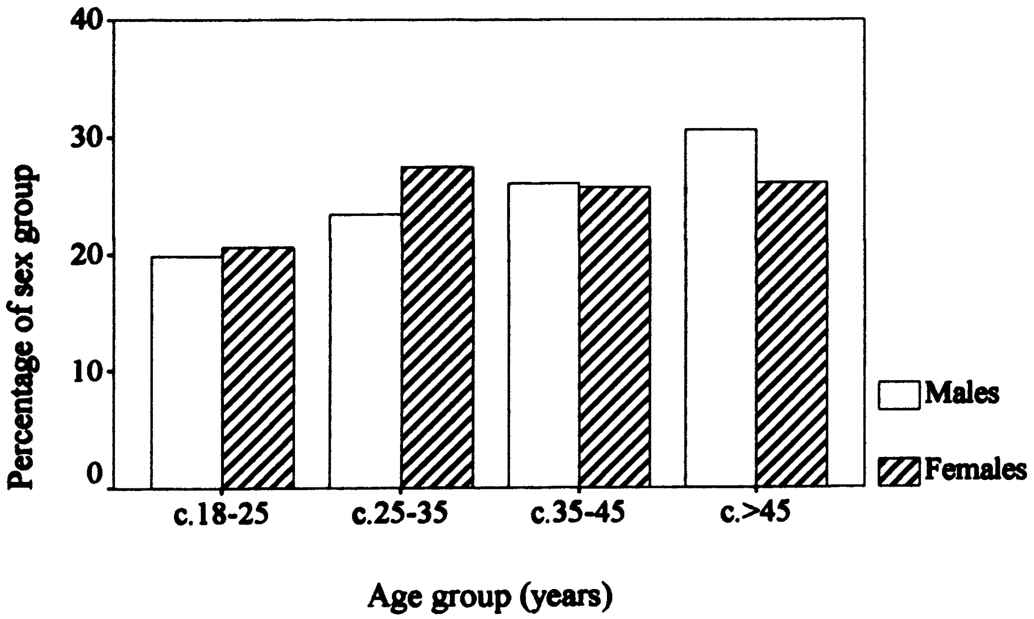
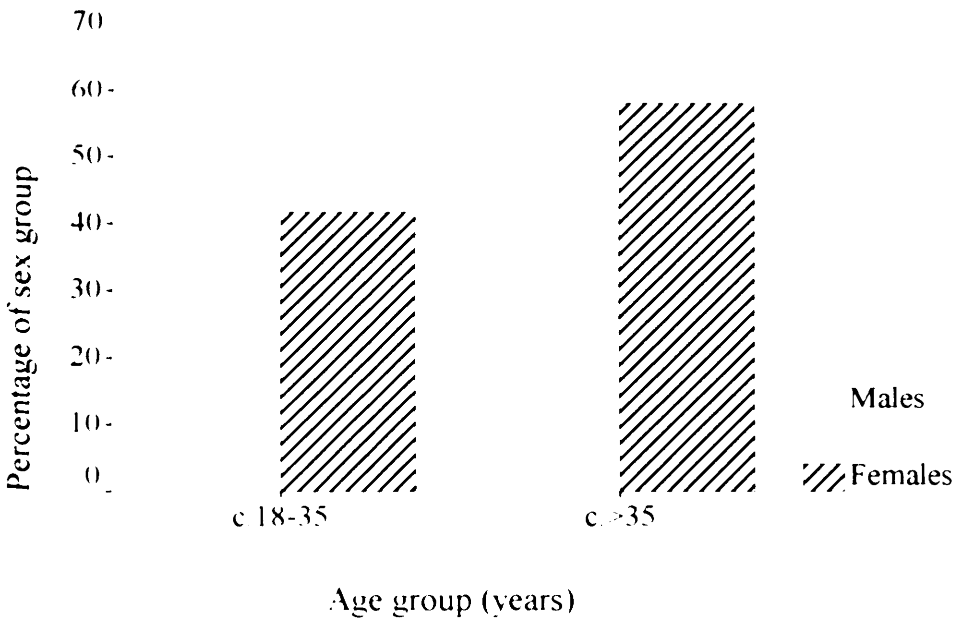
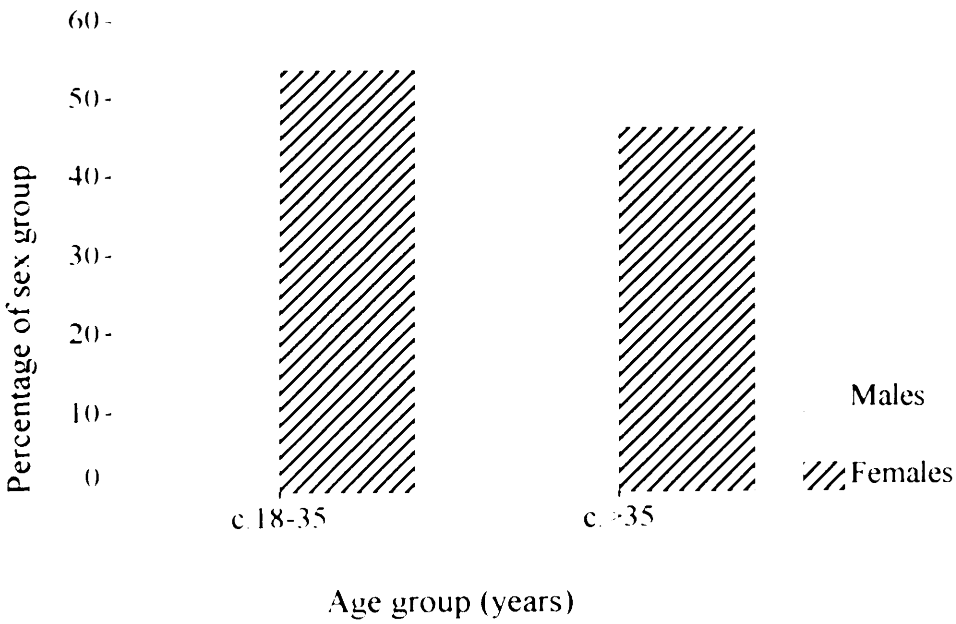


Figure 5.4a-h Bar graphs illustrating the age at death distribution for males and females (data divided into two age categories)

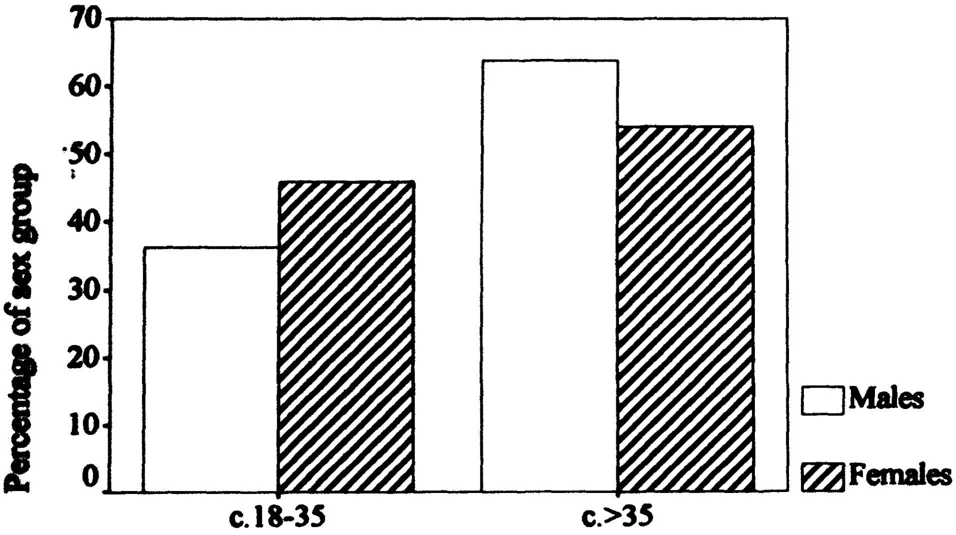
(a) Wharram Percy



(b) Ipswich Blackfriars

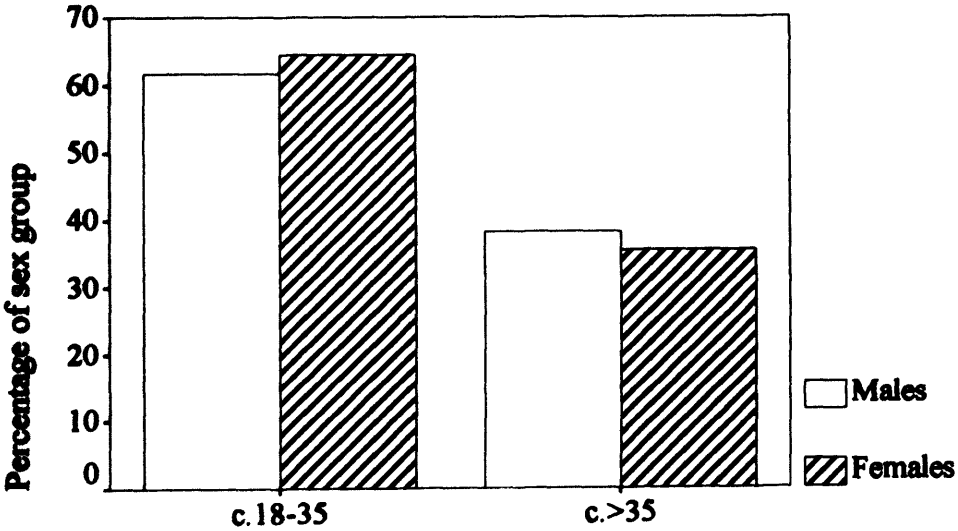


(c) Abingdon



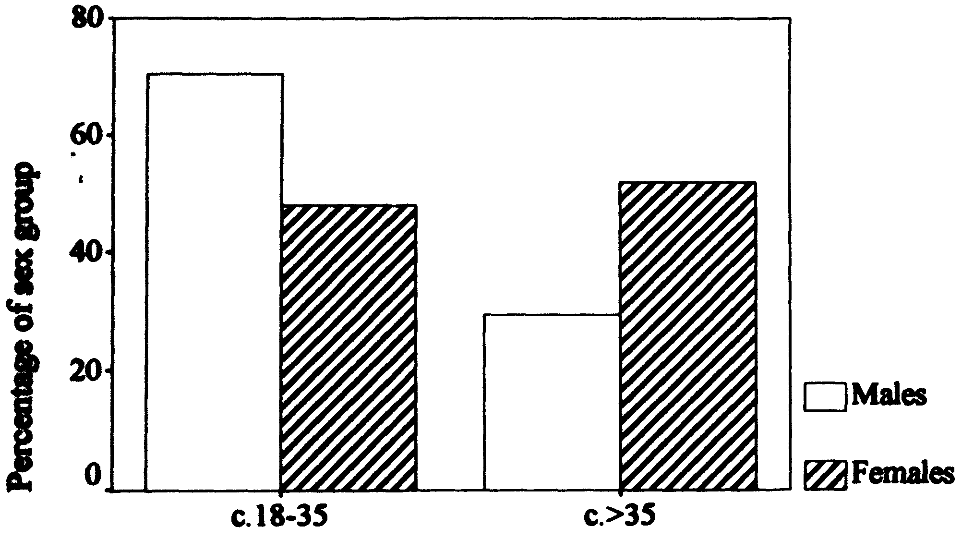
Age group (years)

(d) St Nicholas Shambles



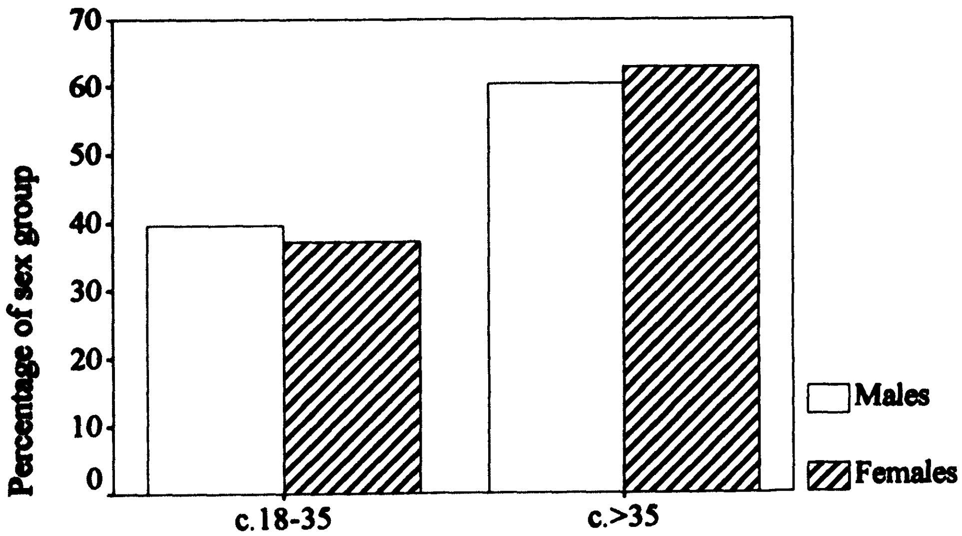
Age group (years)

(e) Fishergate 4



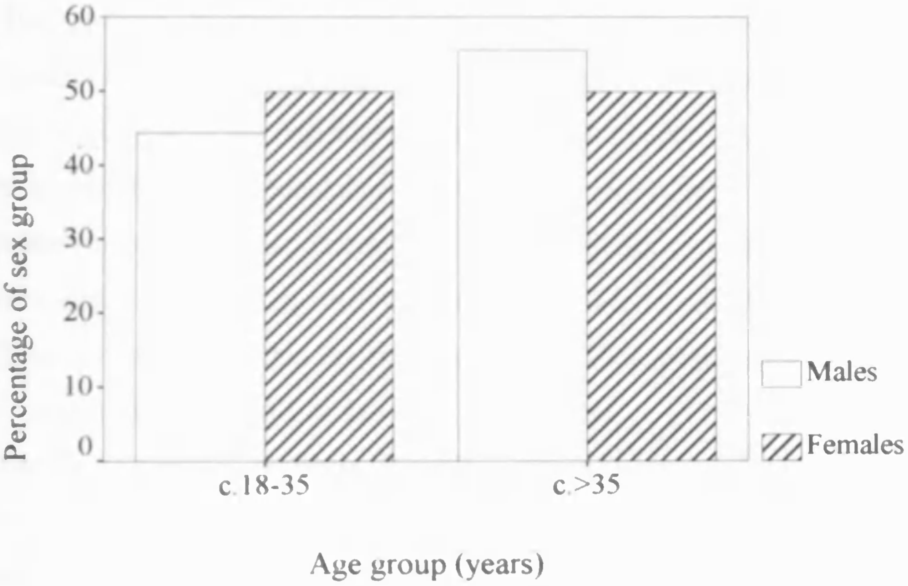
Age group (years)

(f) Fishergate 6

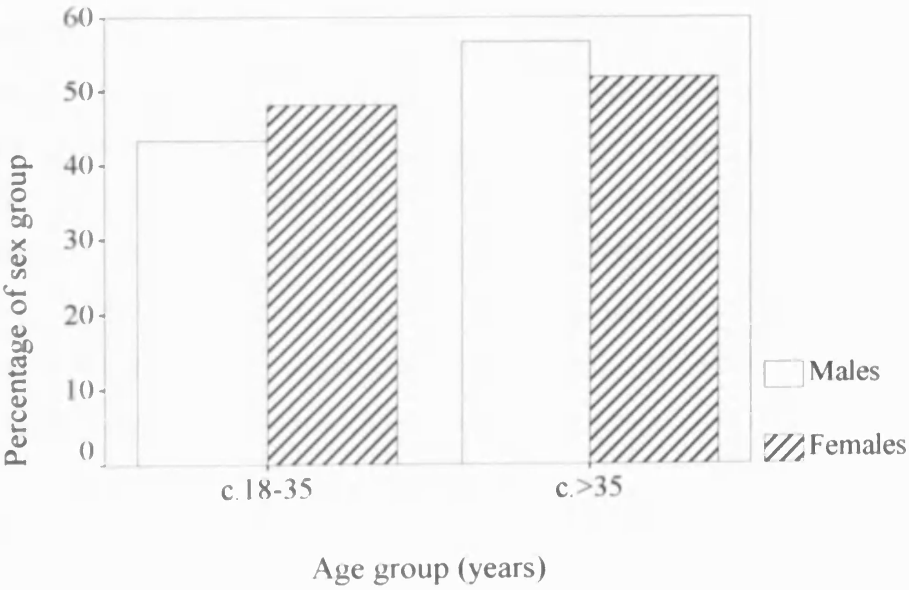


Age group (years)

(g) Jewbury



(h) Pooled Site Data



6. General Health Indicators

6.1 Introduction to the concept of biological stress

The purpose of this chapter was to investigate whether males and females experienced differences in their 'general state of health', through a comparative study of a series of skeletal stress indicators. The previous chapter examined male and female mortality patterns and considered whether these may have been influenced by sex differences in environmental stress, such as that brought about by the different treatment of males and females during childhood or differences in social status among adults. It was therefore anticipated that the analysis of stress indicators might also suggest whether there was any skeletal evidence to support these ideas.

The term 'stress' is applied with various meanings across the literature (Goodman *et al.* 1984;1988; Huss-Ashmore *et al.* 1982; Martin *et al.* 1985; Ribot and Roberts 1996; Roberts and Manchester 1995:163-4), although Larsen (1997:6) describes stress as 'physiological disruption resulting from impoverished environmental circumstances', which is an appropriate definition in this context. Examples of stress inducing factors, or 'stressors', include malnutrition, infectious disease, climate and poor living conditions (Ribot and Roberts 1996; Roberts and Manchester 1995:27). Although the soft tissues tend to be more rapidly and severely affected, the hard tissues do respond to stress, and so hold the potential for revealing information about the general health of past populations and the stressors acting upon them. Bone tends to be less buffered against adverse environmental conditions than teeth, and sensitivity to stress is greater during the growing period than in adulthood (Huss-Ashmore *et al.* 1982; Larsen 1997:61; Martin *et al.* 1985; Goodman *et al.* 1984; Goodman *et al.* 1988; Ribot and Roberts 1996). An array of skeletal indicators of stress has been recognised (Huss-Ashmore *et al.* 1982; Larsen 1997:6-63; Roberts and Manchester 1995:163-185), some of the more commonly used examples being growth rates, attained adult stature, enamel hypoplasia and Harris lines of arrested growth (Grauer 1991; 1993; Mays 1985; 1995b; Ribot and Roberts 1996).

Goodman and colleagues (Goodman *et al.* 1984; Goodman *et al.* 1988; Martin *et al.* 1985; Larsen 1997:6-7) have devised a model for interpreting stress in archaeological samples. They propose that stress is a product of three interacting determinants:

environmental constraints, cultural filters and host resistance. While the environment provides stressors, it also provides resources which may enable stress limitation. Similarly, cultural systems can either buffer or induce stress. Ultimately, the magnitude of physiological disruption depends on the ability of the host to resist the stressors. If stress is not adequately buffered by these three factors, a biological stress response may be observed at the tissue level, including the teeth and skeletal system. The consequences of physiological disruption, such as impaired health or work capacity, may then feed back to influence cultural systems and environmental constraints (Larsen 1997:6). Goodman and co-workers (Goodman *et al.* 1984) contend that when environmental constraints and host resistance are held constant, variations in stress may be attributed to cultural factors. Application of the stress model may therefore facilitate an understanding of cultural causes and responses to stress. However, they also acknowledge that the model may be viewed as having 'limited applicability to past human populations'. In practice, there are many limitations surrounding the interpretation of the stress concept, and it is important to recognise the complex nature of its study.

One of the greatest obstacles stems from the restricted number of ways that the skeletal system responds to stress. Various adverse conditions may incite similar skeletal changes, making it difficult to determine the specific aetiology of many stress indicators (Goodman *et al.* 1988; Huss-Ashmore *et al.* 1982; Ribot and Roberts 1996). Also, many stressors cannot be isolated owing to their relationship with each other. For example, nutrition and disease have a synergistic relationship whereby malnutrition increases susceptibility to infection, and infection impairs the ability to absorb vital nutrients (Larsen 1997:8). Thus, Goodman and colleagues (1988:195) state, 'the stress concept works at a high level of generalisation about cause'. Furthermore, as many indicators of stress are manifest in the soft tissue alone, signs of stress often elude the skeletal system completely.

Differentiating whether skeletal markers represent stress impact, response or adaptive consequence is also problematical (Larsen 1997:336-337). Many skeletal changes are the product of all three factors (Goodman *et al.* 1988). This means that it is often not possible to discern whether skeletal changes are reflecting the stress imposed by cultural filters or environmental constraints; the ability of the host to resist the threat of stress; or the ability of the host to cope or adapt to stress. For example, the absence of stress indicators in a skeleton could be interpreted in different ways: a lack of cultural or environmental stressors; the ability of the host to evade stress or rally from insults before skeletal involvement occurred; or that the host succumbed to stress so rapidly that death ensued before a visible skeletal reaction took place (Roberts and Manchester1995:164). Similarly, the presence of several stress indicators in a skeleton could simply imply a heavy stress load; a low resistance to stress; or a robust health status which enabled the individual to survive, despite the burden of stress imposed (Grauer 1991; Manchester 1983:36). These variables in interpretation can introduce considerable complications when attempting to compare different skeletal population samples, especially when little is known about the various intrinsic and extrinsic factors which could have influenced stress in the samples. They may even engender circularity in interpretation if prior assumptions are made about the samples. Nevertheless, Larsen (1997:61) does assert that 'Studies of stress based on archaeological bones and teeth reveal a number of consistent patterns. Under circumstances conducive to increased stress - such as poor nutrition, population aggregation, and increased infectious disease - skeletons and dentitions exhibit stress indicators in elevated prevalences'.

Host resistance, a key component of the stress concept, is also influenced by various factors, including sex, age and heredity. The relationship between sex and host resistance to stress is particularly relevant to this study. There is a fairly pervasive theory across the anthropological literature that males have a greater biological susceptibility to stress than females (Goodman *et al.* 1984; Huss-Ashmore *et al.* 1982; Johanssen 1984; Mays unpub.:34; 1998:157; Stini 1985; Stinson 1985). Stini (1985) has provided supporting evidence for this hypothesis with reference to adult data from developed countries. Not only does the average female life expectancy exceed that of males by as much as seven years, but the prognosis of recovery from 'virtually all types of disease', including many infections and cancers, is more favourable for females (Stini 1985:212). Stini largely attributes this to the greater effectiveness of the female immune system, which is thought to have developed to support pregnancy and initiate the offspring's immunological capacity (Armelagos 1998; Ortner 1998; Stini 1985:213; Stinson 1985). Stini also presents evidence to suggest that more 'genetic experiments' occur in males, perhaps because they are more expendable to the reproductive process and the investment required to ensure the survival of offspring. This variation is essential to the process of natural selection, but it results in a greater number of maladapted males that are vulnerable in adverse environmental conditions.

Stinson (1985) has undertaken a literature review to evaluate whether males are less buffered against environmental stress than females during growth and development. Stinson found the evidence to be most conclusive for the prenatal period. Male foetuses experience a higher rate of mortality and growth retardation under stressful circumstances, and show a greater response to maternal nutritional supplementation. The evidence is less consistent for the postnatal period. In developed countries, childhood mortality is greater among males, and males generally experience a slightly higher incidence of infectious disease. However, in underdeveloped countries, morbidity and mortality rates tend to be more comparable between the sexes, and in some populations, female morbidity and mortality surpasses that of males. Stinson ascribes the lack of conformity in results to the preferential treatment afforded to male children in many societies, a practice most frequently observed among populations subjected to the most severe environmental stress. In such communities, males typically receive superior nutrition and are more likely to be given medical treatment when ill, and so it cannot be assumed that both sexes are exposed to the same stressors. Stinson concludes that more emphasis must be placed on controlling these confounding factors and identifying the specific stressors involved before the hypothesis of greater male environmental sensitivity during childhood can be demonstrated.

Despite the complexity and limitations surrounding the stress concept, Larsen (1997:6) regards stress as 'central to the study of health and well-being and the reconstruction of adaptation and behavior in earlier and contemporary human societies'. Not all stress indicators are of equal utility and owing to the generalised, non-specific aetiology of many indicators, Goodman and colleagues (Goodman *et al.* 1984; Goodman *et al.* 1988; Huss-Ashmore *et al.* 1982; Martin *et al.* 1985) advocate the simultaneous application of several indicators to assess health status. This provides a more comprehensive picture than the use of a single stress indicator and recognises that health is a composite of various interrelated aspects of life history (Larsen 1997; Ribot and Roberts 1996). Four stress indicators were used in this study: stature, lesions associated with anaemia, enamel hypoplasia, and non-specific infectious disease. These were selected because they are established indicators of stress and each had been routinely recorded among the majority of the samples. The remainder of this chapter presents the analysis undertaken of each respective stress indicator, together with interpretations of the results within the confines of the stress concept.

6.2 Stature

6.2.1 Introduction

Adult height is determined by environmental and genetic factors. The genetic component controls the maximum potential height of an individual, but terminal height may be retarded by environmental constraints that can impede growth. These include infectious disease, hormone deficiencies and even psychological stress, but the overwhelming environmental factor to influence growth is inadequate nutrition (Larsen 1997:8-19). An improvement in circumstances may enable recovery, and potential height to be achieved through a period of catch-up growth (Steckel 1987; Stini 1985). Alternatively, the growth phase may be extended in order to compensate for any previous depression during childhood, so that final stature is attained at a later age (Mays 1998:70). However, in general, individuals experiencing environmental stress, especially chronic malnutrition, tend not attain their genetic height potential, unlike those who develop under optimal conditions (Larsen 1997:8-19; Stini 1985). Thus height is commonly used as an indicator of health in both modern and archaeological studies at the population level (Larsen 1997:8-19; Maat 1993; Mays 1998:70; Padez and Johnston 1999; Stinson 1985).

As discussed in chapter 5, several medieval didactic writers advocated what might be construed as an inferior feeding regime for female infants and children. However, there is currently no evidence to indicate whether or not this advice was actually followed by parents (Shahar 1992:81). A comparative analysis of male and female stature might therefore indicate whether there is any skeletal evidence to support this possibility. Manchester (1983:10) applied this principle when interpreting the discrepancy in male and female height detected in the Romano-British cemetery of Trentholme Drive, York. Using the regression equations derived by Trotter and Gleser (1952), the average height of males was found to be 170.2cm (5'7"), and females 154.9cm (5'1"), giving a sex difference of 15.3cm (Warwick 1968:149). Manchester noted that this difference was greater than for 'modern Western peoples', and suggested that it may testify to the 'underprivileged status of the female in antiquity'; the implication being that the gap between mean male and female stature has closed due to a relatively greater improvement in female status with a consequent increase in their capacity to achieve their maximum potential height. The Department of Health and Social Security commissioned a national survey of heights in Britain in 1984 (Knight 1984). From a sample of 10,000 adults aged between 16 and 64, the mean height of men was found to be 173.8cm (5'8½"), and women 160.9cm (5'3½"), giving a mean sex difference of 12.9cm. This is indeed less than the sex difference observed at Trentholme Drive, lending support to Manchester's hypothesis.

Therefore, the primary objective of the stature analysis was to investigate whether Manchester's hypothesis might be upheld in relation to the medieval cemeteries, by determining whether there was a consistent, comparatively large disparity in average stature between the sexes, and gauging the relative difference between the stature of each sex and their modern 'counterparts'. The modern figures were taken from the DHSS study in 1984. It is known that the mean statures computed from medieval samples tend to be slightly lower than the heights of the living today (Bennike 1985:49-53, Roberts and Manchester 1995:26). Among other factors, this can largely be attributed to recent height increases associated with improvements in nutrition, healthcare and living standards. If medieval females were less likely to reach their full height potential due to their possible underprivileged status, it seemed reasonable to expect that the difference between the mean stature of medieval and modern females would be greater than that between medieval and modern males.

A further goal of the analysis was to identify any site differences in male or female stature, which might be associated with environmental or genetic differences in the assumed social composition of the cemetery samples. It was also necessary to determine whether there was any association between stature and age at death, as this could potentially introduce bias into all the stature analyses through differences in the age structure of the samples. This was also relevant to the assessment of male and female health status. Health in adult life is thought to be related to health in childhood, better child health tending to contribute to improved adult health and vice versa. Modern epidemiological studies have indicated that a number of major causes of adult death, such as heart disease, stroke and bronchitis, are associated with influences which act during childhood, and a relationship has been identified between these diseases and reduced adult height (Barker *et al.* 1990). Although not statistically significant, a tendency was noted among the material from the Spitalfields crypt for individuals with a younger age at death to be of relatively short stature, a tendency more marked among females than males (Molleson and Cox 1993:119). Any association identified within the medieval samples might therefore indicate a poorer health status in either sex.

6.2.2 Method

Stature, for all cemeteries, had been estimated from long-bone measurements using the regression equations derived by Trotter and Gleser (Bass 1987:22-24; Brothwell 1981:101) for use on 'American Whites'. For each individual, the formula deemed by Trotter and Gleser to provide the lowest standard error was applied, depending on which bones were available for measurement. In most cases, the lower limb bones were used, and in particular, a combination of the femur and tibia.

Prior to carrying out statistical tests to confirm any characteristics in the data, the following series of standard exploratory analyses (Kinnear and Gray 1994:50) were performed on the male and female samples from each site respectively, in order to investigate their underlying distributional characteristics. The mean and median were computed to provide a measure of central tendency; the standard deviation, variance, range, minimum and maximum were computed as measures of dispersion; and the values of skewness and kurtosis were used to provide a measure of the shape of each distribution, together with a frequency histogram to visually assess the degree of similarity to a normal probability curve (table 6.1a/b, histograms not included). Box-and-whisker plots categorised by sex were also plotted for each site to allow a quick, visual comparison of the distributions (figure 6.1a-g). Levene tests were applied to test the homogeneity of variance between the male and female samples from each site respectively; between the male samples from all sites, and likewise, between the female samples from all sites (table 6.2 and 6.3).

The frequency histograms indicated that each sample was normally distributed. This was confirmed by the values of skewness and kurtosis which were close to zero, the close similarity between the mean and median values, and the central location of the median line on the boxplots. None of the F values generated from the Levene tests which compared male and female samples within the respective cemeteries were statistically significant ($p>0.05$), indicating that the distributions were of equal variance.

Since the samples were also normally distributed, *t*-tests for independent samples with equal variance were applied to verify whether the differences between the mean male and female statures were statistically significant (table 6.4). One-sample *t*-tests were used to determine whether there was any statistically significant difference between the mean values of male stature from each site and the modern mean of 173.8cm; and the same tests were run to compare the mean female statures with the modern mean of 160.9cm (table 6.5a/b).

A one-way ANOVA test was employed to determine if there were any statistically significant differences among the female means from the respective cemeteries, followed by an a posteriori Tukey's HSD test to identify which of the means differed. However, while the Levene tests on the female samples demonstrated that the distributions were of equal variance, the Levene tests on the male samples revealed that the variances were not homogeneous (F=12.171 p<0.01), so violating one of the assumptions underlying the one-way ANOVA test. Therefore, in addition to carrying out a one-way ANOVA followed by a Tukey's HSD test, a more robust non-parametric equivalent was applied to the male data, the Kruskall-Wallis one-way ANOVA test. An a posteriori Tamhane's T2 test was used to identify which of the male samples differed, which unlike Tukey's HSD, does not assume equal variances between samples (table 6.6 and 6.7; figure 6.2a/b).

Both one-way ANOVA tests and Kruskall-Wallis one-way ANOVA tests were applied to determine whether there were any statistically significant differences in stature between the four age categories in any of the male or female cemetery samples (table 6.8). Both sets of tests, parametric and non-parametric, were run because it was felt that splitting the data by age group may have altered the distributional characteristics of some samples. Rather than investing time in identifying any changes, it was envisaged that the results of each method would either be mutually conclusive or alternatively, indicate that the results of a particular test should be treated with caution.

6.2.3 Results and Discussion

Unsurprisingly, the results presented in table 6.1a/b and figure 6.1a-g demonstrated that there was a considerable overlap in the range of male and female stature distributions from every site. The mean height of males was greater than that of females, the difference between the sexes being statistically significant beyond the 1% level for all sites, according to the results of the independent samples *t*-tests which are presented in table 6.4. However, the actual difference between male and female means gave an unexpected result. With the exception of Fishergate 4 (which displayed a mean sex difference of 14.2cm), the mean sex difference for the remaining six samples ranged from between 10.2cm and 11.5cm, which was in fact *smaller* than the average 12.9cm difference between men and women today. So the general pattern for the medieval sites included in this study did not accord with the finding for the Roman site at Trentholme Drive. The disparity between the medieval samples and that from Trentholme Drive originated in a greater difference between female heights. The mean male height for the pooled medieval data was virtually identical to that of Trentholme Drive, being 170.4cm and 170.2cm respectively. However, females from Trentholme Drive were some 4cm shorter than the pooled medieval female average of 159.1cm. One explanation could be that this reflects a difference in health status, and so perhaps also social status, between Roman and medieval females, although of course this could be construed as an over-interpretation of results since it is drawn on the basis of a single Roman cemetery. It may nevertheless be a subject worthy of further investigation. As discussed in chapter 5, there is both documentary and archaeological evidence to suggest that female infanticide was an accepted practice in Roman society which is concordant with the view that females were held in lower esteem than males, whereas there is no conclusive evidence for the practice in medieval Britain.

As the results presented in table 6.5a/b show, the greater sex difference in modern British heights compared with the medieval cemeteries largely arises from a greater difference between medieval and modern males rather than females, which contradicts the expected trend. For six of the seven samples, the actual difference between the medieval and modern male means exceeded that between medieval and modern females. Fishergate 4 was the only sample that did not follow this pattern. When the data from all the cemeteries were pooled, the medieval females were on average, 1.8cm shorter than their modern counterparts which compares with a difference of 3.4cm for males. Furthermore, the one-sample *t*-tests on males revealed that the difference between the medieval and modern means were statistically significant at a high level of probability, beyond the 1% level, for six of the seven cemeteries. Again, the only exception was

Fishergate 4 which showed no significant difference from the modern mean. By contrast, of the female samples, two displayed no significant difference from the modern mean; these were Ipswich and St Nicholas Shambles. There was a significant difference at the 5% level for the Abingdon and Fishergate 6 cemeteries; and only three of the sites, Wharram Percy, Fishergate 4 and Jewbury, displayed a significant difference beyond the 1% level. These results therefore demonstrated that the stature differences between medieval and modern males tended to be significant at a higher level of probability than the differences between medieval and modern females.

Overall, the results indicated that on average, medieval men and women were closer in height than men and women are today, and the disparity appeared to derive from a relatively greater increment in male height. Medieval men were, relatively speaking, shorter than their modern counterparts by comparison to medieval and modern women who were closer in height. The results of this study did not seem to support the hypothesis that medieval females displayed a comparatively reduced stature indicative of an underprivileged health status, particularly in terms of inadequate nutrition, which could also imply that the advice of didactic authors was not implemented. In fact, it was the males who were more likely to show retarded growth, if of course the figures for modern Britain can be accepted as an appropriate marker on which to base the comparisons. This could suggest that male nutrition was inferior, or at least insufficient to meet their growth requirements. Alternatively, it could lend support to the theory that males have a greater sensitivity to environmental stress (Stini 1985; Stinson 1985). If both sexes were exposed to the same environmental constraints, the impact may have been more deleterious to male growth, which would have the effect of reducing sexual dimorphism. Although the Levene tests demonstrated that the sex differences in variance for each site were not statistically significant, it may be worth noting that for five of the seven sites, the male variance was greater than the female variance. Also, the Levene tests revealed statistically significant differences in male variance between sites, which was not the case for females. This could indicate a greater variability in male stature, perhaps as part of the evolutionary strategy proposed by Stini (1985, and see section 6.1), or as a direct consequence of their increased sensitivity to environmental stress, as Molleson (1993:168) has suggested as one interpretation for a similar sex difference in variance observed at the Romano-British site of Poundbury, Dorset. This in turn may have resulted in an overall reduction in average terminal stature for males.

However, there are limitations of the method which should be borne in mind when making these interpretations. Firstly, the methods used to determine stature for living and archaeological collections are clearly not analogous. The heights of the living can be measured directly; whereas the regression equations used to estimate stature from dried bones are unlikely to generate accurate figures for living stature, partly because they are based on an estimated allowance for joint cartilage and soft tissues, and partly because they are derived from modern reference samples which may not be appropriate for use on other population groups. It is therefore possible that the regression equations led to stature estimates that were biased according to sex; for example, male statures tending to be underestimated and females overestimated. In the absence of an alternative method for computing stature estimates from dried bones, it would be difficult to determine whether there is any foundation to this potential limitation. Even recalculating the stature estimates using regression equations derived from another reference collection, such as those computed by Dupertius and Hadden (1951 in Molleson 1993:167) for use on 'American Whites', would not solve the problem as the results could be biased by a similar limitation. However, a recent preliminary study by Waldron (1998) does confirm that there may be cause for concern. Waldron highlights the fact that a variety of stature estimates may be obtained for a single skeleton, depending on which long-bones are used to compute the estimate. Thus if different bones are used to calculate the stature of individuals in a given population sample, errors will be introduced to the calculation of the mean. Waldron investigated the effect of this problem on two British assemblages by contrasting the results obtained when the femur alone was used and when any bone was used to compute mean male and female stature. He found a close similarity in mean female height using the two approaches in both cemeteries. However, for the males, the value obtained when any bone was used was 4cm lower than that procured from the femur alone in one cemetery, and 5cm lower in the other assemblage, discrepancies which were statistically significant beyond the 1% level. Waldron suggested that the sex difference could be due to the greater similarity in the relative proportions of upper and lower limb bone lengths in females. While emphasising that further research would be required to confirm whether the findings of the study were generally applicable to other cemeteries, he concluded that more emphasis should be placed on the shortcomings of stature methodology when interpreting results, especially in relation to male heights and in comparative studies. Since the stature values in this investigation were not confined to estimates based on a single bone, the interpretation that male growth was retarded could be invalid if male heights were underestimated through failings in the methodology. Perhaps future research should therefore be restricted to estimates based on a single type of bone, or even focus on differences between actual bone lengths rather than calculated stature values (Boldsen 1998). It was anticipated that the results of the analyses of the other stress indicators examined in this study might go some way toward clarifying whether the sex differences in stature were reflecting genuine sex differences in health status or were more likely to be the product of methodological limitations.

Secondly, the interpretations based on the comparisons with modern figures rest on the assumption that men and women today have both now reached their maximum height potential. It is true that there has been a considerable increase in height for both sexes during the latter half of this century, which is largely attributable to the concurrent improvement in childhood nutrition, and the prevention and treatment of childhood disease (Knight 1984; Roberts and Manchester 1995:26). For example, a study by Kemsley (1950 in Knight 1984) put the mean height of men and women in 1943 at 167.7cm (5'6") and 157.2cm (5'2") respectively. Compared with the figures derived from the DHSS survey in 1984, this translates into a height increase of 6.1cm for males and 3.7cm for females. The greater rise in male height may indicate that the environmental factors which have caused the increases have so far worked to the preferential benefit of males, and the possibility that females will show further height gains in the future which would lead to an increased divergence from medieval females cannot be discounted. It is also notable that the mean heights of men and women in 1943 appear to be lower than the figures yielded from the medieval cemeteries, suggesting that height has not necessarily shown a continual increase with time. Such fluctuations may add further doubt as to whether 'modern' figures serve as appropriate markers by which to make comparisons.

Finally, the impact of the genetic determinant on height should not be overlooked. It is likely that in addition to alterations in environmental conditions, secular changes in height may have occurred which are associated with changes in the gene pool. Increased mobility in particular may be partly responsible for recent height gains, as stature has been found increase when there is strong gene dispersion, by a process known as heterostosis (Bennike 1985:49). Given that at least 400 years separates the medieval and modern samples, during which time extensive population movements have taken place, this factor may render the medieval and modern data incomparable.

The results of the inter-site statistical comparisons are presented in table 6.6 and 6.7. Figure 6.2a and 6.2b provide a visual representation of the a posteriori results. The one-way ANOVA test indicated that statistically significant differences ($p<0.01$) existed between the female means from each site. Both the parametric and non-parametric one-way ANOVA tests confirmed that statistically significant differences ($p<0.01$) in stature also existed between the male samples. The results of the a posteriori Tukey's HSD and Tamhane's T2 tests on the male data were in agreement as to which samples showed a statistically significant difference from each other. The a posteriori tests revealed that there were more statistically significant differences among the male samples than the female samples, which may be further evidence to support the view that a greater variability exists in male stature. The cemeteries which showed the most extreme mean values for both sexes were Ipswich, Jewbury and Wharram Percy. Males and females from Jewbury displayed the lowest mean statures, followed by Wharram Percy, and the Ipswich material displayed the highest average statures. The results from these cemeteries will be discussed in greater detail below. The remaining cemeteries occupied intermediate positions and their rank order was not the same for both sexes. For males, Fishergate 4 displayed the second highest average stature, which was similar to that of Ipswich, with no statistically significant difference between the two. This was followed by Fishergate 6, St Nicholas Shambles and Abingdon, the mean statures of which were almost indistinguishable, there being no significant differences between them, or the Fishergate 4 sample. Among the female data, St Nicholas Shambles displayed the second highest mean stature, followed by Abingdon, Fishergate 6, then Fishergate 4. However, the a posteriori pairwise comparisons revealed that none of the differences between these samples, or the Ipswich assemblage, were statistically significant.

The males from Jewbury displayed a mean stature of 166.7cm. This was significantly different from all the other cemeteries with the exception of Wharram Percy. The mean difference between the Jewbury males and the cemetery which yielded the highest average, Ipswich, was 6cm, and the difference between the Jewbury males and the pooled male average was 3.7cm. The female mean of 156.4cm was 4.7cm less than the Ipswich mean and 2.7cm below the pooled female average. It was significantly different from the Ipswich, St Nicholas Shambles and Abingdon means, though not significantly different from the remaining sites. When examining the data, Stroud (1994:435) also noticed that the stature values from Jewbury appeared to be lower than many other medieval assemblages, especially those of the males. Recognising that calculated stature estimates may be subject to error, Stroud compared the humeral and femoral lengths of the Jewbury material with two other medieval sites from York, Fishergate and St Helen-on-the-Walls. Both the male and female long bone lengths from these sites were significantly longer than those from Jewbury, confirming that the men and women buried at Jewbury were likely to have been of shorter average stature than their contemporaries buried in the other city cemeteries. A distinguishing factor between Jewbury and the other sites included in this study was that the burial ground served the Jewish community. The Jewish religion prohibits marriage between Jews and gentiles, and one possible explanation for the stature difference is that it may be evidence of a stature which was characteristic of a distinct immigrant ancestry, having been preserved through the succeeding generations. Alternatively, intermarriage within the Jewish community itself could have contributed to the comparatively short stature. Just as strong gene dispersion can result in height increases, so consanguinity can lead to a reduction in stature, as has been observed among closed communities in North America (Markow and Martin 1993) and rural France (Roberts and Manchester 1995:26). The mean stature of skeletons retrieved from the fairly remote island of Ensay in the Outer Hebrides, dating from *c.*1500 to 1850 AD, were similar to those from Jewbury, being 166.2cm and 155.2cm for males and females respectively (Miles 1989).

The average stature of males from the assemblage which generated the second smallest mean stature values, Wharram Percy, was 168.7cm. This was 1.7cm below the pooled male average, and the difference between the Wharram Percy males and all the other sites was statistically significant, with the exception of Jewbury and St Nicholas Shambles. The female mean of 157.8cm was 1.3cm below the pooled average. It was significantly different from the Ipswich and Abingdon means. A study of child growth, carried out by Mays (1998:66-70), also found that the sub-adults from Wharram Percy were correspondingly short for their age. Skeletons aged as being about fourteen years from dental calcification were only the same height as modern day ten year olds. Mays also found that the growth of sub-adults from Wharram Percy even lagged behind that of nineteenth century factory children, by about one to two years.

Dyer (1989:197) has proposed that the diet of medieval rural communities may have been inferior and less varied than that enjoyed by town dwellers, a view which is shared by Hammond (1993:26,40). Being the only cemetery to serve a truly rural population, this may have had a detrimental impact on the attainment of maximum potential stature, although it is possible that any dietary benefits gained from urban living would have been offset by the densely occupied, squalid living conditions. However, Mays has suggested that the results of the child growth study indicate that the diet and disease load of sub-adults from Wharram Percy must not only have been worse than modern children, but also that of the urban poor during the Industrial Revolution. Although possible, this does seem difficult to reconcile (Roberts and Manchester 1995:125). An alternative explanation for the comparatively short stature might tentatively be that marriage partners were taken from within a geographically limited area and breeding occurred within a restricted gene pool, unlike in towns which contained a high proportion of migrants. From a study of documentary evidence, Smith and co-workers (1993) have suggested that although consanguineous marriages were denounced in medieval society, it is feasible that such unions occurred through ignorance, particularly with respect to more distant relationships such as those to the fourth degree. One problem in ascribing the Wharram Percy results to either aspect of the rural character of the site, is that many immigrant towns dwellers may have spent their childhood in rural settlements, as discussed in chapter 5, thereby clouding the distinction between the factors which affected the growth of those buried in urban and rural cemeteries. Before making any firm interpretations, further comparisons with other rural cemeteries would be necessary to determine whether a consistent pattern of below average stature is observed, or whether the results are an anomaly of Wharram Percy.

Males from the cemetery which produced the highest mean stature values, Ipswich, displayed an average of 172.7cm. This was significantly different from all sites except for Fishergate 4 and St Nicholas Shambles, and 2.3cm greater than the pooled male average. The female mean of 161.1cm was 2.0cm above the pooled average, and significantly different from the two cemeteries which gave the lowest mean statures, Jewbury and Wharram Percy. As a monastic cemetery which also contained wealthier members of the lay community, this may be evidence that the group benefited from superior nutrition during their growth years, assuming of course that the status inferred from the place of burial was similar in childhood. Several studies of prehistoric populations from Europe and America have found the stature of skeletons from so-called elite burials to be greater than those perceived to be non-elites, especially among males (Larsen 1997:18-19). The association between height and social class has long been established. Those from higher social classes tend to be taller than those from less privileged backgrounds and this has chiefly been ascribed to their superior nutritional and living standards (Bielicki 1986; Bielicki and Waliszko 1992). For example, the DHSS survey revealed that British men and women from manual worker households were both, on average, approximately 3cm shorter than those from non-manual worker households (Knight 1984). However, like Ipswich Blackfriars, the collection from the monastic phase at Fishergate was also thought to contain friars and a substantial component of wealthy lay persons, yet the skeletons did not display similarly tall statures which might be expected given their presumed social status. Both male and female means were fairly mediocre compared with the other collections, and for the males, the difference between Ipswich and Fishergate 6 was actually statistically significant. So perhaps social status is not a satisfactory explanation for the above average statures evident in the Ipswich assemblage.

Another possibility is that the Ipswich statures could be a manifestation of regional height variations. One finding of the DHSS survey was that slight regional differences in average adult stature exist in modern Britain. Men living in East Anglia and the East Midlands were found to be taller than the national average, though the women from these regions equalled the national average. Men and women living across the south of the country, excluding London, displayed an above average height, the mean height of Londoners being similar to the British average. Those living in the north of England were shorter than those in the south, displaying mean heights which were below the national average. No interpretation was provided as to why these differences should occur, though possible reasons might include regional disparities in living standards or differences in 'genetic stock'. Whilst being cautious not to over-interpret the data, some similarities can be observed between the pattern identified by the DHSS study and the medieval samples. Like the modern East Anglians, the Ipswich males were of above average stature, the mean being significantly different from all but two of the other samples. Although the females from Ipswich displayed the tallest stature, the mean was not significantly different from the other samples apart from Jewbury and Wharram which exhibited particularly low mean statures. The rank order of female means followed the general pattern detected among the modern data, with all three assemblages from the south displaying average statures which were greater than those from the north. The rank order of males did not quite adhere to this pattern as both Fishergate means exceeded two samples from the south, although neither of the southern sites occupied the lowest rank positions, these being taken by the remaining northern cemeteries. It might tentatively be suggested then that the pattern observed from the DHSS study represents the residual remains of regional genetic variations in stature. However, Barker and co-workers (1990) refute the idea that genetic factors could be responsible for regional variations in modern stature owing to the large population movements which took place during the Industrial Revolution. They identified a similar regional pattern following a study of three national samples born between 1920 and 1970. Men and women living in the south and the east of England were taller than those from the north. The differences were not found to be associated with social class. The authors favoured the idea of regional differences in environmental influences, such as housing, population density or infant feeding practices as possible explanations. These factors would not be applicable to the medieval cemeteries, so if they represent the more likely explanation, they would undermine the argument for regional differences in genetic factors being responsible for the stature variations observed among the medieval cemeteries. A further possible explanation might be associated with regional differences in climate, as climate has been found to influence growth and stature in a variety of ways, sometimes indirectly through its effect on agricultural yields or infectious disease (Molleson and Cox 1993:119; Panter-Brick 1997; Steegman 1985; Stinson 1985). The climate in the north and north-west of England tends to be colder and wetter compared with the warmer, drier conditions in the south and east, including East Anglia (Thompson 1975). Perhaps a comparative study of stature among other archaeological samples from different localities would help to confirm the existence of any regional pattern. If so, the potential causes of modern regional height variations might be inferred through the identification of determinants which are common to both series.

A major difficulty which pervades the interpretation of the site differences in stature is that the genetic and environmental influences acting on the individuals interred in the cemeteries probably varied in an indeterminable number of ways. Although tempting, endeavouring to attribute any differences to a specific cause is likely to be an over-simplistic approach. A particular problem lies in the expansive and non-uniform periods of cemetery use and the lack of precise phasing. For example, it is likely that the Agrarian crisis of the late thirteenth and early fourteenth centuries had a detrimental effect on child growth, as has been observed during famine situations today (Larsen 1997:9). The improved economic circumstances which characterised the late fourteenth and early fifteenth centuries may have had a more beneficial impact on those growing up in the post plague era (see section 5.3). The time-averaged stature estimates would thus serve to mask any potential height fluctuations. A further limitation which cannot be discounted is the possibility of inter-observer variation in measurement, although it is unlikely that this could entirely account for the patterns observed, as the data from Ipswich and Wharram Percy, and both the samples from Fishergate, were collected by a single observer.

It was apparent from visual comparison of the stature means for each age category that the figures for each group were very similar, as shown in table 6.8. This was confirmed by the ANOVA tests. The results of the parametric and non-parametric tests were in agreement, revealing that no statistically significant differences existed between age strata in any cemetery, among males or females, indicating that there was no association between stature and age at death. Nevertheless, the results did confirm that all the previous analyses, concerning the sex and site comparisons, were not influenced by the age structure of the population samples.

Table 6.1a/b Standard exploratory analysis on stature data

(a) Males

n number of individuals in sample $\bar{x}$ sample mean (cm) $\tilde{x}$ sample median (cm) S.D. standard deviation Var. variance
Min. minimum (cm) Max. maximum (cm) Skew. skewness Kurt. kurtosis

	n	$\bar{x}$	$\tilde{x}$	S.D.	Var.	Range	Min.	Max.	Skew.	Kurt.
Wharram	170	168.74	168.85	5.817	33.842	30.1	151.2	181.3	-.541	.319
Ipswich	131	172.67	172.85	4.566	20.849	22.8	162.3	185.1	.203	-.077
Abingdon	206	170.56	170.00	5.423	29.408	33.0	156.0	189.0	.181	.588
St Nicholas	50	170.68	170.42	5.626	31.657	22.9	159.5	182.4	.320	-.718
Fishergate 4	43	172.30	172.04	6.254	39.113	25.2	158.8	183.9	.025	-.672
Fishergate 6	154	170.76	170.66	5.391	29.058	32.7	153.1	185.9	-.042	.133
Jewbury	56	166.66	166.50	4.578	20.956	21.0	157.0	178.0	.240	.041

(b) Females

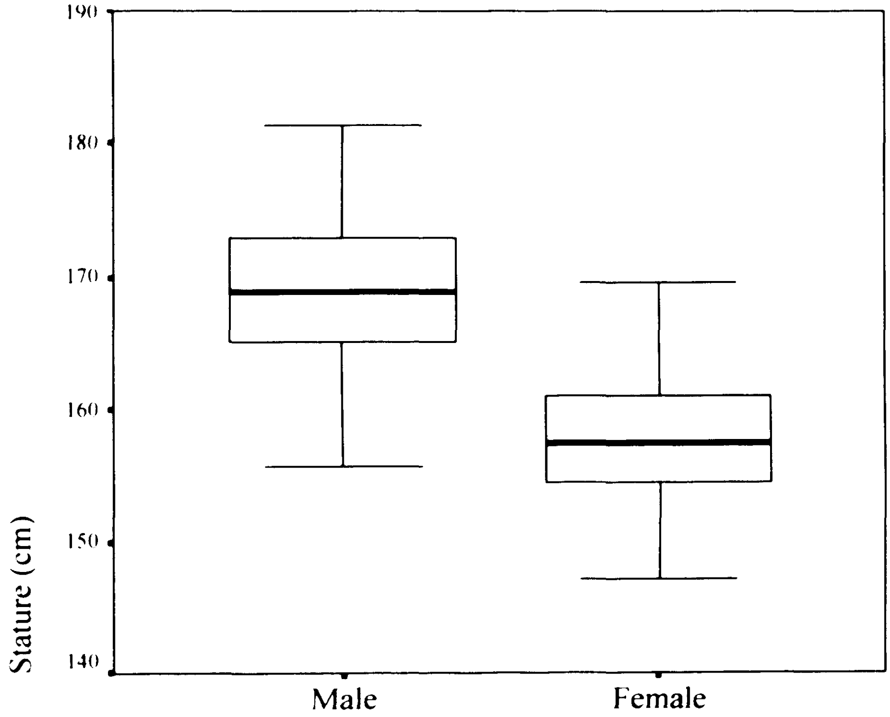
n number of individuals in sample $\bar{x}$ sample mean (cm) $\tilde{x}$ sample median (cm) S.D. standard deviation Var. variance
Min. minimum (cm) Max. maximum (cm) Skew. skewness Kurt. kurtosis

	n	$\bar{x}$	$\tilde{x}$	S.D.	Var.	Range	Min.	Max.	Skew.	Kurt.
Wharram	111	157.75	157.50	5.046	25.460	22.4	147.1	169.5	.132	-.331
Ipswich	58	161.13	160.05	5.675	32.208	30.6	146.3	176.9	.608	.891
Abingdon	153	159.91	160.00	5.265	27.715	28.0	148.0	176.0	.352	.142
St Nicholas	41	160.41	160.57	5.422	29.395	23.7	150.0	173.7	.260	-.180
Fishergate 4	29	158.06	158.64	5.386	29.013	21.9	145.4	167.3	-.548	.022
Fishergate 6	41	159.29	158.83	4.811	23.145	20.6	148.3	168.9	-.120	-.158
Jewbury	42	156.43	156.00	5.487	30.105	27.0	143.0	170.0	.042	.277

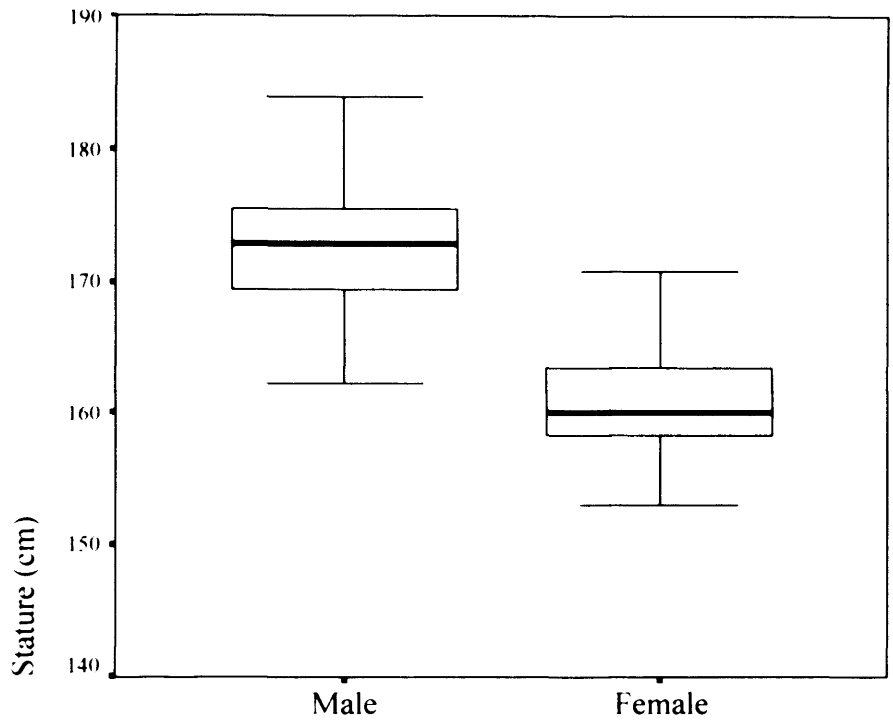
Figure 6.1a-g Box-and-whisker plots comparing characteristics of the male and female stature distributions within the respective cemeteries

The box represents the interquartile range which contains the middle 50% of cases; and the extensions (the 'whiskers') represent the range, excluding cases classified as outliers (defined as values more than 1.5 box-lengths away from the box). The line across the box represents the median. A median that is not centrally placed within the box indicates a skewed distribution.

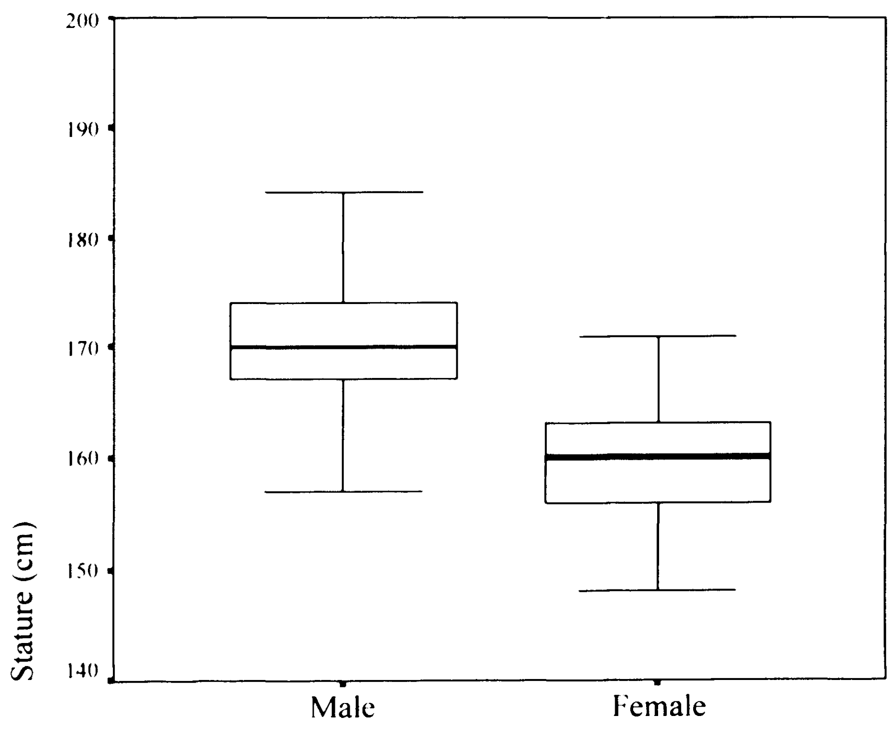
(a) Wharram Percy



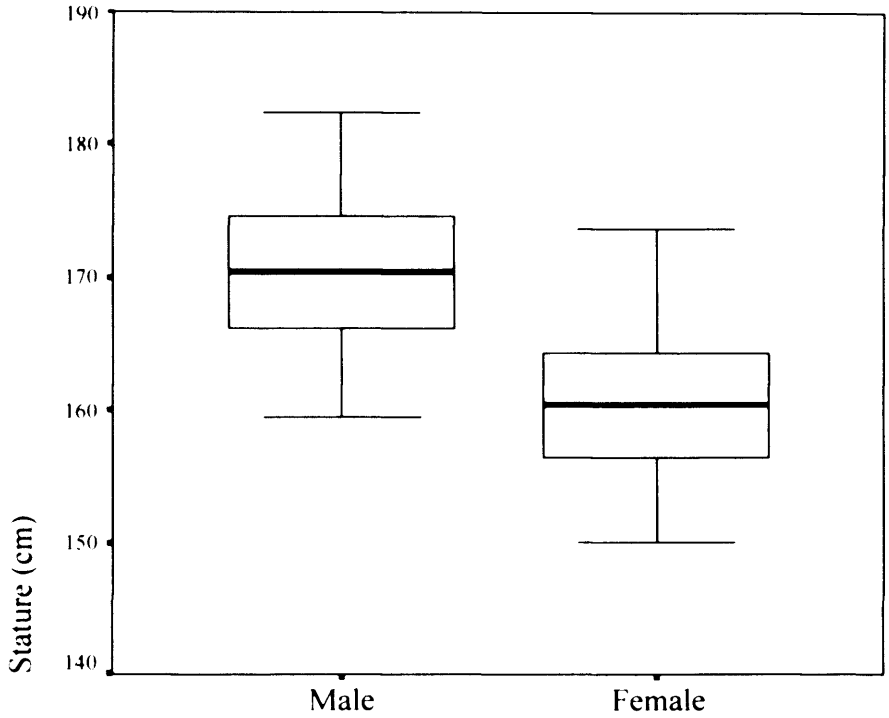
(b) Ipswich Blackfriars



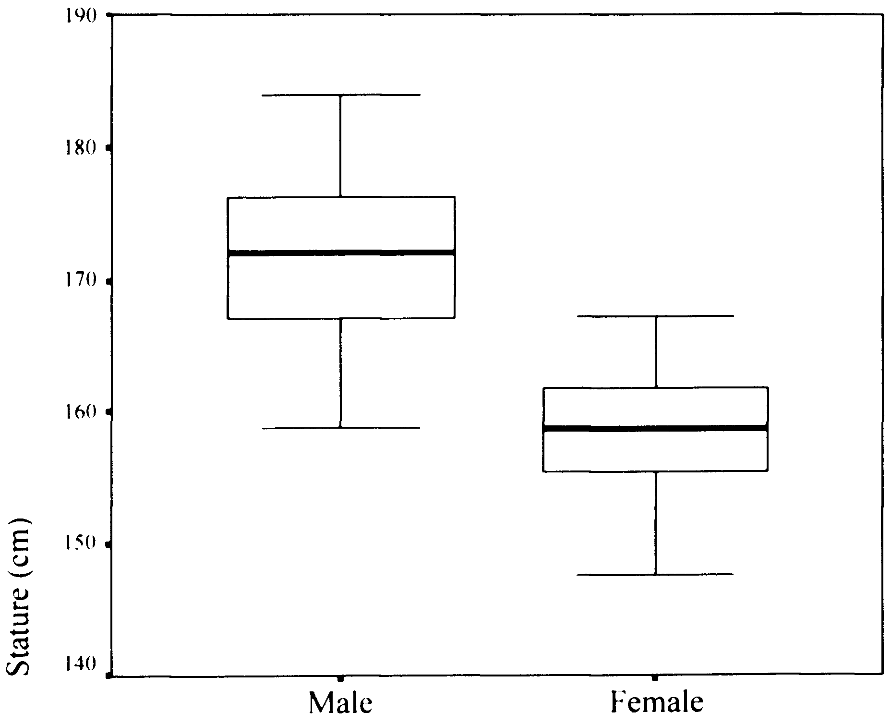
(c) Abingdon



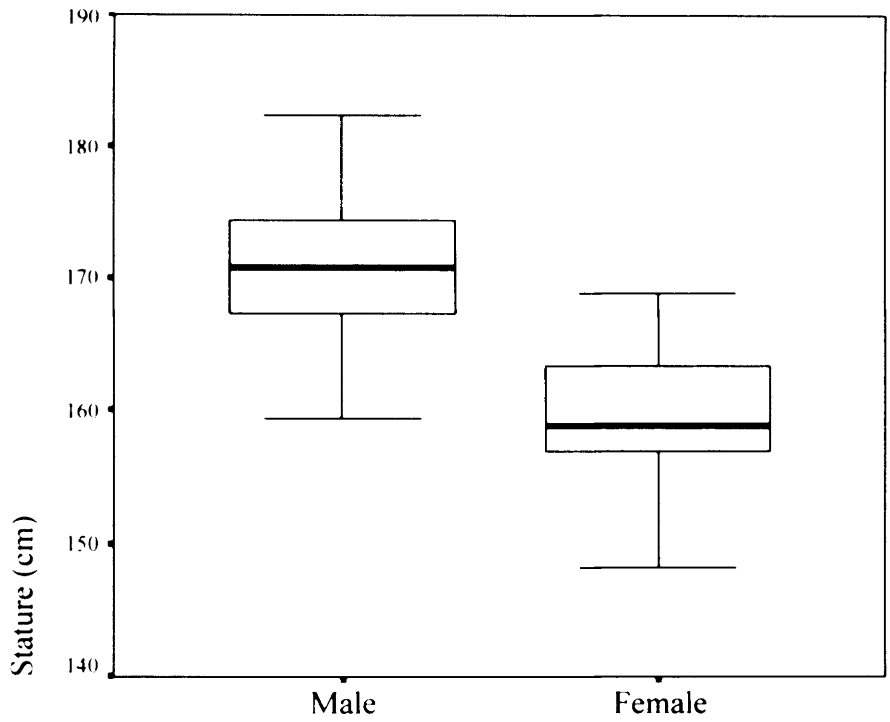
(d) St Nicholas Shambles



(e) Fishergate 4



(f) Fishergate 6



(g) Jewbury

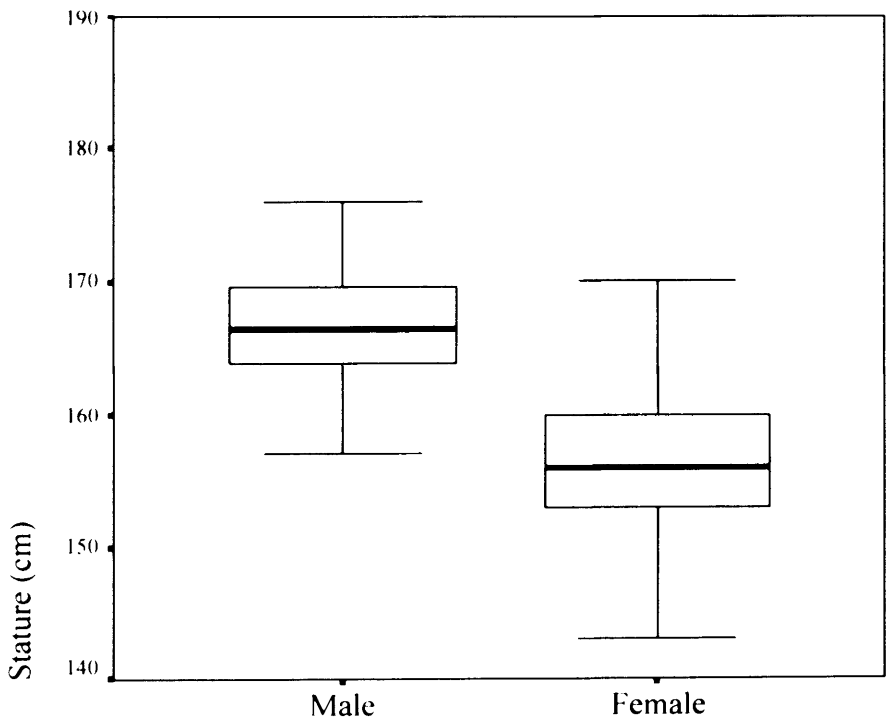


Table 6.2 Levene's tests for homogeneity of variance between male and female samples

F value *p* probability

	F	*p*
Wharram	1.689	.195
Ipswich	1.838	.177
Abingdon	.055	.815
St Nicholas	.263	.609
Fishergate 4	1.569	.214
Fishergate 6	.785	.377
Jewbury	1.335	.251

Table 6.3 Levene's tests for homogeneity of variance between cemetery samples

p probability

	Levene Statistic	*p*
Males	2.215	.040
Females	.174	.984

Table 6.4 Independent samples *t*-tests comparing male and female stature means

n number of individuals in sample $\bar{x}$ sample mean (cm)
$\bar{x}_m - \bar{x}_f$ difference between male and female means (cm) *p* probability

	Males		Females				
	n	$\bar{x}$	*n*	$\bar{x}$	$\bar{x}_m - \bar{x}_f$	*t*	*p*
Wharram	170	168.74	111	157.75	10.99	16.286	.000
Ipswich	131	172.67	58	161.13	11.54	14.863	.000
Abingdon	206	170.56	153	159.91	10.65	18.639	.000
St Nicholas	50	170.68	41	160.41	10.27	8.804	.000
Fishergate 4	43	172.30	29	158.06	14.24	10.010	.000
Fishergate 6	154	170.76	41	159.29	11.47	12.370	.000
Jewbury	56	166.66	42	156.43	10.23	10.053	.000

Table 6.5a/b One-sample *t*-tests comparing medieval mean statures with modern mean statures (Knight 1984)

(a) Males

n number of individuals in sample $\bar{x}$ sample mean (cm)
$\bar{x}_m - \bar{x}_t$ difference between medieval male mean and test value (cm) *t* t value *p* probability

	Males		Test			
	n	$\bar{x}$	Value	$\bar{x}_m - \bar{x}_t$	*t*	*p*
Wharram	170	168.74	173.8	-5.06	-11.351	.000
Ipswich	131	172.67	173.8	-1.13	-2.843	.005
Abingdon	206	170.56	173.8	-3.24	-8.567	.000
St Nicholas	50	170.68	173.8	-3.12	-3.920	.000
Fishergate 4	43	172.30	173.8	-1.50	-1.570	.124
Fishergate 6	154	170.76	173.8	-3.04	-6.999	.000
Jewbury	56	166.66	173.8	-7.14	-11.671	.000
Pooled site data	810	170.39	173.8	-3.41	-17.351	.000

(b) Females

n number of individuals in sample $\bar{x}$ sample mean (cm)
$\bar{x}_f - \bar{x}_t$ difference between medieval female mean and test value (cm) *t* t value *p* probability

	Females		Test			
	n	$\bar{x}$	Value	$\bar{x}_f - \bar{x}_t$	*t*	*p*
Wharram	111	157.75	160.9	-3.15	-6.571	.000
Ipswich	58	161.13	160.9	0.23	.305	.761
Abingdon	153	159.91	160.9	-0.99	-2.330	.021
St Nicholas	41	160.41	160.9	-0.49	-0.575	.569
Fishergate 4	29	158.06	160.9	-2.84	-2.841	.008
Fishergate 6	41	159.29	160.9	-1.61	-2.142	.038
Jewbury	42	156.43	160.9	-4.47	-5.281	.000
Pooled site data	475	159.12	160.9	-1.78	-7.140	.000

Table 6.6 One-way ANOVA tests and Kruskal-Wallis one-way ANOVA tests comparing stature means from the medieval cemeteries

F F value χ^2 chi-square statistic p probability

	ANOVA		Kruskal-Wallis	
	F	p	χ^2	p
Males	12.171	.000	65.408	.000
Females	5.659	.000	-	-

Table 6.7 A posteriori tests to identify which of the cemetery stature means were statistically significantly different from each other

'Site 1' and 'Site 2' denote the sites being compared

$\bar{x}_{S1} - \bar{x}_{S2}$ difference between sample means (cm) for Site 1 and Site 2

p_{Tukey} probability according to Tukey's HSD test $p_{Tamhane}$ probability according to Tamhane's T2 test

		Males			Females	
Site 1	Site 2	$\bar{x}_{S1} - \bar{x}_{S2}$	p_{Tukey}	$p_{Tamhane}$	$\bar{x}_{S1} - \bar{x}_{S2}$	p_{Tukey}
Wharram	Ipswich	-3.93	.000	.000	-3.37	.002
	Abingdon	-1.83	.018	.040	-2.16	.018
	St Nicholas	-1.95	.270	.536	-2.66	.084
	Fishergate 4	-3.57	.002	.026	-0.30	1.000
	Fishergate 6	-2.02	.013	.026	-1.54	.685
	Jewbury	2.07	.158	.139	1.32	.809
Ipswich	Wharram	3.93	.000	.000	3.37	.002
	Abingdon	2.11	.008	.003	1.22	.745
	St Nicholas	1.99	.283	.454	0.71	.994
	Fishergate 4	0.37	1.000	1.000	3.07	.138
	Fishergate 6	1.91	.045	.028	1.84	.611
	Jewbury	6.01	.000	.000	4.70	.000
Abingdon	Wharram	1.83	.018	.040	2.16	.018
	Ipswich	-2.11	.008	.003	-1.22	.745
	St Nicholas	-0.12	1.000	1.000	-0.50	.998
	Fishergate 4	-1.74	.461	.879	1.85	.593
	Fishergate 6	-0.20	1.000	1.000	0.62	.994
	Jewbury	3.90	.000	.000	3.48	.003

Table 6.7 contd. . . /

Table 6.7 (contd.)

Site 1	Site 2	Males			Females	
		$\bar{x}_{S1} - \bar{x}_{S2}$	p_{Tukey}	$p_{Tamhane}$	$\bar{x}_{S1} - \bar{x}_{S2}$	p_{Tukey}
St Nicholas	Wharram	1.95	.270	.536	2.66	.084
	Ipswich	-1.99	.283	.454	-0.71	.994
	Abingdon	0.12	1.000	1.000	0.50	.998
	Fishergate 4	-1.62	.775	.990	2.36	.519
	Fishergate 6	-0.08	1.000	1.000	1.12	.962
	Jewbury	4.02	.002	.003	3.98	.010
Fishergate 4	Wharram	3.57	.002	.026	0.30	1.000
	Ipswich	-0.37	1.000	1.000	-3.07	.138
	Abingdon	1.74	.461	.879	-1.85	.593
	St Nicholas	1.62	.775	.990	-2.36	.519
	Fishergate 6	1.54	.641	.964	-1.23	.962
	Jewbury	5.64	.000	.000	1.63	.861
Fishergate 6	Wharram	2.02	.013	.026	1.54	.685
	Ipswich	-1.91	.045	.028	-1.84	.611
	Abingdon	0.20	1.000	1.000	-0.62	.994
	St Nicholas	0.08	1.000	1.000	-1.12	.962
	Fishergate 4	-1.54	.641	.964	1.23	.962
	Jewbury	4.10	.000	.000	2.86	.169
Jewbury	Wharram	-2.07	.158	.139	-1.32	.809
	Ipswich	-6.01	.000	.000	-4.70	.000
	Abingdon	-3.90	.000	.000	-3.48	.003
	St Nicholas	-4.02	.002	.003	-3.98	.010
	Fishergate 4	-5.64	.000	.000	-1.63	.861
	Fishergate 6	-4.10	.000	.000	-2.86	.169

Figure 6.2 Cemeteries displaying a statistically significant difference in mean stature (visual representation of a posteriori test results)

(a) Males

——— = Interconnecting line represents a statistically significant difference in mean stature between sites

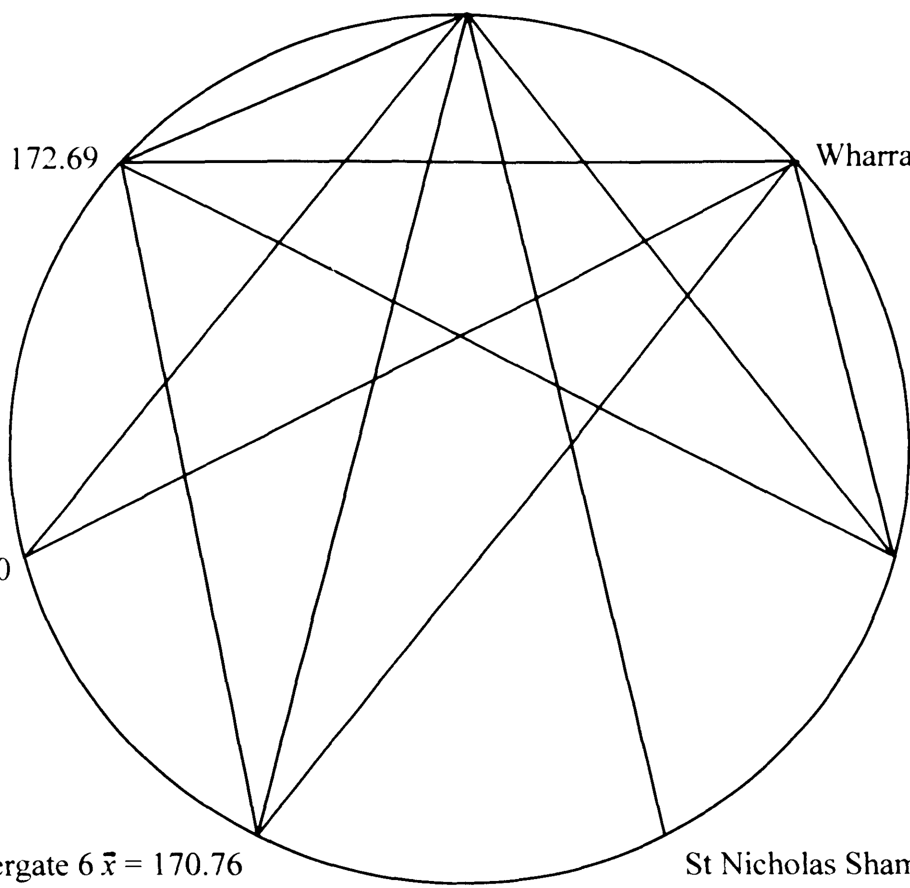


Figure 6.2 (b) Females

——— = Interconnecting line represents a statistically significant difference in mean stature between sites

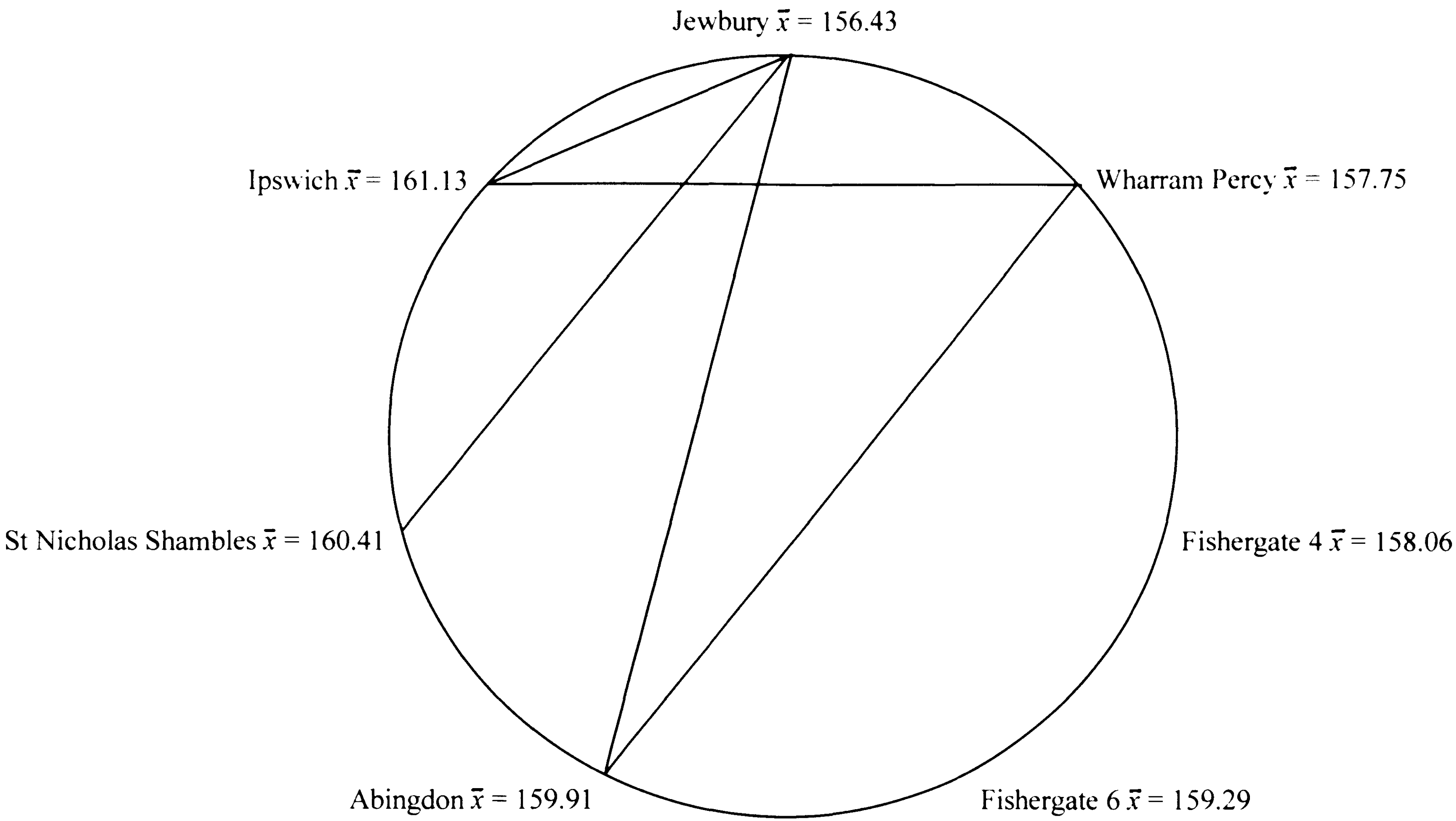


Table 6.8 Age-specific mean stature values; and one-way ANOVA tests and Kruskal-Wallis one-way ANOVA tests comparing age-specific stature means

n number in sample $\bar{x}$ sample mean (cm) *F* F value χ^2 chi-square statistic *p* probability

		c.18-25		*c*.25-35		*c*.35-45		*c*.>45		ANOVA		Kruskal-Wallis	
		n	$\bar{x}$	*n*	$\bar{x}$	*n*	$\bar{x}$	*n*	$\bar{x}$	*F*	*p*	χ^2	*p*
Wharram	Males	22	166.80	26	170.55	29	168.78	59	168.08	1.704	.169	5.718	.126
	Females	18	157.08	21	159.13	21	158.11	40	157.65	0.635	.595	1.645	.649
Ipswich	Males	24	173.05	32	172.13	29	172.89	30	172.31	0.284	.837	1.536	.674
	Females	11	162.84	15	160.51	8	159.71	14	161.05	0.518	.672	2.478	.479
Abingdon	Males	22	169.05	46	170.85	57	170.26	70	171.34	1.119	.342	3.116	.374
	Females	20	159.15	43	159.84	40	160.20	42	160.48	0.313	.816	.584	.900
St Nicholas	Males	15	170.19	12	170.83	10	172.76	2	162.80	1.667	.192	3.988	.263
	Females	4	163.76	19	160.30	10	159.46	4	159.52	.624	.604	.600	.896
Fishergate 4	Males	17	173.31	12	172.32	9	172.96	3	164.93	1.592	.208	3.581	.310
	Females	6	160.25	6	158.76	10	157.62	3	157.18	.353	.788	1.934	.586
Fishergate 6	Males	20	173.14	37	170.35	42	169.63	45	170.85	2.028	.113	5.872	.118
	Females	3	161.29	13	158.91	12	159.80	9	159.23	.231	.874	1.066	.785
Jewbury	Males	7	165.14	14	168.14	13	166.85	17	166.18	.809	.495	1.935	.586
	Females	9	156.89	12	157.58	10	153.10	9	156.67	1.628	.200	3.571	.312
Pooled site data	Males	127	170.55	179	170.82	189	170.32	226	169.97	.791	.499	2.501	.475
	Females	71	159.35	129	159.51	111	158.79	121	159.12	.393	.758	.905	.824

6.3 Anaemia

6.3.1 Introduction

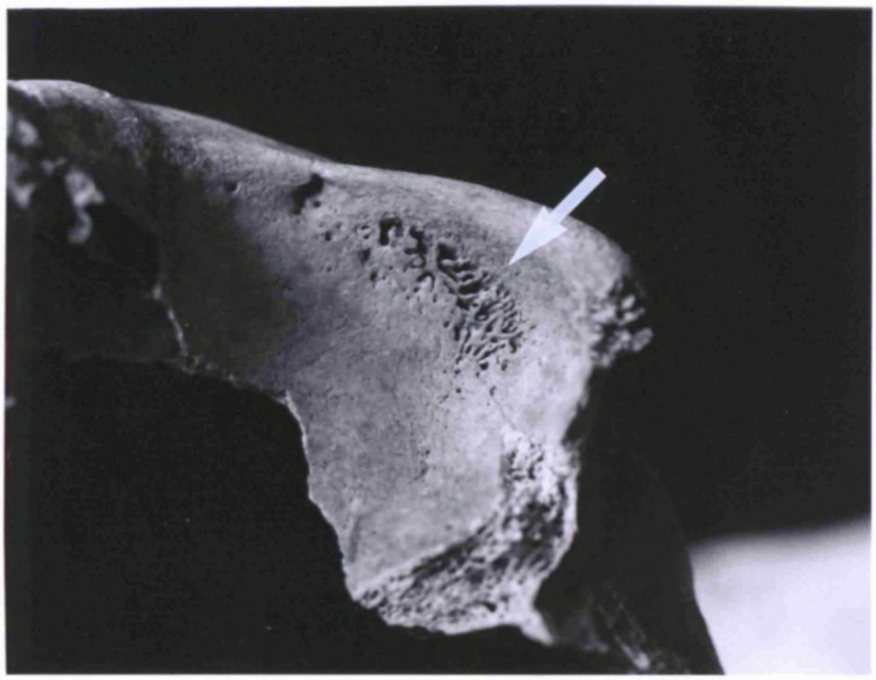
Anaemia can be broadly defined as a subnormal concentration of haemoglobin or red blood cells (Kent 1992:2; Roberts and Manchester 1995:166; Stuart-Macadam 1989:212). Common clinical symptoms include pallor, fatigue, breathlessness, palpitations and gastrointestinal disturbances. In children, severe and chronic anaemia may also produce bone changes, particularly on the skull. These skull lesions are detectable in skeletal remains and are termed porotic hyperostosis (Larsen 1997:30-40; Roberts and Manchester 1995:167; Stuart-Macadam 1987a; 1987b; 1988; 1989; 1992).

Porotic hyperostosis is characterised by pitting and thinning of the outer layer of compact bone and thickening of the middle diploic layer. The bone changes can be found on the skull vault, particularly the parietal, occipital and frontal bones. However, the lesions occur most frequently on the superior surfaces of the orbital roofs. When located on the eye orbits, the lesions are often referred to by an alternative terminology, 'cribra orbitalia', illustrated in plate 6.1. The skull vault and orbits may be affected concurrently or independently in a single individual, but it is unusual for porotic hyperostosis to occur on the vault alone. There has been some debate as to whether a relationship between orbit and vault lesions actually exists, but the similarity of the lesions upon radiographic analysis has led to the consensus that they do share a common aetiology, although it has been suggested that vault changes may represent a more severe or advanced form of anaemia (Larsen 1997:30-32; Roberts and Manchester 1995:167; Stuart-Macadam 1989).

The bone alterations are associated with marrow hypertrophy, a proliferative compensatory response to the anaemia whereby the blood-forming marrow tissue expands in an attempt to increase red blood cell production. This process is thought to induce bone changes in young children because the available marrow space is already filled to capacity and their incompletely mineralised bones are relatively malleable. The marrow expansion exerts an outward pressure on the adjacent compact bone, thickening the skull vault and eroding the compact layer so that it becomes thin and porous. In adults, there is usually sufficient marrow space to accommodate the hypertrophic reaction, so avoiding the possibility of excessive pressure developing within the diploë.

Mature bones would also be able to resist any potential stress arising through expansion. The age at which the skull bones cease to respond to pressure changes has not been determined, but it is estimated that the bones are most susceptible before the age of five years. As the skeletal manifestations of anaemia are confined to children, it is unlikely that the adult prevalence of the condition could be determined among archaeological populations. Nevertheless, while the lesions may undergo remodelling, they can persist throughout adult life thereby providing retrospective evidence for childhood anaemia (Larsen 1997:32; Mittler and Van Gerven 1994; Stuart-Macadam 1985).

Plate 6.1 Cribra Orbitalia



Since genetic anaemias were unlikely to have affected archaeological populations from northern Europe, porotic hyperostosis from this region is regarded to represent an acquired iron deficiency anaemia (Roberts and Manchester 1995:167-171; Stuart-Macadam 1992). Among other functions, iron is necessary for the development of haemoglobin in newly forming red blood cells in bone marrow. Therefore, insufficient iron impairs the process of red blood cell production leading to an anaemic state. It has traditionally been assumed that iron deficiency anaemia develops as a direct result of a diet low in iron, or a diet high in agents which impede the absorption of iron through the intestine. Plant sources of iron tend to be poorly absorbed and many plant foodstuffs, including cereals, contain compounds such as phytates which inhibit the absorption of dietary iron. By contrast, meat is a rich source of iron which is efficiently absorbed. Furthermore, meat promotes the absorption of iron from other foods consumed with it, as does the ingestion of iron enhancers such as ascorbic acid (vitamin C) (Kent 1992:22; Larsen 1997:29; Mays 1998:143-144; Mensforth *et al.* 1978; Roberts and Manchester 1995:166). Thus anthropologists have considered porotic hyperostosis to be a good indicator of nutritional stress, often analogous with a diet of low meat intake and a heavily reliance on cereal crops. This has been used to explain the observed increase in porotic hyperostosis which has accompanied the transition from a hunter-gathering to an agriculturally based economy in skeletal populations from many parts of the world (Garn 1992; Larsen 1997:35-37; Mays 1998:142-145; Roberts and Manchester 1995:166; Stuart-Macadam 1988; 1992).

However, in recent years the dietary hypothesis has been challenged. Various clinical and population studies have failed to demonstrate a relationship between iron intake and iron deficiency anaemia (Stuart-Macadam 1988; 1989; 1992; Wadsworth 1992), and there is now a widespread conviction that diet is not a major factor in its aetiology. Stuart-Macadam (1992:166) describes the connection as 'simplistic' and believes that only in situations of overwhelming malnutrition with a concomitant deficiency of many other essential nutrients will diet play an important role in the development of anaemia. Kent (1992:20) explains that it often 'seems reasonable to attribute the most obvious point about a phenomenon to its cause. The most obvious point about iron levels is that an extremely deprived diet can ultimately lead to acquired anaemia. It is debatable whether such diets actually exist now or in the past except where people are literally starving to death'. Wadsworth (1992) points out that some iron is present in the majority of natural foods, including water, and Crosby (1974 in Stuart-Macadam 1992:157) believes that 'it is difficult to contrive a diet so poor in iron as to cause iron deficiency anaemia'. Arthur and Ibister (1987 in Stuart-Macadam 1992:157) estimate that 'even if iron intake was reduced to nil, which is virtually impossible even with the most frugal diets, it would still take at least two to three years to develop iron deficiency anaemia'. This is because iron metabolism has evolved to ensure that there is always an adequate supply to meet physiological requirements. It is a highly efficient, adaptable system based on conservation (Kent 1992; Stuart-Macadam 1992; 1988; 1989; Wadsworth 1992). Under normal conditions, body losses of iron are minimal. About 90% of the iron needed to manufacture new red blood cells is derived by recycling senescent red blood cells. The remaining 10% is obtained from storage iron and the diet. The mechanism by which intestinal absorption is regulated is not fully understood, but it is known that absorption adjusts to meet demand. During times of need absorption is increased, even from a low iron diet, whereas if the body becomes overloaded with iron, absorption is reduced. The body appears to be as much concerned with gaining too much iron as it is too little. Hence iron metabolism is virtually a closed system with most of the iron requirement being met by internal sources. As Stuart-Macadam states (1992:157), 'only a small amount of iron is needed from the diet to compensate for losses and dietary lack of iron is of minor importance in most cases of iron deficiency'. She therefore recommends that 'porotic hyperostosis is not a good skeletal indicator of nutritional stress, and anthropologists should re-evaluate the implications of porotic hyperostosis in past human populations' (Stuart-Macadam 1988:286).

An alternative explanation for the common cause of iron deficiency anaemia has evolved from the long-standing observation that anaemia is often associated with infectious disease. There is compelling evidence to support the theory that iron deficiency is actually part of a natural defence strategy employed by the body to protect itself against pathogens (Kent 1992; Stuart-Macadam 1992; 1998; Weinberg 1992). Bacteria and viruses require iron to survive and multiply, but because they are unable to store it in a non-toxic form, they must acquire it from the host. In response, the body attempts to withhold iron from invading micro-organisms by lowering the levels of circulating iron, a state known as hypoferremia. Rather than being expelled from the body, the iron withdrawn from circulation is simultaneously shifted into storage, primarily bound in protein molecules called ferritin, concentrated in the liver. Intestinal absorption of iron is also suppressed as part of the iron-withholding process. Studies have shown that in depriving micro-organisms of this vital nutrient, being transiently hypoferremic can be advantageous to the host in the situation of microbial invasion by rendering the blood less suitable for microbial growth and strengthening host resistance to infection. This has been corroborated by studies which have demonstrated that the opposing state of excess iron, hyperferremia, stimulates pathogen growth. However, the iron-withholding mechanism not only sequesters iron from pathogens, but also haemoglobin synthesis for the duration of the infectious episode. Therefore, if the hypoferremic response is prolonged through repeated or continuous exposure to pathogens, iron deficiency anaemia may develop and ultimately the bone changes associated with it. Following this theory, Stuart-Macadam (1992:159) argues that 'the presence of porotic hyperostosis in archaeological populations . . . is related to the total pathogen load of a population'. The archaeological picture of porotic hyperostosis is consistent with this hypothesis (Kent 1986; Larsen 1997:29-40; Stuart-Macadam 1992). Porotic hyperostosis occurs more frequently in populations associated with greater pathogen loads, especially those derived from warm climates; lowland, coastal and marshy areas; and aggregated sedentary communities. The latter tend to experience high morbidity because pathogen transmission is encouraged when groups of people live in close proximity. Hygiene and sanitation tends to be poorer and water supplies are often contaminated. It would also explain the rise in porotic hyperostosis with the transition to agriculture as this process usually involved the establishment of sedentary, aggregated communities.

Another important, established cause of anaemia is severe or chronic blood loss (Garn 1992; Kent 1986; Larsen 1997:30; Mays 1998:142-145; Mittler and Van Gerven 1994; Wadsworth 1992). This can arise through parasitic infestation, chronic diarrhoea, haemorrhage, cancer and injury. Blood loss through parasitism varies according to the number and type of worm present. The parasites extract blood from the host in feeding, and may cause gastrointestinal bleeding and diarrhoea. In severe and chronic diarrhoea, blood can pass with the stools. Enteric disease and parasitism can also invoke hypoferremia as the body attempts to withhold iron from the invading organisms. The conditions associated with aggregation and sedentism favour the spread of these diseases. The recovery of parasite eggs from archaeological deposits on British medieval sites testifies to the problem of parasitic infection (Pike 1968). For example, ova of the intestinal worms *Ascaris* sp.(roundworm) and *Trichuris* sp. (whipworm) were identified in samples collected from the contents of a fifteenth century barrel-latrine in Worcester (Greig 1981), and medieval cesspits in York (Jones 1985). Neoplasia and inflammatory conditions, particularly arthropathies, can also induce a hypoferremic response and subsequent anaemia (Weinberg 1992; Kent 1992). Like pathogens, cancer cells require iron for growth and replication, so a lowered iron level deters their proliferation. Inflammation causes the production of neutrophils, white blood cells which produce iron binding proteins, thereby contributing to the hypoferremic defence response. However, as porotic hyperostosis is thought to represent childhood anaemia, these aetiological factors are probably of minor importance with respect to archaeological populations, as cancer and arthropathy are uncommon in young children. Factors specifically affecting infants include low maternal iron stores, prematurity and problems accompanying weaning (Stuart-Macadam 1985; 1988; 1989). Low iron levels are particularly common during the first trimester of pregnancy, the most vulnerable stage in foetal development. Reduced iron status during pregnancy has therefore been interpreted as an adaptation to increase resistance against disease. A 'physiological iron lack' is routinely observed in infants between the ages of six and eighteen months. Again, this is a period of immunological vulnerability as the child loses the passive immunity conferred by its mother and is exposed to a greater number of pathogens, so iron deficiency may develop as a defence mechanism to strengthen immunity.

The purpose of this study was to carry out a comparative investigation of male and female porotic hyperostosis in the medieval cemeteries. Following the traditional belief that anaemia develops as a result of a dietary iron lack, a sex difference in the prevalence of porotic hyperostosis might be expected if preferential feeding practices were employed toward either sex. As discussed in chapter 5, some contemporary medical authors advocated that greater attention should be placed on the nourishment of male children. To have any impact on the prevalence of anaemia, this would probably have had to entail the feeding of a more varied diet to boys, with a greater emphasis on iron rich foods such as meat, and less emphasis on cereal based foods. Alternatively, if the more recent view that anaemia is predominantly caused by pathogenic exposure is correct, then it is unlikely that any sex differences would be identified in the data. Male and female children were not normally raised in segregated or radically different environments, so they were probably exposed to a similar pathogen load. However, if males are more susceptible to environmental stress, it is possible that a higher prevalence of cribra orbitalia would be observed among males. It might also be argued that inferior nutrition, either in quality or quantity, might lead to an increased susceptibility to infection. If a poorer diet was generally afforded to female children, this in turn may have resulted in increased levels of anaemia.

If, as Stuart-Macadam believes, porotic hyperostosis is related to the total pathogen load of a population, then differences in male or female prevalence might be expected between the cemeteries. It is possible that large urban centres experienced heavier pathogen loads than smaller rural communities as they may have been more prone to the hygiene problems associated with human aggregation. The difficulty of comparing data between cemeteries is that of differences in recording protocol. Both Larsen (1997:35) and Stuart-Macadam (1989) have lamented on the variations in criteria, methodology and descriptive techniques which have been used over the years to investigate porotic hyperostosis, which can greatly inhibit the comparison of data. It was therefore recognised that this problem would have to be taken into consideration when comparing data between sites.

One advantage of this study was that it did provide the unusual opportunity to examine sex differences in porotic hyperostosis among the sample of subadults from Abingdon and Fishergate which had been sexed using the tooth measurement technique, discussed in chapter 3. As with the adults, many of the lesions among the subadults were probably not active at the time of death as many exceeded the age at which skull bones respond to the pressures exerted by marrow hypertrophy. Nevertheless, it was thought that the subadult lesions were less likely to have been subject to remodelling, thereby providing a more contemporary record of porotic hyperostosis than that provided by adult skulls.

6.3.2 Method

The presence or absence of cribra orbitalia had been noted for each individual from Ipswich and Wharram Percy, and each orbit available for examination from Abingdon, Fishergate and St Nicholas Shambles. Only positive identifications of cribra orbitalia were recorded among the orbits surviving from Jewbury. Lesions identified among the material from St Nicholas Shambles and Jewbury were not graded according to their degree of severity, although all lesions noted among the St Nicholas Shambles assemblage were described as 'mild'. The scheme devised by Stuart-Macadam (1982) was used to record the severity of cribra orbitalia on orbits from Abingdon and Fishergate, which classifies lesions into five grades, as detailed in table 6.9(a). A three grade system based on that devised by Knip (1971 in Brothwell 1981:165) was used to score the severity of cribra orbitalia present within the Ipswich and Wharram Percy collections, which differentiates lesions as either 'porotic', 'cribrotic' or 'trabecular', as detailed in table 6.9(c).

Porotic hyperostosis was rarely noted on the skull vault, amounting to a total of just 26 confirmed cases among the sexed individuals from all cemeteries combined, comprising 17 males and 9 females. Despite the superiority in the number of males affected, the sex difference is unlikely to be statistically significant. This is partly because there was a larger component of males in the total sample, and also because if these figures were to be translated into a proportion of the total number of male and female crania available for examination, taking into account those which did not display vault lesions, the prevalence for both sexes would be minimal. Owing to the small number affected, and considering that virtually all the skulls with porotic hyperostosis on the skull vault also displayed orbital lesions, this data was not submitted to any further statistical analysis.

While both orbits were available for examination in the majority of individuals, only one orbit was present in some skulls. To ensure that prevalence estimates would not be biased by the inclusion of data from skulls with only one surviving orbit, it was necessary to verify that there was no side bias to lesion prevalence. Lesions do tend to be manifest symmetrically (Mensforth *et al.* 1978; Roberts and Manchester 1995:167; Robledo *et al.* 1995; Stuart-Macadam 1992), and this was supported by a visual inspection of the data yielded from skulls in which both orbits were preserved. If lesions were present on the right orbit they were invariably present on the left and vice versa. A chi-square test on one sample, arbitrarily chosen as the adults from Abingdon, further confirmed that there was no statistically significant association between lesion prevalence and orbit symmetry (χ^2=0.71 p=.790). The visual examination of the data indicated that similar results would be obtained from the remaining samples if the same

Table 6.9a-c Methods used to record the severity of cribra orbitalia

(a) Stuart-Macadam 1982 (Abingdon and Fishergate)	(b) Stuart-Macadam 1985	(c) Knip 1971 in Brothwell 1981:165 (Ipswich and Wharram)
1 - Capillary-like impressions on the bone 2 - Scattered fine foramina	Mild	 Porotic - scattered, isolated fine apertures
3 - Large and small isolated foramina 4 - Foramina that have linked to form a trabecular structure	Moderate	Cribrotic - conglomerate of larger but still isolated apertures Trabecular - apertures confluent resulting in the formation of bone trabeculae
5 - Outgrowth in trabecular structure from outer table surface	Severe	

tests were to be applied. Therefore, it was assumed that for skulls with only one surviving orbit, the existence of cribra orbitalia in the absent orbit could be inferred from the orbit which was present. The same assumption was applied to lesion severity, as lesions were almost always of equal severity on the right and left orbits of a given individual. In the few cases where lesion severity was not comparable in the right and left sides, the most severe grade of lesion was used for the purposes of analysis.

The male and female prevalence of cribra orbitalia was computed for each of the adult cemetery samples, the sexed subadults from Abingdon and Fishergate, and the pooled site data for adults and subadults respectively (table 6.10 and 6.11). The prevalence estimates were based on the number of individuals with positive diagnoses out of the total number of individuals with a minimum of one orbit available for examination. This was with the exception of the assemblage from Jewbury because negative identifications were not recorded, so preventing the total number of individuals with orbits available for examination from being determined. However, Brothwell and Browne (1994 in Lilley *et al.* 1994:460) have provided a rough approximation of the male and female prevalence of cribra orbitalia in the Jewbury cemetery by using the number of frontal bones discernible on *in situ* photographs. They do point out that the figures are likely to be underestimates of the true prevalence because the fragile orbits may not actually have been preserved even though the frontal bone was visible on the photograph, but this approach at least enabled them to generate minimum prevalence figures. Chi-square tests were used to determine whether there was any statistical association between sex and the prevalence of cribra orbitalia in any of the samples (table 6.10 and 6.11).

The prevalence of cribra orbitalia was also computed for each of the four age categories in the adult male and female samples in order to provide an indication of whether prevalence varied with age (table 6.12). This process was repeated with the data divided into two groups, amalgamating the two youngest and eldest cohorts, as any emergent trends may not have been apparent after splitting the data into four groups due to the reduction in sample size (table 6.13). Again, the Jewbury data was excluded from these procedures because the total number of skulls with orbits available for examination in each of the age categories was unknown. Nevertheless, Brothwell and Browne (1994 in Lilley *et al.* 1994:460) did produce age related minimum prevalence figures using *in* *situ* photographs, albeit using slightly different age groupings than those used in this study, and these have been included in table 6.12.

The severity of male and female lesions were compared for those cemeteries in which an assessment of severity had been undertaken. For the Abingdon and Fishergate samples, this was initially attempted using the original five grade system of Stuart-Macadam (1982). However, dividing the data into five groups was found to be problematical. The data were fragmented into almost meaningless sample sizes, spread across a large number of categories, producing results which could not be interpreted. This difficulty was moderated by amalgamating the severity grades into just three groups: 'mild', 'moderate' and 'severe', as shown in table 6.9(b). This method is similar to a revised system of classification proposed by Stuart-Macadam (1985), which has also been adapted and recommended for general use in a recent publication by a committee of American anthropologists who aimed to set minimum standards for the collection of osteological data (Buikstra and Ubelaker 1994:121). The method provided a further advantage because the divisions roughly correlated with the Knip system used to assess the material from Ipswich and Wharram Percy, so making the analysis more uniform between sites. As table 6.9 indicates, 'porotic' and 'mild' changes broadly corresponded; as did 'cribrotic', 'trabecular' and 'moderate' changes. The data from Ipswich and Wharram Percy were therefore reclassified accordingly. Nevertheless, there were discrepancies between the two systems. There was no clear analogy in the Knip system for the mildest (grade 1) and most severe (grade 5) forms of bone change detailed in the original Stuart-Macadam system, and it was difficult to determine whether these changes had been recorded among the material from Ipswich and Wharram Percy but incorporated into the 'porotic' and 'trabecular' classifications, or whether the changes were omitted from classification. It was therefore important to recognise this limitation with respect to any analysis of pooled site data or comparisons between sites. The proportion of individuals displaying each grade of lesion severity was computed for the adult male and female samples, the sexed subadults from Abingdon and Fishergate, and the pooled site data for adults and subadults respectively. Chi-square tests were applied to determine whether there was any statistical association between sex and lesion severity (table 6.14 and 6.15).

Whilst acknowledging that any process which compared data between sites could be influenced by variations in recording methods, chi-square tests were also used to determine whether there was any association between cribra orbitalia prevalence and the cemeteries from which the samples were derived, for males and females respectively. The Jewbury data were omitted from these statistics as the figures were likely to be underestimates.

6.3.3 Results and Discussion

As the results in table 6.10 demonstrate, a higher proportion of adult males than females displayed cribra orbitalia within the collections from Ipswich and St Nicholas Shambles, a similar percentage of each sex were affected from Abingdon, and a higher proportion of females were affected within the remaining four adult assemblages. However, the chi-square tests demonstrated that none of these sex differences were statistically significant. Only in one assemblage, Wharram Percy, did the chi-square statistic approach significance (χ^2=3.742 p=.053). When the data from all cemeteries were pooled, the percentage of males and females displaying lesions was found to be similar, with 21.0% and 25.2% affected respectively. This similarity was confirmed by the chi-square test which again demonstrated that there was no significant association between sex and the prevalence of cribra orbitalia (χ^2=2.343 p=.126). The results therefore suggested that with the possible exception of the rural cemetery from Wharram Percy, there was no association between sex and the prevalence of anaemia. Following the traditional dietary hypothesis, this indicated that what might be construed as a superior diet, containing a higher component of iron rich foods such as meat, was not fed to male children. Following the more recent theory, the results suggested that neither male or female children were more greatly affected by the infectious agents which produce anaemia, whether parasitic, bacterial or viral. They did not provide evidence to suggest that females were more susceptible to infectious disease as a possible result of inferior nutrition, or that males experienced a higher rate of infection due to an innately greater vulnerability to infectious disease. However, other interpretations cannot be excluded. An alternative interpretation could be that females did experience an elevated level of anaemia which was associated with inferior nutrition, and males experienced raised levels of anaemia due to a greater susceptibility to environmental stress, but that the prevalence of anaemia was inflated by a similar degree, the two factors effectively cancelling each other out. It is also possible that sex differences in anaemia did exist, but the differences were not manifest skeletally.

As with the adults, no statistical association between sex and cribra orbitalia prevalence was identified among the subadults from Abingdon and Fishergate, as the results presented in table 6.11 indicate. The proportion affected was similar for each sex, giving support to the conclusion that boys and girls were equally likely to experience anaemia, at least according to the skeletal evidence. However, the most striking feature of the subadult results was that the percentage displaying lesions was considerably higher than all of the adult samples. Seventy-two percent of all subadult males and 76.2% of all subadult females displayed lesions, which was more than three times the corresponding figures for the pooled adult data, a difference which was statistically significant at a high level of probability for both males (χ^2= 35.105 p<.001) and females (χ^2=25.845 p<.001). These results suggest that either childhood lesions do undergo substantial remodelling, leading to a reduced proportion of adults with extant lesions; or that children who experienced anaemia were more likely to die before reaching adulthood. If the latter interpretation is correct, this may have been due to any of three possible reasons. Firstly, perhaps children who experienced anaemia during childhood were more likely to be predisposed to a premature death because they had 'weaker constitutions', rendering them more susceptible to stress; whereas those surviving into adulthood had a greater inherent resistance to stress. This concept basically conforms to the Darwinian idea of 'selective advantage', or to use the colloquial pseudonym, 'the survival of the fittest' (Green *et al.* 1984:865). Secondly, the subadults may have been more representative of individuals who were exposed to a higher level of stress, one possibility being that they encountered greater pathogenic exposure or received inadequate nutrition because they were drawn from more deprived socio-economic backgrounds, which in turn contributed to a premature death. Alternatively, following the 'biological damage' hypothesis proposed by Goodman and Armelagos (1988 in Mays 1998:161), individuals experiencing stress early in life may somehow lose the ability to cope with stress later in life, again contributing to decreased longevity.

Other studies have also identified a substantially higher prevalence of cribra orbitalia among juveniles (Mittler and Van Gerven 1994; Robledo *et al.* 1995; Stuart-Macadam 1985), although this is not exclusively the case as Grauer (1993) found a higher prevalence of cribra orbitalia among adults from the medieval cemetery of St Helen-on-the-Walls, York, which she interpreted as evidence for those of stronger constitution surviving childhood episodes of disease to reach adulthood. The difference in adult and subadult prevalence identified in this study suggests that the pattern of cribra orbitalia in adults does not necessarily provide a very accurate reflection of childhood anaemia. This could imply that it may not be appropriate to use data derived from sexed adults to draw inferences about sex differences in anaemia prevalence among children; although the results of this study could suggest that adult data may represent an approximate pro rata prevalence of childhood anaemia since males and females displayed a similar prevalence among adults and subadults, albeit at a lower level for both sexes among adults.

When the adult data were broken down into the four age categories, as shown in table 6.12, it was difficult to discern a consistent pattern among the cemeteries, largely due to the problem of reduced sample size. However, a fall in lesion prevalence between the youngest and eldest groups was noted within all but three of the fourteen male and female cemetery samples. The pooled cemetery data showed a fall in lesion prevalence with each successive age group among the males, and a general fall in lesion prevalence was observed from the youngest to the eldest female groups. This tendency was most apparent when the data from the two youngest and eldest categories were amalgamated, as shown in table 6.13. These results confirmed that the inverse relationship between cribra orbitalia prevalence and age continued throughout adulthood. Just as subadults were found to display a higher cribra orbitalia prevalence than adults, young adults displayed a higher prevalence than older adults. Again, this would either suggest that the lesions continue to become obliterated throughout adult life as a result of bone remodelling; or that adults who had developed anaemia during childhood were more likely to experience a shorter adult lifespan than those who did not experience anaemia in childhood. Like the subadults, this may have been because the younger adults were representative of individuals who were exposed to a higher level of stress; or had an inherently greater vulnerability to stress; or were 'damaged' by early insults which resulted in a decreased ability to cope with later episodes of stress. These results also indicate that when undertaking comparative analyses of cribra orbitalia, such as comparisons of male and female prevalence, the age structure of the samples should be taken into consideration as this could influence the outcome of a study if there was a marked disparity between the age structures of the samples being compared. The age-specific prevalence figures computed for this study confirmed the similarity in male and female prevalence previously identified within the total samples.

As tables 6.14 and 6.15 demonstrate, there was no apparent sex difference in lesion severity within any of the adult or subadult cemetery samples, and this observation was supported by the results of the chi-square tests which revealed no statistically significant associations between sex and lesion severity. Neither was any statistical association identified between the two variables when the data from all cemeteries were pooled. The proportion of males and females allotted to each grade of severity was similar for the pooled adults and subadults. The results therefore suggest that neither sex experienced a greater or lesser degree of bone change, which concords with the findings for lesion prevalence. From the pooled cemetery data, it was also noted that the percentage of male and female subadults with lesions classified as 'mild' was similar to that among adults, around 40%. Likewise, a similar proportion of adults and subadult lesions, approximately 60%, were classified as either 'moderate' or 'severe'. This suggests that unlike lesion prevalence, there was no relationship between lesion severity and whether death occurred in childhood or adulthood. This either implies that both the mild and more severe bone changes were equally likely to become obliterated through bone remodelling; or that the degree of lesion development bore no relation to whether an individual who experienced anaemia as a child survived into adulthood. This may indicate that the severity of bone changes bears no relation to the severity of the anaemia. This interpretation is consistent with clinical findings which show that the symptoms of anaemia do not necessarily correlate with its severity. It is apparently not uncommon to find asymptomatic patients with severe anaemia, especially if the condition has developed gradually (Stuart-Macadam 1989).

The percentage of adult males and females affected by cribra orbitalia within each of the cemetery samples, presented in table 6.10, have been reproduced graphically in figure 6.3a/b but with the samples placed in ascending order of the percentage affected.

These illustrate how the figures ranged from a low of about 15% to more than 40% across the samples. Chi-square tests revealed that there was a statistical association between the proportion of males affected by cribra orbitalia and the cemeteries from which the samples were derived, which was significant at the 1% probability level (χ^2=18.810 p=.002). However, no significant association (χ^2=7.389 p=.193) was identified between the female cemetery samples and cribra orbitalia prevalence. This may have been related to the fact that the female samples were smaller than the male samples and so less likely to yield a statistically significant result, or more likely to have been affected by atypical cases as these can exert a relatively greater influence among smaller samples. Alternatively, as with the greater variance in stature observed among males, it may represent further evidence that a greater biological susceptibility to environmental stress exists among males. Perhaps the inter-site differences in environmental stress were greater than any inter-sex differences. Due to their greater biological susceptibility, males may have been more likely to respond to the more extreme differences in stress exerted on the different cemetery populations; whereas similar extremes in stress between the cemeteries may have had less impact on females. As a result, the greater biological susceptibility among males to environmental stress was not detectable within the respective cemeteries, and only became apparent through the inter-site comparisons.

However, to what extent the rank order differences between the male samples represented actual differences in prevalence or simply differences in recording methods between sites is almost impossible to assess. Differences in the age structure of the samples may also have had some influence upon both the male and female results. It may not therefore be appropriate to place much credence on any interpretation of inter-site differences. It is interesting to note, however, that among the male samples, the rural assemblage from Wharram Percy contained one of the lowest proportion of skulls affected by cribra orbitalia and the assemblage from London, St Nicholas Shambles, displayed the highest; a pattern which might be expected if the pathogen load was higher in the capital than the rural site. This pattern is consistent with that obtained from the age at death study, discussed in chapter 5. The age structure of the samples probably had some influence on this disparity, as cribra orbitalia prevalence decreases with increasing age and Wharram Percy contained a high component of elderly individuals, whereas the age at death profile for St Nicholas Shambles was skewed toward the younger groups. Nevertheless, the age-specific prevalence figures did tend to support the apparent difference in prevalence between the two sites. However, the remaining cemeteries did not particularly accord with this urban/rural pattern. The material from Abingdon displayed the highest prevalence of cribra orbitalia, which contradicts the expected pattern as the assemblage was thought to contain a substantial rural component. The other cemeteries did not display a consistent hierarchy in prevalence once the age-specific figures were taken into consideration, so it would be difficult to ascribe the site differences to a given characteristic. Perhaps this is unrealistic, owing to the limitations surrounding the assumptions made about the composition of a cemetery, discussed in section 2.8. All the cemeteries were in use for a prolonged period, and each probably served populations which experienced unique and varied patterns in pathogen load and transmission, particularly during times of famine, plague and other epidemics. The problem of site differences in recording protocol might be minimised in future studies by the use of a consistent technique. Comparative studies of existing data might be improved by conducting a structured preliminary study of a representative sample of material from each collection in an effort to tally recording techniques. Unfortunately, these procedures may not even surmount the problem as the scoring of porotic hyperostosis ultimately relies upon a subjective judgement, which may therefore be prone to considerable inter- and intra-observer variation in recording.

Table 6.10 Prevalence of cribra orbitalia among the adult male and female cemetery samples

n_{co} number of individuals displaying cribra orbitalia n_t total number of individuals with orbits in sample
% percentage of sample displaying cribra orbitalia χ^2 chi-square statistic p probability

	Males		Females			
	n_{co}/n_t	%	n_{co}/n_t	%	χ^2	p
Wharram	22/144	15.3	25/99	25.3	3.742	.053
Ipswich	28/112	25.0	9/48	18.8	.738	.390
Abingdon	32/93	34.4	28/78	35.9	.041	.839
St Nicholas	9/23	39.1	8/31	25.8	1.087	.297
Fishergate 4	7/25	28.0	5/10	50.0	1.534	.215
Fishergate 6	10/71	14.1	5/20	25.0	1.351	.245
Jewbury	16/122	13.1	19/107	17.8	.949	.330
Pooled site data	124/590	21.0	99/393	25.2	2.343	.126

Table 6.11 Prevalence of cribra orbitalia among the subadult male and female cemetery samples

n_{co} number of individuals displaying cribra orbitalia n_t total number of individuals with orbits in sample
% percentage of sample displaying cribra orbitalia χ^2 chi-square statistic p probability

	Males		Females			
	n_{co}/n_t	%	n_{co}/n_t	%	χ^2	p
Abingdon	14/18	77.8	10/13	76.9	.003	.955
Fishergate	4/7	57.1	6/8	75.0	.536	.464
Pooled site data	18/25	72.0	16/21	76.2	.104	.747

Table 6.12 Age-specific prevalence of cribra orbitalia among the adult male and female cemetery samples (data divided into four age categories)

n_{co} number of individuals in age group displaying cribra orbitalia
n_t total number of individuals with orbits in age group % percentage of sample displaying cribra orbitalia

		c.18-25		*c*.25-35		*c*.35-45		*c*.>45	
		n_{co}/n_t	%	n_{co}/n_t	%	n_{co}/n_t	%	n_{co}/n_t	%
Wharram	Males	7/22	31.8	3/25	12.0	4/33	12.1	7/62	11.3
	Females	7/21	33.3	3/20	15.0	4/21	19.0	9/32	28.1
Ipswich	Males	8/21	38.1	6/33	18.2	6/29	20.7	7/28	25.0
	Females	0/10	0.0	3/14	21.4	2/6	33.3	3/14	21.4
Abingdon	Males	6/13	46.2	8/21	38.1	6/17	35.3	10/35	28.6
	Females	7/16	43.8	9/22	40.9	5/15	33.3	5/21	23.8
St Nicholas	Males	3/6	50.0	1/5	20.0	3/8	37.5	2/4	50.0
	Females	1/4	25.0	4/13	30.8	3/10	30.0	0/4	0.0
Fishergate 4	Males	5/13	38.5	2/8	25.0	0/2	0.0	0/2	0.0
	Females	3/3	100.0	0/3	0.0	1/2	50.0	1/2	50.0
Fishergate 6	Males	4/11	36.4	3/14	21.4	1/18	5.6	2/27	7.4
	Females	0/0	0.0	2/6	33.3	2/7	28.6	1/7	14.3
Pooled site data	Males	33/86	38.4	23/106	21.7	20/107	18.7	28/158	17.7
	Females	18/54	33.3	21/78	26.9	17/61	27.9	19/80	23.8
		c.20-30		*c*.30-40		*c*.40+			
Jewbury	Males	7/32	21.9	6/26	23.1	2/54	3.7		
	Females	6/36	16.7	4/22	18.2	6/37	16.2		

Table 6.13 Age-specific prevalence of cribra orbitalia among the adult male and female cemetery samples (data divided into two age categories)

n_{co} number of individuals in age group displaying cribra orbitalia
n_t total number of individuals with orbits in age group   % percentage of sample displaying cribra orbitalia

		c.18-35		*c*.>35	
		n_{co}/n_t	%	n_{co}/n_t	%
Wharram	Males	10/47	21.3	11/95	11.6
	Females	10/41	24.4	13/53	24.5
Ipswich	Males	14/54	25.9	13/57	22.8
	Females	3/24	12.5	5/20	25.0
Abingdon	Males	14/34	41.2	16/52	30.8
	Females	16/38	41.1	10/36	27.8
St Nicholas	Males	4/11	36.4	5/12	20.0
	Females	5/17	29.4	3/14	21.4
Fishergate 4	Males	7/21	33.3	0/4	0.0
	Females	3/6	50.0	2/4	50.0
Fishergate 6	Males	7/25	28.0	3/45	6.7
	Females	2/6	33.3	3/14	21.4
Pooled site data	Males	56/192	29.2	48/265	18.1
	Females	39/132	29.6	36/141	25.5

Table 6.14 Adult prevalence of cribra orbitalia according to lesion severity

n_{co} number of individuals displaying cribra orbitalia n_t total number of individuals with orbits in sample
% percentage of sample displaying cribra orbitalia χ^2 chi-square statistic p probability

		Mild/ Porotic		Moderate/ Cribrotic/ Trabecular		Severe			
		n_{co}/n_t	%	n_{co}/n_t	%	n_{co}/n_t	%	χ^2	p
Wharram	Males	8/22	36.4	14/22	63.6	0/22	0.0		
	Females	7/25	28.0	18/25	72.0	0/25	0.0	.377	.539
Ipswich	Males	5/28	17.9	23/28	82.1	0/28	0.0		
	Females	4/9	44.4	5/9	55.6	0/9	0.0	2.615	.106
Abingdon	Males	19/32	59.4	10/32	31.3	3/32	9.4		
	Females	13/28	46.4	7/28	25.0	8/28	28.6	3.677	.159
Fish 4	Males	1/7	14.3	3/7	42.9	3/7	42.9		
	Females	0/5	0.0	3/5	60.0	2/5	40.0	.891	.640
Fish 6	Males	1/10	10.0	5/10	50.0	4/10	40.0		
	Females	3/5	60.0	1/5	20.0	1/5	20.0	4.275	.118
Pooled site data	Males	34/99	34.3	55/99	55.6	10/99	10.1		
	Females	27/72	37.5	34/72	47.2	11/72	15.3	1.582	.453

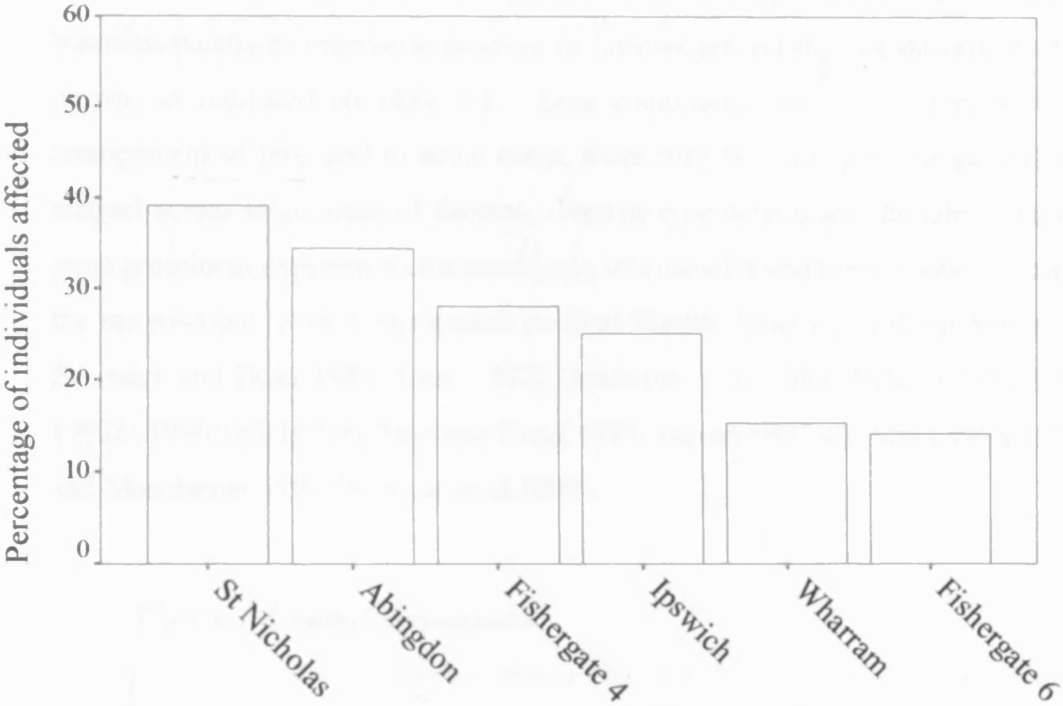
Table 6.15 Subadult prevalence of cribra orbitalia according to lesion severity

n_{co} number of individuals displaying cribra orbitalia n_t total number of individuals with orbits in sample
% percentage of sample displaying cribra orbitalia χ^2 chi-square statistic p probability

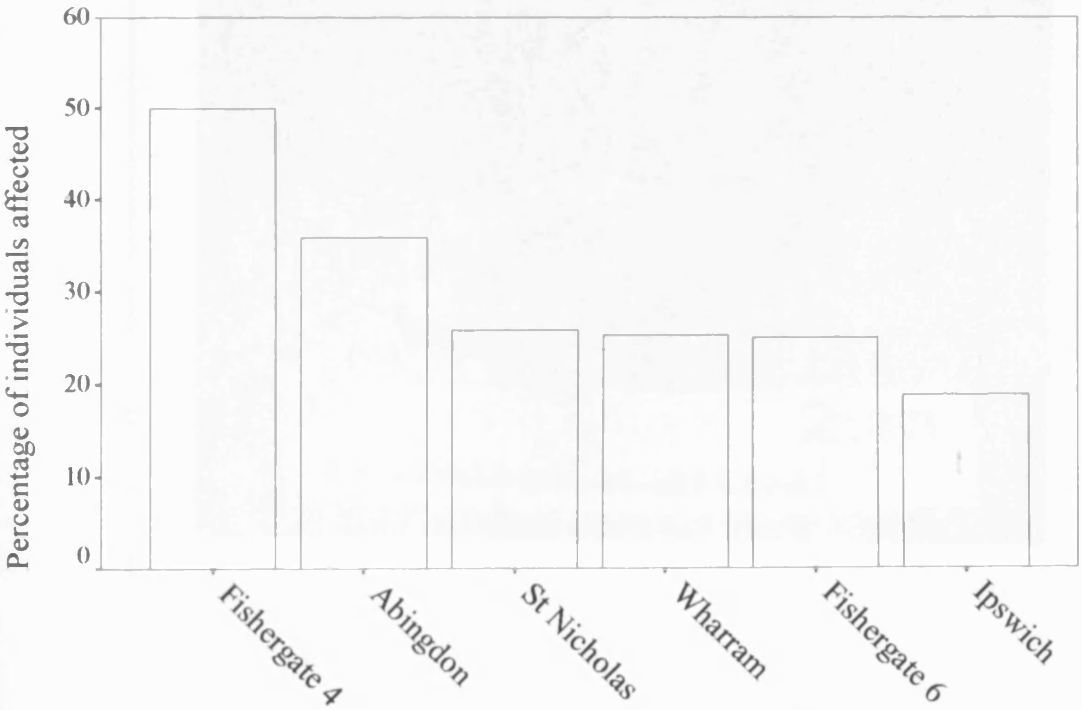
		Mild/ Porotic		Moderate/ Cribrotic/ Trabecular		Severe			
		n_{co}/n_t	%	n_{co}/n_t	%	n_{co}/n_t	%	χ^2	p
Abingdon	Males	6/14	42.9	8/14	57.1	0/14	0.0		
	Females	5/10	50.0	5/10	50.0	0/10	0.0	.120	.729
Fishergate	Males	1/4	25.0	3/4	75.0	0/4	0.0		
	Females	2/6	33.3	4/6	66.6	0/6	0.0	.079	.778
Pooled	Males	7/18	38.9	11/18	61.1	0/18	0.0		
Subadult data	Females	7/16	43.8	9/16	56.3	0/16	0.0	.083	.774

Figure 6.3a/b Bar graphs illustrating the site differences in the prevalence of cribra orbitalia

(a) Males



(b) Females

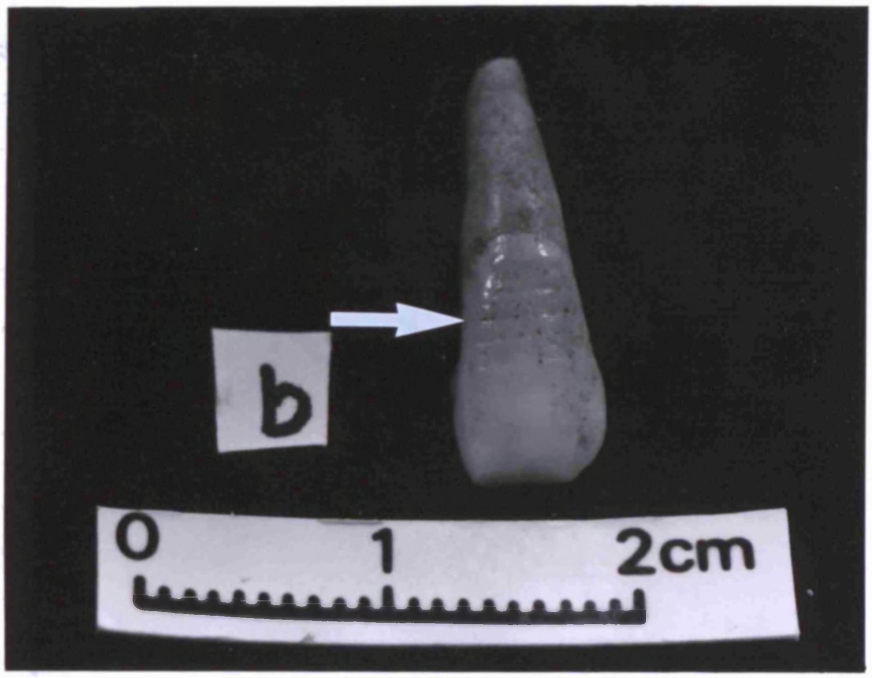


6.4 Enamel Hypoplasia

6.4.1 Introduction

Enamel hypoplasia is a deficiency in enamel formation, usually visible macroscopically as transverse grooves or furrows around the circumference of the tooth crown, as indicated on plate 6.2. Less commonly, the defects present as a linear arrangement of pits, and in some cases, there may be a complete or partial absence of enamel across large areas of dentine. Furrow-type defects are thought to represent the most prominent expression of a continuum of enamel disruptions which extends down to the microscopic level (Commission on Oral Health, Research and Epidemiology 1982; Bromage and Dean 1985; Dean 1987; Goodman *et al.* 1984; Hillson 1986:129; 1992a; 1992b; 1996:165-167; Hillson and Bond 1997; Larsen 1997:45; Mays 1998:156; Roberts and Manchester 1995:58; Rose *et al.* 1985).

Plate 6.2 Enamel Hypoplasia



Dental enamel is formed in a two stage process known as amelogenesis. During the first stage, ameloblasts (enamel-producing cells) secrete a proteinaceous matrix. This is followed by the maturation phase in which the matrix is mineralised to form fully mature enamel. Enamel hypoplasia occurs as a result of episodic growth disturbances which cause a cessation in the first stage of amelogenesis, leading to reduced matrix formation and consequently, decreased enamel thickness. Since amelogenesis occurs along a co-ordinated front from the coronal to the cervical extremities of the tooth crown, the defects form as localised bands of thinned enamel to provide a chronological record of growth disruptions during enamel development. With the exception of the third molars, hypoplastic defects in the permanent dentition therefore represent growth disruptions occurring between the first year of life and about seven years. As enamel is a non-vital tissue, the record remains throughout life unless obliterated by attrition, erosion or abrasion (Goodman *et al.* 1984; Hillson 1986:113-114, 148-149; 1992a; 1992b; Hillson and Bond 1997; Huss-Ashmore *et al.* 1982; Larsen 1997:43-45; Mays 1998:156; Roberts and Manchester 1995:58-61; Rose *et al.* 1985).

The defects have been associated with a wide variety of systemic and local causes (Pindborg 1982), although they have predominantly been identified with periods of malnutrition or infectious disease (Larsen 1997:45-46; Mays 1998:157-158; Roberts and Manchester 1995:58). This has been demonstrated experimentally by artificially induced fevers and vitamin deficiencies in laboratory animals (Hillson 1986:130; 1996:166; Kreshover and Clough 1953; Larsen 1997:46). Recent research by James (pers. comm.) indicates that acute episodes of stress may be the most important cause of hypoplasia in humans. Using a scanning electron microscope, James' preliminary study indicates that the majority of defects represent disruptions of only a few days duration. This suggests that the defects are more likely to be the direct result of short-term insults, particularly fevers and infections, rather than chronic disturbances such as those which would develop through malnutrition. However, owing to the synergistic relationship between diet and disease, malnutrition may still be indirectly implicated in the aetiology of enamel hypoplasia, as it can lower an individual's resistance to infection (Rose *et al.* 1985; and see section 6.1).

The occurrence of hypoplasia does not necessarily correlate with specific episodes in the medical history of an individual (Hillson 1986:130; 1996:166; Mays 1998:158;

Ribot and Roberts 1996; Rose *et al.* 1985) but numerous studies of contemporary groups have indicated a general association between environmental stress and hypoplasia at the population level (Hillson 1986:130; 1996:166; Larsen 1997:50; Mays 1998:158; Roberts and Manchester 1995:60). For example, Sweeney and colleagues (1969; 1971) found higher frequencies of defects among Guatemalan children suffering from severe malnutrition and increased rates of infectious diseases, compared with the general population; Zhou (1995 in Larsen 1997:46) found severe hypoplastic defects among individuals who underwent enamel development during the starvation famine of China between 1959-1961; and Enwonwu (1973) identified a higher prevalence of hypoplasia among Nigerian children of low socio-economic status compared with those from more affluent backgrounds. Goodman and co-workers have investigated the prevalence of hypoplasia in different groups of children in Mexico (1991; 1992). Among their results they identified a higher prevalence of hypoplasia among poor children compared with those from wealthier families; a reduction in the frequency of hypoplasias among Mexican children who had been given nutritional supplements compared with those on unsupplemented diets; and they found girls to have more hypoplasias than boys, which was consistent with other evidence that suggested girls received inferior nutrition. However, Mays (1998:158) has cited three studies conducted in England (Dobney and Goodman 1991), Wales (Dummer *et al.* 1986) and California (Nation *et al.* 1987) which failed to identify any association between hypoplasia prevalence and social class. He suggested that this may have been because all the social classes in these developed nations were of a relatively high socio-economic status compared with the greater contrast between many social groups in developing countries. Poorer classes within developing countries are exposed to a far greater spectrum of environmental stress than poorer classes in developed countries, such as contaminated water supplies, poor sanitation and malnutrition; all factors which promote infectious disease and thus the development of enamel hypoplasia (Wakely pers. comm.).

Enamel hypoplasia has become established as an indicator of non-specific physiological stress in archaeological populations, especially in relation to making inferences about subsistence strategies, social status, age at death and also gender (Huss-Ashmore *et al.* 1982; Larsen 1997:50-56; Mays 1998:158; Rose *et al.* 1985). The primary objective of this study was to compare the male and female prevalence of enamel hypoplasia among the adult samples from each cemetery, and the subadults which had been sexed using the tooth measurement technique discussed in chapter 3. Rose and co-workers (1985) and Mays (1998:157) have advocated the use of enamel hypoplasia as a marker for inferring gender-specific health patterns or nutritional adequacy in childhood, although Mays cautions that 'care is required here as males and females have inherently unequal resistance to growth disruptions'. Similarly, with reference to a study of a medieval assemblage from Västerhus, Sweden, which identified an elevated prevalence of hypoplasia among males, Huss-Ashmore and co-workers (1982:446) commented that this 'may reflect the fact that boys have lower nutritional reserves at birth, combined with a greater calorific need'.

A further aim was to investigate whether there was any association between hypoplasia prevalence and age at death in either sex. This was partly to establish whether any differences in the age structure of the samples could have biased the comparisons between the sexes, but also to determine whether there was any association between longevity and health stress during childhood, as indicated by the prevalence of hypoplasia.

In line with other aspects of this project, it was also the intention to compare the prevalence of hypoplasia between males and females from the various cemeteries. However, it should also be emphasised that any comparison of data recorded by different observers is likely to be severely impaired by the high degree of inter-observer variability which exists in the scoring of hypoplastic defects. Danforth *et al.* (1993) compared the scores attributed by three observers who evaluated the same series of 59 teeth from a Mississippian assemblage (AD 1000-1250). Approximately 25% of the sample was scored inconsistently between observers with respect to teeth affected by hypoplasia, and in terms of individual episodes recorded, there was less than 39% agreement between observers. Discrepancies were even revealed in intra-observer replicability. Two observers re-examined the sample eight weeks after the first evaluation. Both scored 85% of the sample consistently for the presence/absence of hypoplasia by tooth, but only about two thirds of individual defects were identified consistently between rounds. One observer recorded an increased number of episodes upon second examination whereas the other noted fewer hypoplastic defects, indicating that a drift in personal scoring criteria may take place over time. Similarly, a test of intra-observer repeatability carried out by Mays (1998:157) revealed an 88% agreement between scoring sessions with regard to the number of individual dentitions affected by hypoplasia. These anomalies in scoring have been attributed to the highly variable appearance of hypoplasia, particularly in terms of magnitude, as the defects range through to microscopic disturbances of a single growth layer. A defect defined as a hypoplasia by one observer may be overlooked by another, and similarly, as the studies described above illustrate, what is recorded by a single observer may vary between recording sessions. Although several scoring systems have been devised (Hillson 1986:132), including the Developmental Defects of Enamel (DDE) Index (Commission on Oral Health, Research and Epidemiology 1982) which has been advocated as a standard for classification by Hillson (1986:132), there is at present no consensus on what the minimum requirements should be to constitute a hypoplasia. Hillson and Bond (1997:89) believe that 'without this, it is impossible to standardise records for comparison between studies'. However, they also acknowledge that it may not be feasible to devise reliable standards for scoring at the macroscopic level, owing to the variation in hypoplasia appearance, and even conclude with the suggestion that perhaps the most effective solution for future studies would be to confine the study to the microscopic level (Hillson and Jones 1989).

6.4.2 Method

Each tooth present in the skulls from Abingdon, Wharram Percy, Ipswich and Fishergate had been scored for hypoplasia. The position of each defect on the tooth crown had been measured from the cemento-enamel junction. Tooth surfaces obscured by calculus were omitted from examination, as were teeth which had suffered attrition, abrasion or erosion to the extent that hypoplastic defects had clearly been obliterated. Each tooth displaying hypoplasia among the individuals from St Nicholas Shambles had been noted. Owing to the time constraints placed on the examination of the material from Jewbury, enamel hypoplasia had simply been recorded as present, absent or unscorable with respect to the complete dentition of each individual (Watson 1994:495). The assemblages from Fishergate, St Nicholas Shambles, Wharram Percy and Ipswich had been scored by a single observer. More than one observer had examined the material from Abingdon and Jewbury.

The measurement data were not utilised in this study. This information might have been useful for comparing the age at which males and females sustained stress, as in the past it has been used to estimate age at defect formation using schemes based on established developmental sequences of the dentition (Hillson 1992a; 1992b; Huss-Ashmore *et al.* 1982; Larsen1997:48; Roberts and Manchester 1995:60; Rose *et al.* 1985). However, recent research has cast serious doubts over the reliability of methods which depend on odontometric data recorded at the macroscopic level (Hillson 1992a; 1992b; 1996:172-176; Hillson and Bond 1997; Skinner and Goodman 1992).

Various approaches have been adopted to assess hypoplasia prevalence. Some studies simply focus on the presence or absence of hypoplasia whereas others examine the frequency of defects. The range of teeth examined also varies, although three approaches are commonly discussed in the literature (Goodman *et al.* 1984; Huss-Ashmore *et al.* 1982). The 'single tooth' method restricts analysis to a single tooth, invariably the mandibular canine as it has a long developmental period and is reported to be relatively sensitive to environmental stress. One disadvantage of the method that has been noted by Huss-Ashmore and co-workers (1982:445) is that it 'loses some validity as a measure of general systemic stress' because it does not distinguish whether the origin of stress was systemic or local. However, James (pers. comm.) contends that the two causes can be distinguished, as local stress, typically trauma or an abscessed deciduous predecessor, tends not to produce linear hypoplasia. The effect on the ameloblasts is usually greater and recovery may be incomplete, resulting in a larger, irregularly shaped defect. An alternative 'multiple tooth' method involves the examination of all available teeth in the dentition. Using this technique, systemic stress is apparent as the same episode is evident on different teeth. It also has the advantages of increasing the sample size and extending the period of dental development represented across the different tooth types. The main drawbacks are that the procedure is more time consuming and complex than the single tooth method. A further approach, termed the 'best teeth' method, has been proposed by Goodman and co-workers (1984; Huss-Ashmore *et al.* 1982). This uses a combination of the canines and incisors. Following a study of material from the prehistoric Dickson Mound series, Illinois, Goodman and colleagues found that 95% of all systemic disruptions were evident in these teeth, so the approach effectively offers a compromise between the previous two methods. By eliminating the postcanine teeth, the procedure is less time consuming than the multiple tooth method, yet it retains most of the benefits.

In this study, both the presence/absence of hypoplasia and the frequency of defects were investigated. A 'multiple tooth' approach was adopted to generate the presence/absence figures. As the data had already been recorded, the time consuming aspect of its practical application was not an issue. However, many of the skeletons lacked a full complement of permanent teeth, and this presented a limitation as it diminished uniformity among the individuals on which the diagnoses were based, which can be undesirable in comparative analyses. Nevertheless, had a 'single tooth' approach been applied, a substantial proportion of skeletons would have been excluded because they lacked the designated tooth, and positive evidence of hypoplasia would have been disregarded in cases where defects were confined to other teeth. These factors would have served to reduce the size of the samples available for analysis. Although a visual inspection of the data supported the findings of Goodman and colleagues, that the canines and incisors were the most frequently affected teeth, the 'best teeth' approach could not have been implemented for all cemeteries included in this study as teeth displaying defects were not specified for the Jewbury assemblage. Neither would this method have circumvented the problem of including skeletons with an incomplete dentition as it is the incisor teeth which are most often lost post mortem. In order to assess the frequency of stress episodes, a 'single tooth' approach was adopted, using the number of defects present on the mandibular canine. This enabled mean figures to be computed from teeth which represented stress over a similar period of development.

The frequency and percentage of dentate males and females displaying hypoplasia was computed for each of the adult cemetery samples, the sexed subadults from Abingdon and Fishergate, and the pooled adult and subadult data. Chi-square tests were applied to determine whether there was any statistical association between sex and the prevalence of enamel hypoplasia (table 6.16 and 6.17). The mean number of defects on the lower canine was computed for males and females from the four cemeteries in which the number of defects had been recorded (table 6.18 and 6.19). Only individuals displaying a minimum of one hypoplastic defect were included in this procedure, as the purpose was to provide an indication of whether there was any sex difference in the average number of stress episodes, out of those exhibiting hypoplasia. The age specific prevalence of hypoplasia was computed for each of the four adult age categories (table 6.20), and for the two youngest and eldest groups combined (table 6.21), in order to determine whether there was any change in hypoplasia prevalence according to age. Similarly, the mean number of hypoplastic defects was computed for males and females displaying hypoplasia in each of the age categories (table 6.22 and 6.23). Chi-square tests were used to determine whether there was any statistical association between hypoplasia prevalence and cemetery.

6.4.3 Results and Discussion

As the results in tables 6.16 and 6.17 demonstrate, a higher percentage of males than females displayed hypoplasia in the majority of samples. These included the subadult sample from Abingdon, and the adults from Ipswich, St Nicholas Shambles, Fishergate 6 and Wharram Percy. Of these, only Wharram Percy produced a chi-square value which attained statistical significance (χ^2 = 3.842 p=.050), perhaps due to the relatively large size of the sample. The percentage of males and females affected by hypoplasia was virtually identical in the subadult assemblage from Fishergate, and the adult assemblages from Abingdon and Jewbury. Only in one sample, Fishergate 4, did the percentage of females displaying hypoplasia slightly exceed that of males. None of the sex differences in these samples were statistically significant, as indicated by the chi-square values which were close to zero. However, the greater prevalence of hypoplasia among males in the majority of the adult samples resulted in a statistically significant association between sex and hypoplasia prevalence being realised when the adult data from all the cemeteries were pooled into one large sample (χ^2 = 5.919 p=.015). Expressed in percentage terms, 59.4% of all adult males were affected compared with 51.4% of females. The pooled subadult data did not reveal a statistically significant association between sex and hypoplasia prevalence, although again, a higher proportion of males were affected; 83.8% of all subadult males displayed hypoplasia compared with 75.9% of females.

As the results in tables 6.18 and 6.19 reveal, the mean number of hypoplastic defects also tended to be greater among males. Only in the Ipswich collection did the female mean exceed that of males. The male mean surpassed the female mean in both the subadult samples and in the four remaining adult assemblages: Abingdon, Wharram Percy, Fishergate 4 and Fishergate 6.

The age-specific prevalence figures, detailed in tables 6.20 and 6.21, confirmed the tendency toward a greater prevalence of hypoplasia among adult males within the respective cemetery collections. This was not particularly apparent when the data were divided into four age categories, largely due to the small size of the resulting samples, but when the data were divided into two age groups, males displayed a higher prevalence of hypoplasia in the majority of samples. When the data from all sites were pooled, males unequivocally displayed a higher prevalence, a greater percentage of males being affected in all age categories, whether the data were split into two or four cohorts.

These results therefore indicated that males were more inclined than females to display enamel hypoplasia, and of those affected by hypoplasia, males tended to exhibit a greater number of defects. This suggests that males were more likely to experience growth disruptions, and a greater frequency of growth disruptions than females. By implication, it also suggests that the general health of males could have been inferior to that of females. The most immediate interpretation would be that the results provide further evidence to support the theory that males have a lower resistance to environmental stress, particularly fevers and infections, if these are the most important aetiological factors. The results did not indicate that females experienced a higher level of environmental stress, or suggest that preferential treatment was conferred on boys which may have afforded greater protection against stress. This said, other lines of interpretation could be considered. It might be argued that the higher prevalence of enamel hypoplasia among males reflects a more robust health status, which enabled survival despite the stress imposed. Another possibility is that males experienced greater pathogenic exposure. Hanawalt (1977) has inferred gender differences in child activity patterns from a study of medieval coroner's inquests (see section 7.3), which suggest that girls spent more time within the home and boys more time outdoors, so this might represent a potential source of sex difference in pathogen exposure. However, it would not necessarily follow that the chances of contracting infection were any less within the home environment, particularly when taking into consideration the comparatively poor standards of hygiene that were generally practised during the Middle Ages (Carver 1980:97-98; Dyer 1989:189-193, 167-168). Furthermore, it seems unlikely that any sex difference in pathogen exposure could have been particularly pronounced, as boys and girls were not actually raised in segregated environments, and most acute infections probably attacked indiscriminately, irrespective of sex.

The interpretation that males experienced a poorer health status accords with that derived from the stature analysis, discussed in section 6.2. Concern was raised as to whether methodological limitations may have impeded the analysis of stature, but the results of the hypoplasia analysis would tend to support the idea that the sex differences in stature might well be attributed to a greater biological susceptibility to stress among males. Although the results of the cribra orbitalia analysis did not actually contradict those obtained from the analysis of hypoplasia, neither did they reveal any apparent sex difference in prevalence. This may indicate that different aetiological factors influence the development of the two stress indicators. Perhaps cribra orbitalia develops as a result of chronic infection whereas hypoplasia reflects disruptions caused by acute infections. A recent study by Wakely, James and Morgan (1999) provides evidence to support this interpretation. Wakely and co-workers examined a sample of skeletons from the medieval cemeteries of Abingdon Vineyard and Wollaston, a rural site in Northamptonshire, and found that cribra orbitalia and enamel hypoplasia were rarely present in the same individual. This was interpreted as evidence to suggest that the two stress indicators reflect different aspects of response to infection, cribra orbitalia being indicative of chronic infection, and enamel hypoplasia being indicative of acute infection. Further interpretations are that cribra orbitalia is a less sensitive indicator of gender-related stress, or that subtle sex differences in cribra orbitalia prevalence are more likely to become rapidly obliterated through bone remodelling, whereas sex differences in hypoplasia prevalence, and of course terminal stature, are more likely to leave a permanent record.

The percentage of subadults displaying enamel hypoplasia exceeded the percentage of adults in both sexes from the Abingdon assemblage, and the mean number of defects was also greater among subadult males and females compared with their adult counterparts. This corresponded with the pattern observed for cribra orbitalia. It either suggested that hypoplastic defects were already becoming obliterated before the onset of adulthood resulting in a lower proportion of adults displaying defects, or that children displaying enamel hypoplasia were more inclined to die before attaining adulthood. As with the interpretations proposed for cribra orbitalia, the latter could have been due to an inherently greater susceptibility to stress; a greater exposure to stress; or an inability to cope with stress as a consequence of damage suffered through previous episodes of stress. In the Fishergate assemblage, the proportion of adults and subadults displaying hypoplasia was similar. However, this is probably a manifestation of the particularly meticulous recording technique which was applied to the assemblage. More that 90% of all individuals in the cemetery were reported to display enamel hypoplasia, although many of the defects were described as being 'faint', and the mean number of defects was greater than in any other cemetery. Since virtually the entire sample was recorded as displaying hypoplasia, this would tend to obscure any small differences in prevalence between age cohorts.

The age-specific prevalence figures for enamel hypoplasia in adults also revealed a general fall in prevalence with advancing age for both sexes, as indicated in tables 6.20 and 6.21. When the data were divided into four age categories, the percentage of individuals displaying hypoplasia was lower in the eldest age group compared with the youngest group in ten of the fourteen samples, although a consistent fall in prevalence was not necessarily observed in each successive age category. Four of the samples displayed no apparent change in prevalence with age. When the data were divided into two age groups, nine of the fourteen samples displayed a fall in the percentage displaying hypoplasia with increasing age, although four samples showed a rise and one showed no change. Nevertheless, the pooled site data displayed a general fall in prevalence with increasing age, particularly the females. Similarly, the mean frequency of lines tended to be lower among older individuals, as the results tables 6.22 and 6.23 indicate. When the data were divided into two age groups, the mean number of defects was lower in the eldest age category in seven out of the ten cemetery samples, though the remaining three samples showed a rise in the mean number of defects with age. When the data were divided into four age groups, some of the resulting samples were too small to allow a meaningful average number of defects to be computed. As the results in table 6.22 show, some age-specific sub-samples contained less than ten cases. However, the pooled site data showed a general fall in mean frequency with increasing age. As with the fall in hypoplasia prevalence observed between subadults and adults, the general fall across younger to older adults might either be attributed to the obliteration of defects with increasing age, or an association between stress and reduced longevity. However, the fall in hypoplasia prevalence with increasing adult age was not as decisive as that observed for cribra orbitalia, and similarly, the difference between the percentage of subadults and adults affected was less exaggerated than for cribra orbitalia. This could suggest that cribra orbitalia is more prone to obliteration through bone remodelling than enamel hypoplasia is through attrition; or that the episodes of stress which caused hypoplasia were more likely to be of a non-serious nature, and less likely to contribute toward reduced longevity.

For both sexes, the association between cemetery and the proportion recorded as displaying enamel hypoplasia was found to be significant at the 1% probability level, according to the chi-square tests (males χ^2 = 115.815 p<.001; females χ^2 = 71.288 p<.001). As figure 6.4a/b depict, the percentage of males purported to display hypoplasia ranged from approximately 40% to more than 95% across the different cemetery samples, and the percentage of females affected ranged from about 25% to more than 95%. Owing to the high level of inter-observer variation which is known to exist in the recording of hypoplasia, these differences between cemeteries may well be reflecting differences in recording techniques rather than genuine differences in hypoplasia prevalence. However, it was interesting to note that for both sexes, the cemeteries from London and York contained the highest percentage of individuals affected whereas the rural assemblage from Wharram Percy contained the lowest percentage affected. These differences were supported by the age-specific prevalence figures (tables 6.20 and 6.21), indicating that the disparity was not solely a product of the age composition of the samples. The Wharram Percy assemblage also displayed a low cribra orbitalia prevalence, a high typical age at death and a fairly distinct stature; traits which were attributed to the rural character of the settlement. It is therefore tempting to link the low hypoplasia prevalence to the rural nature of the settlement, on the assumption that the pathogen load may have been lower than in the densely populated urban centres of York and London. However, inter-observer differences in methodology may be the overriding factor, one indication being that the percentage of individuals displaying hypoplasia among the Ipswich collection was similar to that from Wharram Percy, and both assemblages were scored by the same observer.

Table 6.16 Prevalence of enamel hypoplasia among the adult male and female cemetery samples

n_{eh} number of individuals displaying enamel hypoplasia n_t total number of dentate individuals in sample
% percentage of sample displaying enamel hypoplasia χ^2 chi-square statistic p probability

	Males		Females			
	n_{eh}/n_t	%	n_{eh}/n_t	%	χ^2	p
Wharram	47/121	38.8	21/82	25.6	3.842	.050
Ipswich	36/91	39.6	11/42	26.2	2.248	.134
Abingdon	50/95	52.6	39/74	52.7	.000	.993
St Nicholas	25/31	80.7	32/47	68.1	1.498	.221
Fishergate 4	29/31	93.6	20/21	95.2	.066	.798
Fishergate 6	97/101	96.0	26/29	89.7	1.803	.179
Jewbury	58/106	54.7	49/90	54.4	.001	.970
Pooled site data	342/576	59.4	198/385	51.4	5.919	.015

Table 6.17 Prevalence of enamel hypoplasia among the subadult male and female cemetery samples

n_{eh} number of individuals displaying enamel hypoplasia n_t total number of dentate individuals in sample
% percentage of sample displaying enamel hypoplasia χ^2 chi-square statistic p probability

	Males		Females			
	n_{eh}/n_t	%	n_{eh}/n_t	%	χ^2	p
Abingdon	16/21	76.2	9/15	60.0	1.081	.298
Fishergate	15/16	93.8	13/14	92.9	.010	.922
Pooled site data	31/37	83.8	22/29	75.9	.645	.422

Table 6.18 Mean number of hypoplastic lines displayed on the mandibular canine of adult males and females

n number of individuals in sample displaying enamel hypoplasia
$\bar{x}$ mean number of hypoplastic defects evident on the mandibular canine

	Males		Females	
	n	$\bar{x}$	*n*	$\bar{x}$
Wharram	47	1.53	21	1.24
Ipswich	36	1.56	11	1.82
Abingdon	50	2.30	39	2.00
Fishergate 4	29	2.48	20	2.30
Fishergate 6	97	2.71	26	2.54

Table 6.19 Mean number of hypoplastic lines displayed on the mandibular canine of subadult males and females

n number of individuals in sample displaying enamel hypoplasia
$\bar{x}$ mean number of hypoplastic defects evident on the mandibular canine

	Males		Females	
	n	$\bar{x}$	*n*	$\bar{x}$
Abingdon	16	3.00	9	2.90
Fishergate	15	3.19	13	2.29

Table 6.20 Age-specific prevalence of enamel hypoplasia among the adult male and female cemetery samples (data divided into four age categories)

n_{eh} number of individuals displaying enamel hypoplasia in age group n_t total number of dentate individuals in age group
% percentage of sample displaying enamel hypoplasia χ^2 chi-square statistic p probability

		c. 18-25		*c.* 25-35		*c.* 35-45		*c.* >45	
		n_{eh}/n_t	%	n_{eh}/n_t	%	n_{eh}/n_t	%	n_{eh}/n_t	%
Wharram	Males	9/24	37.5	10/26	38.5	14/33	42.4	13/37	35.1
	Females	6/22	27.3	8/20	40.0	5/20	25.0	2/17	11.8
Ipswich	Males	10/23	43.5	10/34	29.4	12/23	52.2	3/10	30.0
	Females	3/8	37.5	3/16	18.8	3/7	42.9	2/9	22.2
Abingdon	Males	12/17	70.6	12/26	46.2	11/26	42.3	13/23	56.5
	Females	9/18	50.0	13/27	48.1	6/11	54.6	9/15	60.0
St Nicholas	Males	4/5	80.0	7/9	77.8	9/12	75.0	4/4	100.0
	Females	6/7	85.7	14/19	73.7	8/15	53.3	3/5	60.0
Fishergate 4	Males	16/16	100.0	9/9	100.0	3/5	60.0	1/1	100.0
	Females	5/5	100.0	6/6	100.0	6/7	85.7	3/3	100.0
Fishergate 6	Males	15/15	100.0	21/22	95.5	27/28	96.4	33/35	94.3
	Females	3/3	100.0	10/10	100.0	7/7	100.0	6/9	66.7
Jewbury	Males	14/24	58.3	15/27	55.6	21/32	65.6	7/21	33.3
	Females	23/34	67.6	6/18	33.3	13/22	59.1	6/15	40.0
Pooled site data	Males	80/124	64.5	84/153	54.9	97/159	61.0	74/131	56.5
	Females	55/97	56.7	60/116	51.7	48/89	53.9	31/73	42.5

Table 6.21 Age-specific prevalence of enamel hypoplasia among the adult male and female cemetery samples (data divided into two age categories)

n_{eh} number of individuals displaying enamel hypoplasia in age group n_t total number of dentate individuals in age group
% percentage of sample displaying enamel hypoplasia χ^2 chi-square statistic p probability

		c. 18-35		*c.*>35	
		n_{eh}/n_t	%	n_{eh}/n_t	%
Wharram	Males	19/50	38.0	27/70	38.6
	Females	14/42	33.3	7/37	18.9
Ipswich	Males	20/57	35.1	15/33	45.5
	Females	6/24	25.0	5/16	31.3
Abingdon	Males	24/43	55.8	24/49	50.0
	Females	22/45	48.9	15/26	57.7
St Nicholas	Males	11/14	78.6	13/16	81.3
	Females	20/26	76.9	11/20	55.0
Fishergate 4	Males	25/25	100.0	4/6	66.7
	Females	11/11	100.0	9/10	90.0
Fishergate 6	Males	36/37	97.3	60/63	95.2
	Females	13/13	100.0	13/16	81.3
Jewbury	Males	29/51	56.9	28/53	52.8
	Females	29/52	55.8	19/37	51.4
Pooled site data	Males	164/277	59.2	171/290	59.0
	Females	115/213	54.0	79/162	48.8

Table 6.22 Mean number of hypoplastic lines displayed on the mandibular canine of adult males and females from each age group (data divided into four age categories)

n number of individuals in age group displaying enamel hypoplasia
$\bar{x}$ mean number of hypoplastic defects evident on the mandibular canine

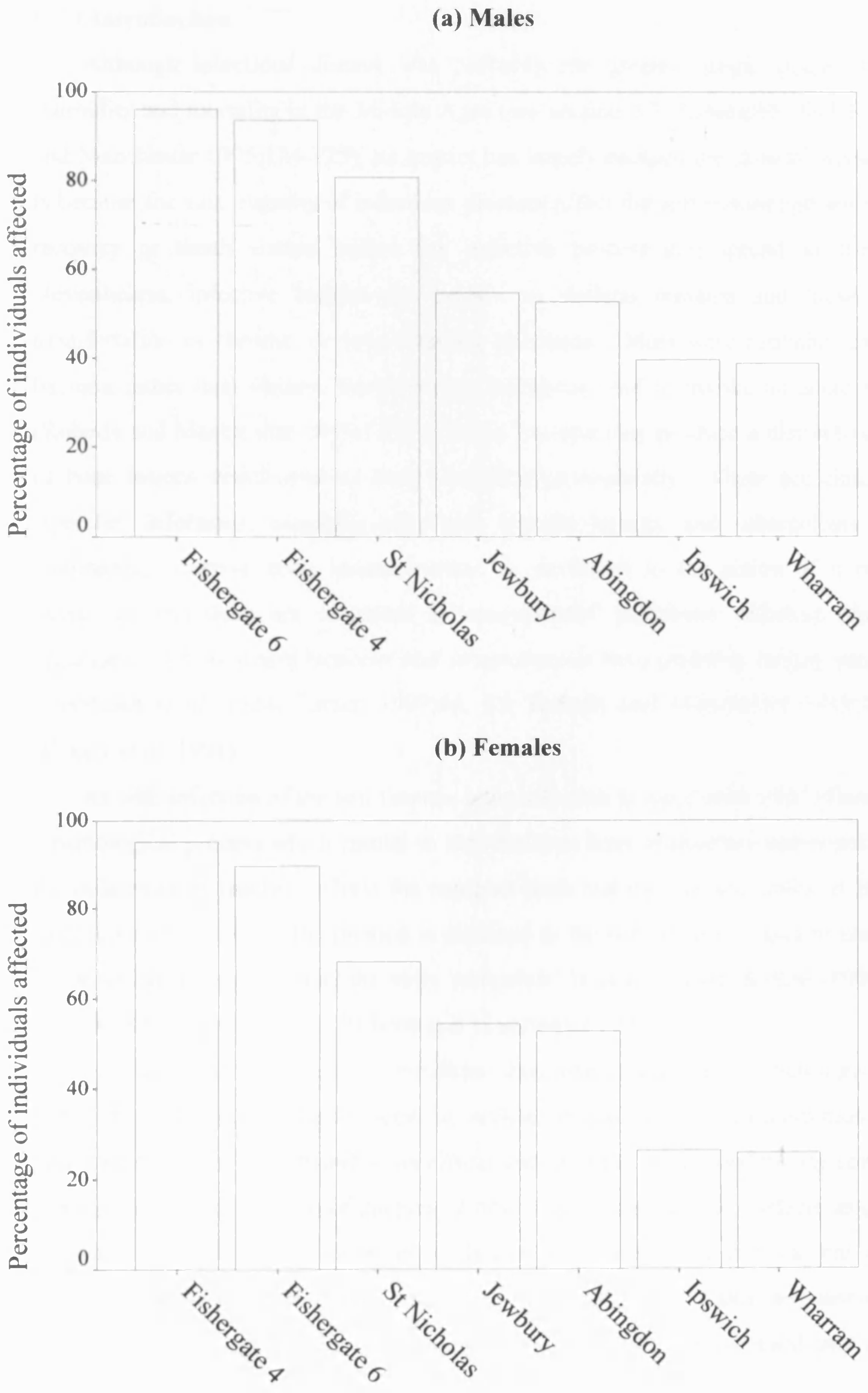
		*c.*18-25		*c.*25-35		*c.*35-45		*c.*>45	
		n	$\bar{x}$	*n*	$\bar{x}$	*n*	$\bar{x}$	*n*	$\bar{x}$
Wharram	Males	9	2.11	10	1.30	14	1.43	13	1.46
	Females	6	1.00	8	1.13	5	1.80	2	1.00
Ipswich	Males	10	1.80	10	1.40	12	1.42	3	2.00
	Females	3	2.00	3	1.33	3	2.00	2	2.00
Abingdon	Males	12	2.25	12	2.25	11	2.64	13	2.15
	Females	9	1.67	13	2.23	6	2.00	9	1.67
Fishergate 4	Males	16	2.75	9	2.33	3	1.33	1	3.00
	Females	5	3.40	6	2.33	6	1.67	3	1.67
Fishergate 6	Males	15	3.40	21	2.71	27	2.70	33	2.36
	Females	3	2.67	10	2.60	7	2.14	6	2.83

Table 6.23 Mean number of hypoplastic lines displayed on the mandibular canine of adult males and females from each age group (data divided into two age categories)

n number of individuals in age group displaying enamel hypoplasia
$\bar{x}$ mean number of hypoplastic defects evident on the mandibular canine

		*c.*18-25		*c.*25-35	
		n	$\bar{x}$	*n*	$\bar{x}$
Wharram	Males	19	1.68	27	1.44
	Females	14	1.07	7	1.57
Ipswich	Males	20	1.60	15	1.53
	Females	6	1.67	5	2.00
Abingdon	Males	24	2.25	24	2.38
	Females	22	2.00	15	1.80
Fishergate 4	Males	25	2.60	4	1.75
	Females	11	2.82	9	1.67
Fishergate 6	Males	36	3.00	60	2.57
	Females	13	2.62	13	2.46

Figure 6.4a/b Bar graphs illustrating the site differences in the prevalence of enamel hypoplasia



6.5 Non-Specific Infection

6.5.1 Introduction

Although infectious disease was probably the greatest single cause of human morbidity and mortality in the Middle Ages (see section 5.3; Rawcliffe 1995:3; Roberts and Manchester 1995:124-125), its impact has largely escaped the skeletal record. This is because the vast majority of infectious diseases affect the soft tissues and are acute, so recovery or death ensues before the infective process can spread to the bones. Nevertheless, infective lesions are evident in skeletal remains and these are the manifestation of chronic, or long-standing infections. Most were probably caused by bacteria rather than viruses, because viral infections tend to invoke an acute response (Roberts and Manchester 1995:125). Certain bacteria may produce a distinctive pattern of bone lesions which enables their identification skeletally. These are classified as 'specific' infections, examples of which include leprosy and tuberculosis. More commonly, infective bone lesions cannot be attributed to the action of a particular bacterium, and these are classified as 'non-specific' infections; although like today, organisms such as *staphylococcus* and *streptococcus* were probably largely responsible (Goodman *et al.* 1984; Larsen 1997:64, 83; Roberts and Manchester 1995:125-126; Wakely *et al.* 1991).

As with infection of the soft tissues, bone infection is associated with inflammation, a pathological process which results in simultaneous bone destruction and repair. When the inflammatory reaction affects the compact bone and the marrow cavity, it is termed 'osteomyelitis'. If the inflammation is confined to the periosteum, a layer of connective tissue which covers the bone, the term 'periostitis' is usually used (Kelley 1989; Larsen 1997:82-83; Mays 1998:123; Roberts and Manchester 1995:126).

Periostitis is a far less serious condition than osteomyelitis and is the most common form of inflammatory lesion seen in archaeological bone. Inflammation of the periosteum may initially manifest as pitting and striation of the underlying cortex, and subsequently the deposition of plaques of new bone on the cortical surface, as plate 6.3 illustrates. The skeletal distribution of lesions may sometimes indicate the cause of infection (Wakely *et al.* 1991), although the majority of cases are non-specific. Furthermore, although chronic local and systemic infection is recognised as a cause of

Plate 6.3 Periostitis

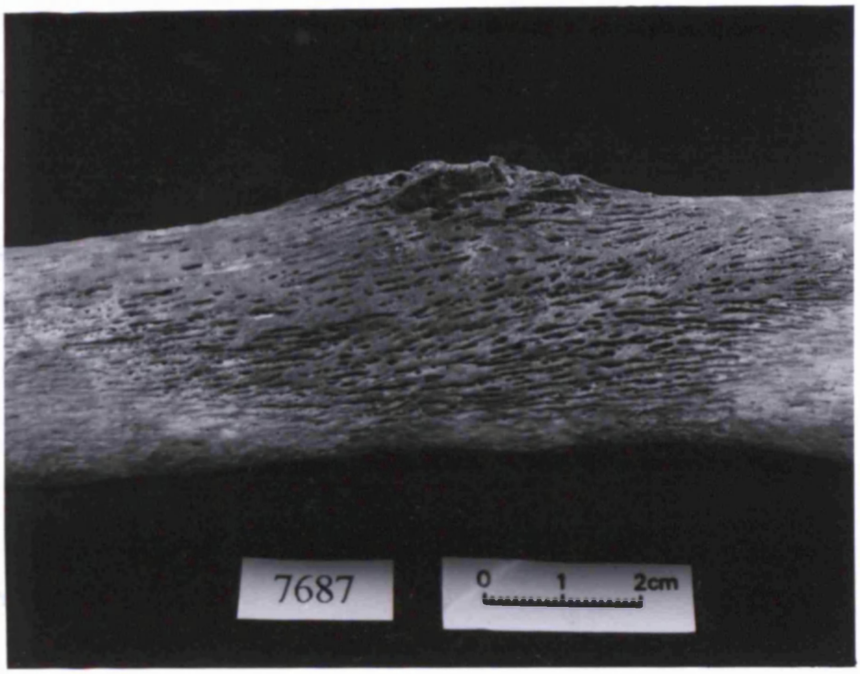


Plate 6.4 Osteomyelitis (from Manchester 1983:Plate 7)
Left (1) and right (2) tibiae.
Right tibia thickened and deformed by osteomyelitis.
Arrow points to drainage sinus.

periosteal inflammation, other aetiological factors have been implicated (Mensforth *et al.* 1978). Since the lesions are most frequently found on the tibia, a bone which is prone to repeated minor injury, it has been suggested that trauma may provoke a periosteal reaction. Chronic venous insufficiency and consequent lower leg ulceration has also been associated with inflammation of the periosteum (Larsen 1997:83; Roberts and Manchester 1995:129-130).

Osteomyelitis usually causes severe pain and debilitation. It may arise through two principal modes of bacterial transmission to bone: either by direct infection such as from an open fracture; or via the bloodstream from another primarily infected site such as the tonsils. The initial result of inflammation is bone destruction and pus formation. The blood supply may be obstructed to localised areas of bone which consequently become necrotic. Pus and necrotic fragments, known as sequestra, may be discharged from the bone interior into surrounding tissues leaving an open channel, termed a drainage sinus or cloaca. The attendant bone reparative process is manifest as plaques of new bone deposition on the outer cortex, beneath the periosteum. The proliferative bone may eventually form a shell, or involucrum, around the original cortex. Thus osteomyelitis may be recognised skeletally as an enlarged, deformed bone with the presence of cloacae (Rogers and Waldron 1989), as illustrated on plate 6.4. Roberts and Manchester (1995:127-129) note that blood infection, or septicaemia, is a potentially fatal condition, and contend that cases of osteomyelitis caused by blood infection may actually represent 'the survival of the fittest'. The immune status of afflicted individuals must have been sufficient to prevent them from succumbing to the acute onslaught of infection, so allowing the chronic bone changes to develop.

Several authors have used chronic infectious lesions as a general measure of health status among various population groups (Grauer 1991; Grauer 1993; Larsen 1997:84-93; Mensforth *et al.* 1978; Ribot and Roberts 1996; Roberts and Manchester 1995:129). As with the other stress indicators, the purpose of this study was to compare the prevalence of non-specific periostitis and osteomyelitis in males and females from the medieval cemeteries. Unlike cribra orbitalia and enamel hypoplasia, these lesions are not necessarily representative of childhood stress, so they offered the opportunity to investigate potential sex differences in stress which may have occurred later in life. Unfortunately it is not possible to determine the age at which a healed lesion was active, although lesions that were current at the time of death may be identified by the presence of bone with a woven, porous appearance. Specific infections were not considered in this study because the number of individuals displaying lesions attributable to specific causes was too few to allow meaningful comparative figures to be produced.

6.5.2 Method

All material had been examined macroscopically, and radiographs were taken as an aid to diagnosis in some suspected cases of osteomyelitis from Wharram Percy and Ipswich. The presence and distribution of inflammatory bone lesions had been recorded for all skeletons. In most cases, a description of each lesion had also been provided, which tended to include information such as the extent of the lesion, its appearance, severity, and whether any remodelling had taken place to indicate healing. However, this information was not used for the purposes of data analysis because it had been recorded qualitatively, without the use of any standardised scale or terminology, so any attempt to categorise the lesions according to type would have relied on the subjective interpretation of this data.

The 'crude' prevalence of individuals displaying non-specific periostitis and osteomyelitis was computed for adult males and females from each site respectively, the sexed subadults from Abingdon and Fishergate, and the pooled adult and subadult data (table 6.24, 6.25 and 6.26). 'Crude' prevalence is defined as the proportion of individuals displaying lesions out of the total number of individuals in the sample, and in this instance, expressed as a percentage (Waldron 1994:43-55):

$$\text{Crude prevalence (\%)} = \frac{\text{Number of individuals in sample displaying lesions}}{\text{Total number of individuals in sample}} \times 100$$

Chi-square tests were applied in order to determine whether there was any statistical association between sex and the prevalence of periostitis in any of the adult samples (table 6.24). It was inappropriate to apply chi-square tests of association to the subadult data, or the frequencies of adult males and females affected by osteomyelitis, owing to the small number of individuals affected.

As the term implies, the 'crude' prevalence provides a rather inaccurate measure of the 'true' prevalence because it does not take into account the fact that a substantial proportion of the skeletons were incomplete, as is usually the case when dealing with archaeological remains (Waldron 1994:53-54). It assumes that all missing skeletal elements did not display pathological lesions, when in fact they may have done but the evidence has not survived. This limitation inevitably leads to an underestimate of the true prevalence because all individuals contribute to the denominator in the crude prevalence equation, regardless of their completeness and therefore their potential to provide positive pathological evidence. This is particularly problematical when comparing the crude prevalence of different samples as the results may be biased by differences in sample preservation. As the estimates of skeletal preservation computed in chapter 5 indicated, there were differences in male and female preservation within and between the various cemetery samples, though not consistently towards any particular demographic group.

Therefore, 'corrected' prevalence figures for periostitis were also computed for each of the lower limb bones in the respective adult cemetery samples and the pooled site data (table 6.27a-g). Corrected prevalence is defined as the proportion of elements displaying lesions out of the total number of elements present (Waldron 1994:53-54):

$$\text{Corrected prevalence (\%)} = \frac{\text{Number of elements in sample displaying lesions}}{\text{Total number of elements in sample}} \times 100$$

This procedure circumvents the problem of incomplete preservation of the entire skeleton by expressing prevalence in relation to specific skeletal elements. Cases lacking the relevant skeletal element are eliminated from the calculation. However, the procedure does assume that the prevalence of periostitis among the missing elements was similar to that among the elements which were present. It also fails to take into account the problem of incomplete bone preservation. Evidence of periostitis may have been lost from long bones which were fragmented or where the exterior surface had been degraded through taphonomic changes. This problem could have been avoided by excluding all incompletely preserved bones, but this would then have resulted in the problem of reduced sample size. A further limitation with the approach is that by reflecting the prevalence of periostitis in specific bones, it disregards periostitis elsewhere in the skeleton. Nevertheless, on balance, the corrected prevalence statistic does tend to yield more accurate and consistent figures for comparative purposes than those provided by the crude prevalence. Corrected prevalence figures were generated for the lower limb bones because these were the most frequently affected skeletal elements. Table 6.28 lists the other skeletal elements which were affected less commonly. The corrected prevalence figures for the lower limb bones were computed for the left and right sides separately as although there was a tendency for periosteal lesions to present bilaterally, this was not necessarily so. Producing combined side figures would have created the problem of how to deal with cases in which the bone from only one side was present. It was not possible to compute corrected prevalence figures for the Jewbury assemblage because a skeletal inventory had not been recorded. Corrected prevalence figures were not produced for osteomyelitis due to the small number of bones affected. Chi-square tests were used to determine whether there was any statistically significant association between sex and the prevalence of periostitis in the tibiae from each respective cemetery, which was the bone most frequently involved out of all the skeletal elements, and thus offered the greatest sample size for the purposes of analysis (table 6.27a-f). Owing to the large samples generated when the data from all cemeteries were pooled, chi-square tests were applied to determine whether there was any statistically significant association between sex and periostitis in all the lower limb bones (table 6.27 g).

Age-specific prevalence figures were computed to identify whether there was any change in the prevalence of tibial periostitis with age. Again, this bone was examined because it was the most frequently affected skeletal element. As with the other stress indicators, figures were computed for each of the four age categories and for the two youngest and eldest cohorts combined (table 6.29 and 6.30). Although any comparison of data between cemeteries was likely to be hampered by variations in recording technique, chi-square tests were applied to determine whether there was any statistical association between cemetery and periostitis on the tibiae for either sex.

6.5.3 Results and Discussion

According to the crude prevalence figures, presented in table 6.24, neither sex displayed a consistently higher prevalence of periostitis among the adult samples from the medieval cemeteries. A higher percentage of males were affected in the assemblages from Wharram Percy, Abingdon, and the early phase of Fishergate; whereas a higher percentage of females were affected in the assemblages from St Nicholas Shambles, Jewbury and the later phase of Fishergate. A similar percentage of males and females were affected within the Ipswich collection. No statistically significant association between sex and crude prevalence was identified within any of the cemeteries according to the chi-square tests, although statistical significance was virtually attained in the Abingdon assemblage (χ^2=3.629 p=.057). A slightly higher percentage of males were affected in the pooled site sample, with 16.4% of all males displaying lesions compared with 15.3% of females, but the chi-square test confirmed that the sex difference in frequency was not statistically significant.

However, the corrected prevalence figures for adults, presented in table 6.27a-g, generally pointed toward a greater prevalence of periostitis among the lower limb bones of males. In most comparisons the percentage of bones affected was either greater in males or similar for both sexes. Only a minority of comparisons displayed a higher prevalence of periostitis among females. Within the assemblage from Wharram Percy, a higher percentage of male bones were affected for all six bone types. Similar results were obtained for Abingdon, except a similar percentage of male and female left fibulae were affected. In all collections, males displayed a higher prevalence of femoral periostitis, with the exception of Fishergate 4 in which no cases were identified. A higher percentage of male tibia were affected in this collection, although a similar percentage of male and female fibulae displayed lesions. In the later phase of the cemetery, each sex displayed a similar percentage of tibiae and fibulae with periostitis. A slightly higher percentage of male fibulae were affected within the collections from Ipswich and St Nicholas Shambles, although a similar percentage of male and female tibiae were affected in Ipswich, and a higher percentage of female tibiae were affected in St Nicholas Shambles. However, no statistically significant association between sex and tibial periostitis was identified within any of the cemeteries. When the data from all the cemeteries were pooled, a higher percentage of male bones were affected for every bone type. The sex difference was not statistically significant for the tibiae and fibulae, but a statistically significant association was identified between prevalence of periostitis and sex for both the right (χ^2=5.582 p=.018) and left (χ^2=6.345 p=.012) femora.

Overall, these results appeared to accord with the findings from the analysis of stature and enamel hypoplasia. Though not especially pronounced, males were inclined to display a higher prevalence of periostitis, at least in the lower limb bones. It is likely that the sex difference was too slight to be detected using the crude prevalence statistics. There was certainly no evidence to suggest that females exhibited a higher prevalence of periostitis. Again, these results would tend to point toward a poorer general health status among adult males, just as the results of the stature and hypoplasia analysis indicated for males during childhood. Owing to the rather ambiguous aetiology of periostitis, it is difficult to interpret the results any further, although they may be reflecting further evidence to suggest that males have a greater biological susceptibility to environmental stress, particularly infectious disease. However, Grauer (1991) also noted a slightly higher prevalence of periostitis among males from the medieval cemetery of St Helen-on-the-Walls, York, and although the sex difference was not statistically significant, she interpreted the result as evidence that males had a greater ability to rally from infectious insults. Rather than reflecting an inferior male health status, Grauer suggested that the higher prevalence of periostitis indicated a superior health status which enabled men to survive episodes of disease, allowing chronic bone lesions to develop, whereas females were more likely to succumb to infection. Another interpretation could be that males partook in more physically hazardous activities than females which exposed them to more minor trauma, as repeated minor trauma has been implicated in the aetiology of periostitis. This possibility is discussed in the following chapter.

When the data for periostitis on the tibiae were split into four age categories, potential patterns in the age-specific prevalence were difficult to discern due to the small size of the resulting samples. However, as table 6.29 illustrates, there appeared to be a general increase in prevalence with advancing age for both sexes. This contrasted with the results obtained from the analysis of cribra orbitalia and enamel hypoplasia which showed a decrease in prevalence with increasing age. Sixteen of the twenty-four samples displayed a rise in prevalence between the youngest and eldest age groups. Five samples displayed the reverse trend and three samples showed no obvious change in prevalence with age. As the results in table 6.30 illustrate, the pattern was more apparent when the data were divided into just two categories. Fifteen samples showed an increase in periostitis prevalence between the youngest and eldest age group, five showed a decrease and four displayed no clear difference in the percentage affected. This trend is open to several interpretations. It is possible that lesions were not readily remodelled and therefore accumulated with age. It could suggest that the lesions are manifestations of infectious insults that were fairly trivial, or at least not life threatening, so that recovery was the norm resulting in an accumulation in lesion prevalence among older age cohorts. Alternatively, following Grauer's hypothesis, the results could be reflecting the process of 'the survival of the fittest', with those who were able to rally from insults surviving into old age, the lesions from such episodes remaining on the skeleton and thus accumulating with age. In future studies it may be beneficial to routinely record whether a lesion exhibited any signs of healing at the time of death, as Grauer (1993:204) has suggested that this could elucidate any relationship between lesion prevalence and survival. Another possibility could be that the rise in periostitis reflects a greater susceptibility to infection with increasing age, or a slower healing rate. Alternatively, as periostitis has been linked with circulatory problems such as venous insufficiency, the pattern could simply be reflecting the expected rise in this age related condition.

The age-specific prevalence figures also served to support the results obtained from the total samples. The slightly elevated prevalence of periostitis observed among males could potentially have been a product of the age structure of the assemblages, as the modal age at death tended to be greater among males. Though the respective cemetery samples were rather small having been divided by sex and age group, the age-specific prevalence figures for periostitis among the pooled cemetery data tended to be slightly greater among males. The sex difference became more pronounced with increasing age, although this may have been a manifestation of the rise in numbers affected, which served to enhance any sex differences in prevalence.

The prevalence of periostitis among the sexed subadults also conformed to the general trend for an increase in prevalence with age, as indicated by the results in table 6.25. Just one female displayed periostitis among the sample from Fishergate, and the lesion was on the ribs, not on the lower limb bones which was the most common site for lesions among the adult skeletons. Within the Abingdon sample, 15% of subadult males and 26% of subadult females displayed periostitis, although these figures actually represented just nine individuals, four of which were male and five female. Lesions were present on the tibia and fibula of only one individual, classified as a female. The remaining sexed subadults from Abingdon displayed lesions elsewhere on the skeleton. The different distribution of periostitis among the few subadults affected may suggest that alternative aetiological factors were involved in the development of periostitis in adults, which became increasingly important with advancing age. Perhaps subadults were less prone to repeated minor trauma, or minor trauma was less likely to incite a periosteal reaction in subadult bones. The lack of periostitis in the lower limbs might be associated with the rarity of circulatory disorders in subadults. Another possibility could be that subadults were more likely to succumb to acute episodes of infection whereas those surviving into adulthood had a greater capacity to survive infection. However, an alternative interpretation might simply be that periostitis is generally under recorded in children. There may be a reluctance to diagnose it because periostitis resembles the normal process of subperiosteal bone deposition which occurs during growth to enable the bones to thicken (Mays 1998:8; Wakely pers. comm.).

Substantial differences were noted in the prevalence of tibial periostitis among the various cemeteries. These are illustrated graphically in figures 6.5a-d. The percentage of male tibia with periostitis ranged from 7% to about 20% across the cemeteries, and the percentage of female tibia affected ranged from about 5% to approximately 29%. The cemetery differences in periostitis prevalence did not quite attain statistical significance for the left tibia in either sex according to the results of the chi-square tests (males χ^2 = 10.494 p=.062; females χ^2 = 10.213 p=.069); although a statistical association between periostitis prevalence and cemetery was identified at the 1% probability level for the right tibia of both males (χ^2 = 15.083 p=.010) and females (males χ^2 = 15.397 p<.009). The differences in periostitis prevalence may simply be a product of differences in recording techniques. Stroud (1993:217) has commented that periostitis may show 'considerable variability in presentation and subsequently in identification, both by the same observer over a period of time or between different observers'. Nevertheless, there are several similarities between the rank order of periostitis prevalence and those obtained from the analyses of the other stress indicators. Yet again, the rural cemetery of Wharram Percy displayed the lowest overall prevalence of tibial periostitis, which is consistent with the hypothesis that the rural character of the settlement may have afforded some protection against infectious disease. This low prevalence emerged despite the fact the cemetery displayed a high typical age at death, which would tend to increase the prevalence of periostitis in the total sample owing to the rise in periostitis prevalence that was identified with advancing age. The age-specific prevalence figures further confirmed the low prevalence of periostitis within the cemetery. The Ipswich assemblage, recorded by the same observer, did also display a comparatively low prevalence of periostitis, as it did cribra orbitalia and enamel hypoplasia, although like these stress indicators, the percentage affected still exceeded that of Wharram Percy. Like the prevalence of hypoplasia, and cribra orbitalia in males, the cemetery from St Nicholas Shambles displayed the highest prevalence of tibial periostitis according to the age-specific and the total sample prevalence figures. This conforms with the interpretation that the high population density in London encouraged the spread of infectious disease. However, the samples from the other urban cemeteries did not all display a similarly high prevalence, which may indicate that this interpretation is over-simplistic.

The hierarchy observed for tibial periostitis also demonstrated the value of computing 'corrected prevalence' figures. According to the 'crude prevalence' statistics, males from St Nicholas Shambles were one of the groups least affected by periostitis, and females occupied a mediocre position in the hierarchy. In fact, as the corrected prevalence figures demonstrated, both males and females from St Nicholas Shambles displayed the highest prevalence of periostitis of all the cemeteries. These discrepancies can be attributed to the poor preservation of the collection. As the analysis of bone preservation in chapter 5 revealed, St Nicholas Shambles was the most poorly preserved assemblage of all the cemeteries. As a result, a relatively large proportion of the skeletons contributing to the denominator in the crude prevalence equation lacked tibiae, resulting in a greater underestimate of the true prevalence compared with the other assemblages which were better preserved. Conversely, the crude prevalence figures indicated that Ipswich contained one of the highest percentages of individuals with periostitis when in fact, as the corrected prevalence figures demonstrated, a comparatively low percentage of tibiae were affected. Again, sample preservation was probably responsible for this disparity, as Ipswich was the most well preserved collection of all the cemeteries.

The crude prevalence of osteomyelitis was generally low for both males and females, as the results in table 6.26 indicate. The percentage affected ranged from zero to almost 6% across the various cemetery samples, although it may be inappropriate to express the results in percentage terms as there were less than five individuals affected in all but two of the respective cemetery samples. Nevertheless, the proportion of males affected exceeded the proportion of females in five of the seven cemeteries: Wharram Percy, Fishergate 4, Fishergate 6, Abingdon and St Nicholas Shambles. A fractionally higher percentage of females displayed lesions in the collection from Ipswich, and no cases of osteomyelitis were identified within the Jewbury assemblage. These results therefore concord with those for periostitis. They may indicate a slightly greater biological susceptibility to infection among males, or a greater ability to rally from infection. Another possibility might be that males were at an elevated risk of exposure to pathogens. For example, if males sustained more injuries, as will be discussed in the following chapter, this might increase the opportunity for the direct infection of bone. It is notable that all cases of osteomyelitis associated with fractures were identified in males.

Table 6.24 Crude prevalence of periostitis among the adult male and female cemetery samples

n_p number of individuals displaying periostitis n_t total number of individuals in sample
% percentage of sample displaying periostitis χ^2 chi-square statistic p probability

	Males		Females			
	n_p/n_t	%	n_p/n_t	%	χ^2	p
Wharram	24/212	11.3	12/129	9.3	.346	.556
Ipswich	26/146	17.8	11/64	17.2	.012	.913
Abingdon	60/223	26.9	32/171	18.7	3.629	.057
St Nicholas	12/91	13.2	11/74	14.9	.096	.757
Fishergate 4	8/47	17.0	4/33	12.1	.365	.546
Fishergate 6	29/176	16.5	11/53	20.8	.517	.472
Jewbury	14/161	8.7	22/150	14.7	2.705	.100
Pooled site data	173/1056	16.4	103/674	15.3	.372	.542

Table 6.25 Crude prevalence of periostitis among the subadult male and female cemetery samples

n_p number of individuals displaying periostitis n_t total number of individuals in sample
% percentage of sample displaying periostitis

	Males		Females	
	n_p/n_t	%	n_p/n_t	%
Abingdon	4/27	14.8	5/19	26.3
Fishergate	0/20	0.0	1/17	5.9
Pooled site data	4/47	8.5	6/36	16.7

Table 6.26 Crude prevalence of osteomyelitis among the adult male and female cemetery samples

n_o number of individuals displaying osteomyelitis (bracketed figures denote the number of cases of direct bone infection resulting through fracture) n_t total number of individuals in sample
% percentage of sample displaying osteomyelitis χ^2 chi-square statistic p probability

	Males		Females	
	n_o/n_t	%	n_o/n_t	%
Wharram	2 (1)/212	0.9	0/129	0.0
Ipswich	4/146	2.7	2/64	3.1
Abingdon	19 (6)/223	8.5	9/171	5.3
St Nicholas	3/91	3.3	1/74	1.4
Fishergate 4	1/47	2.1	0/33	0.0
Fishergate 6	3/176	1.7	0/53	0.0
Jewbury	0/161	0.0	0/150	0.0
Pooled site data	32 (7)/1056	3.0	12/674	1.8

Table 6.27a-g Corrected prevalence figures for periostitis on the lower limb bones

(a) Wharram Percy

n_p number of long bones displaying periostitis n_t total number of long bones in sample
% percentage of long bones displaying periostitis χ^2 chi-square statistic p probability

	Males		Females			
	n_p/n_t	%	n_p/n_t	%	χ^2	p
Right Tibia	9/128	7.0	4/84	4.8	.454	.501
Left Tibia	11/123	8.9	4/84	4.8	1.298	.255
Right Fibula	9/119	7.6	2/78	2.6		
Left Fibula	8/113	7.1	1/80	1.3		
Right Femur	4/138	2.9	0/95	0.0		
Left Femur	2/146	1.4	0/92	0.0		

(b) Ipswich Blackfriars

n_p number of long bones displaying periostitis n_t total number of long bones in sample
% percentage of long bones displaying periostitis χ^2 chi-square statistic p probability

	Males		Females			
	n_p/n_t	%	n_p/n_t	%	χ^2	p
Right Tibia	13/128	10.2	6/58	10.4	.002	.969
Left Tibia	13/134	9.7	6/58	10.4	.019	.891
Right Fibula	7/119	5.9	2/53	3.8		
Left Fibula	9/122	7.4	2/52	3.9		
Right Femur	0/129	0.0	0/59	0.0		
Left Femur	3/130	2.3	0/58	0.0		

(c) Abingdon

n_p number of long bones displaying periostitis n_t total number of long bones in sample
% percentage of long bones displaying periostitis χ^2 chi-square statistic p probability

	Males		Females			
	n_p/n_t	%	n_p/n_t	%	χ^2	p
Right Tibia	32/159	20.1	17/119	14.3	1.599	.206
Left Tibia	32/157	20.4	16/122	13.1	2.545	.111
Right Fibula	9/150	6.0	5/114	4.4		
Left Fibula	7/153	4.8	6/121	5.0		
Right Femur	5/162	3.1	1/116	0.9		
Left Femur	2/168	1.2	1/131	0.8		

(d) St Nicholas Shambles

n_p number of long bones displaying periostitis n_t total number of long bones in sample
% percentage of long bones displaying periostitis χ^2 chi-square statistic p probability

	Males		Females			
	n_p/n_t	%	n_p/n_t	%	χ^2	p
Right Tibia	8/39	20.5	10/35	28.6	.651	.420
Left Tibia	5/39	12.8	7/29	24.1	1.466	.226
Right Fibula	8/36	22.2	7/31	22.6		
Left Fibula	7/36	19.4	4/27	14.8		
Right Femur	3/53	5.7	1/49	2.0		
Left Femur	5/47	10.6	0/39	0.0		

(e) Fishergate 4

n_p number of long bones displaying periostitis n_t total number of long bones in sample
% percentage of long bones displaying periostitis χ^2 chi-square statistic p probability

	Males		Females			
	n_p/n_t	%	n_p/n_t	%	χ^2	p
Right Tibia	3/38	7.9	1/22	4.6	.251	.616
Left Tibia	6/38	15.8	2/21	9.5	.453	.501
Right Fibula	2/39	5.1	1/18	5.6		
Left Fibula	3/36	8.3	2/21	9.5		
Right Femur	0/40	0.0	0/22	0.0		
Left Femur	0/42	0.0	0/23	0.0		

(f) Fishergate 6

n_p number of long bones displaying periostitis n_t total number of long bones in sample
% percentage of long bones displaying periostitis χ^2 chi-square statistic p probability

	Males		Females			
	n_p/n_t	%	n_p/n_t	%	χ^2	p
Right Tibia	23/138	16.7	7/42	16.7	.000	1.000
Left Tibia	18/141	12.7	8/44	18.2	.814	.367
Right Fibula	15/131	11.5	4/41	9.8		
Left Fibula	11/136	8.1	5/43	11.6		
Right Femur	5/150	3.3	1/43	2.3		
Left Femur	3/146	2.1	0/44	0.0		

(g) Pooled Site Data

n_p number of long bones displaying periostitis n_t total number of long bones in sample
% percentage of long bones displaying periostitis χ^2 chi-square statistic p probability

	Males		Females			
	n_p/n_t	%	n_p/n_t	%	χ^2	p
Right Tibia	88/630	14.0	45/360	12.5	.425	.515
Left Tibia	85/632	13.5	43/358	12.0	.420	.517
Right Fibula	50/594	8.4	21/335	6.3	1.401	.237
Left Fibula	45/596	7.6	20/344	5.8	1.022	.312
Right Femur	17/672	2.5	2/384	0.5	5.582	.018
Left Femur	15/679	2.2	1/387	0.3	6.345	.012

Table 6.28 Corrected prevalence figures for periostitis located elsewhere on the skeleton other than the lower limb bones

n_p number of individuals displaying periostitis n_t total number of individuals with the relevant skeletal component represented % percentage of sample with the relevant skeletal component displaying periostitis

		Males		Females	
		n_p/n_t	%	n_p/n_t	%
Wharram	Skull/Facial Bones	3/166	1.8	1/113	0.9
	Maxillary Sinuses	2/166	1.2	2/113	1.8
	Ribs	1/156	0.6	2/153	1.3
	Scapulae	0/142	0.0	1/108	0.9
	Pelvis	1/119	0.8	0/85	0.0
	Radii	1/128	0.8	0/97	0.0
	Ulnae	1/134	0.7	0/98	0.0
	Hands	1/148	0.7	0/112	0.0
	Feet	3/114	2.6	0/82	0.0
Ipswich	Skull/Facial Bones	3/146	2.1	4/64	6.3
	Maxillary Sinuses	2/146	1.4	0/64	0.0
	Ribs	0/115	0.0	1/50	2.0
	Feet	3/129	2.3	3/60	5.0
Abingdon	Skull/Facial Bones	7/223	3.1	2/171	1.2
	Maxillary Sinuses	6/223	2.7	7/171	4.1
	Ribs	10/159	6.3	4/128	3.1
	Manubrium	1/134	0.7	0/107	0.0
	Scapulae	1/157	0.6	0/114	0.0
	Spine	1/175	0.6	0/133	0.0
	Pelvis	5/169	3.0	1/128	0.8
	Clavicles	2/140	1.4	0/103	0.0
	Humeri	5/154	3.2	1/118	0.8
	Radii	3/158	1.9	0/117	0.0
	Ulnae	5/160	3.1	1/120	0.8
	Hands	3/161	1.9	3/125	2.4
	Feet	1/146	0.7	4/117	3.4
Fishergate 4	Skull/Facial Bones	1/35	2.9	1/23	4.3
	Ribs	1/42	2.4	0/27	0.0
	Humeri	1/40	2.5	0/25	0.0
	Radii	1/40	2.5	0/24	0.0
	Feet	1/37	2.7	0/19	0.0
Fishergate 6	Skull/Facial Bones	0/118	0.0	1/38	2.6
	Ribs	2/146	1.4	0/43	0.0
	Pelvis	1/145	0.7	0/42	0.0
	Humerus	1/136	0.7	0/38	0.0
	Radius	1/139	0.7	0/38	0.0
	Ulna	1/140	0.7	0/38	0.0
	Feet	2/129	1.6	1/47	2.1

Table 6.29 Age-specific prevalence of tibial periostitis among the adult male and female cemetery samples (data divided into four age categories)

n_p number of long bones in age group displaying periostitis n_t total number of long bones in age group
% percentage of long bones in age group displaying periostitis

		c.18-25		c.25-35		c.35-45		c.>45	
		n_p n_t	%	n_p n_t	%	n_p n_t	%	n_p n_t	%
Wharram	Males Right Tibia	1/19	5.3	0/19	0.0	0/16	0.0	4/44	9.1
	Males Left Tibia	1/18	5.6	2/22	9.1	0/17	0.0	5/41	12.2
	Females Right Tibia	1/16	6.3	0/15	0.0	1/11	9.1	2/33	6.1
	Females Left Tibia	2/16	12.5	0/16	0.0	0/10	0.0	2/33	6.1
Ipswich	Males Right Tibia	3/22	13.6	3/33	9.1	4/30	13.3	2/29	6.9
	Males Left Tibia	2/23	8.7	4/35	11.4	4/32	12.5	3/30	10.0
	Females Right Tibia	1/11	9.1	3/14	21.4	0/8	0.0	1/16	6.3
	Females Left Tibia	1/11	9.1	2/15	13.3	0/8	0.0	3/16	18.8
Abingdon	Males Right Tibia	1/20	5.0	6/34	17.7	13/42	31.0	10/53	18.9
	Males Left Tibia	0/19	0.0	8/33	24.2	11/41	26.8	12/53	22.6
	Females Right Tibia	2/16	12.5	3/33	9.1	5/32	15.6	6/33	18.2
	Females Left Tibia	1/18	5.6	3/33	9.1	5/31	16.1	6/33	18.2
St Nicholas	Males Right Tibia	4/9	44.4	2/10	20.0	0/8	0.0	1/2	50.0
	Males Left Tibia	3/9	33.3	0/9	0.0	0/8	0.0	0/1	0.0
	Females Right Tibia	1/5	20.0	4/13	30.8	3/8	37.5	1/4	25.0
	Females Left Tibia	0/2	0.0	4/12	33.3	2/8	25.0	1/3	33.3

Table 6.29 contd. . . /

Table 6.29 (contd.)

		c.18-25		c.25-35		c.35-45		c.>45	
		n_p/n_t	%	n_p/n_t	%	n_p/n_t	%	n_p/n_t	%
Fishergate 4	Males Right Tibia	1/17	5.9	0/8	0.0	2/8	25.0	0/2	0.0
	Males Left Tibia	1/15	6.7	0/9	0.0	2/8	25.0	2/3	66.7
	Females Right Tibia	0/2	0.0	0/4	0.0	0/8	0.0	0/2	0.0
	Females Left Tibia	0/2	0.0	1/5	20.0	0/8	0.0	0/2	0.0
Fishergate 6	Males Right Tibia	0/19	0.0	6/29	20.7	6/37	16.2	8/37	21.6
	Males Left Tibia	0/20	0.0	5/29	17.2	5/36	13.9	5/41	12.2
	Females Right Tibia	0/3	0.0	1/12	8.3	2/9	22.2	2/11	18.2
	Females Left Tibia	0/3	0.0	1/13	7.7	5/11	45.5	1/10	10.0
Pooled site data	Males Right Tibia	10/106	9.4	17/133	12.8	25/141	17.7	25/167	15.0
	Males Left Tibia	7/104	6.7	19/137	13.9	22/142	15.5	27/169	16.0
	Females Right Tibia	5/53	9.4	11/91	12.1	11/76	14.5	12/99	12.1
	Females Left Tibia	4/52	7.7	11/94	11.7	12/76	15.8	13/97	13.5

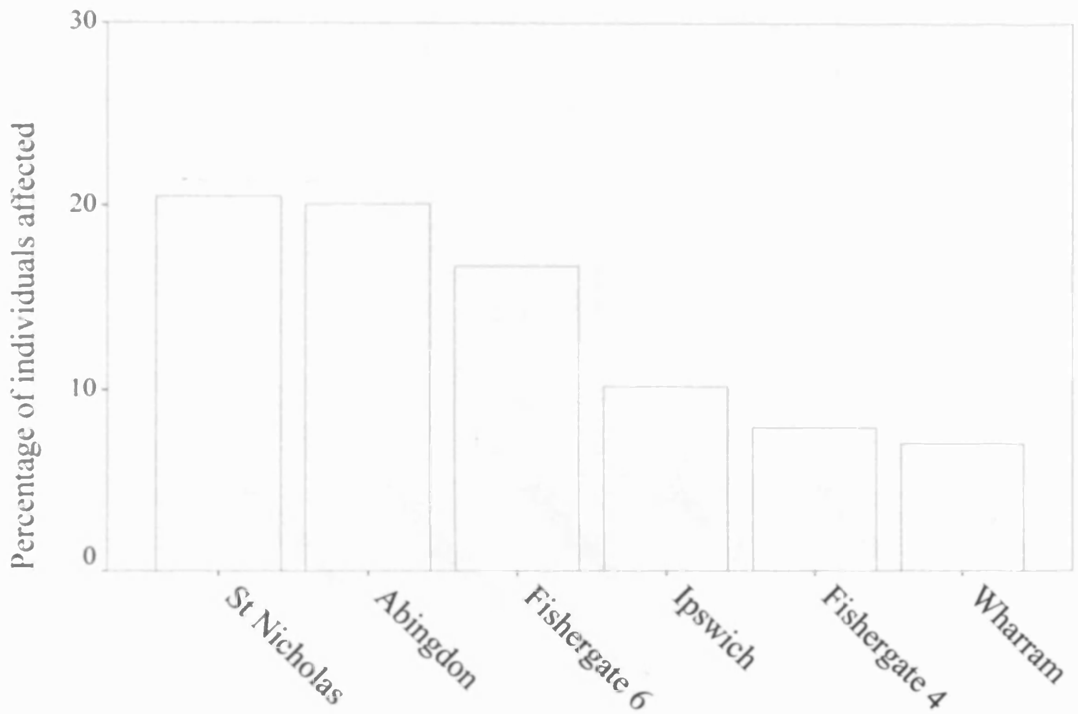
Table 6.30 Age-specific prevalence of tibial periostitis among the adult male and female cemetery samples (data divided into two age categories)

n_p number of long bones in age group displaying periostitis n_t total number of long bones in age group
% percentage of long bones in age group displaying periostitis

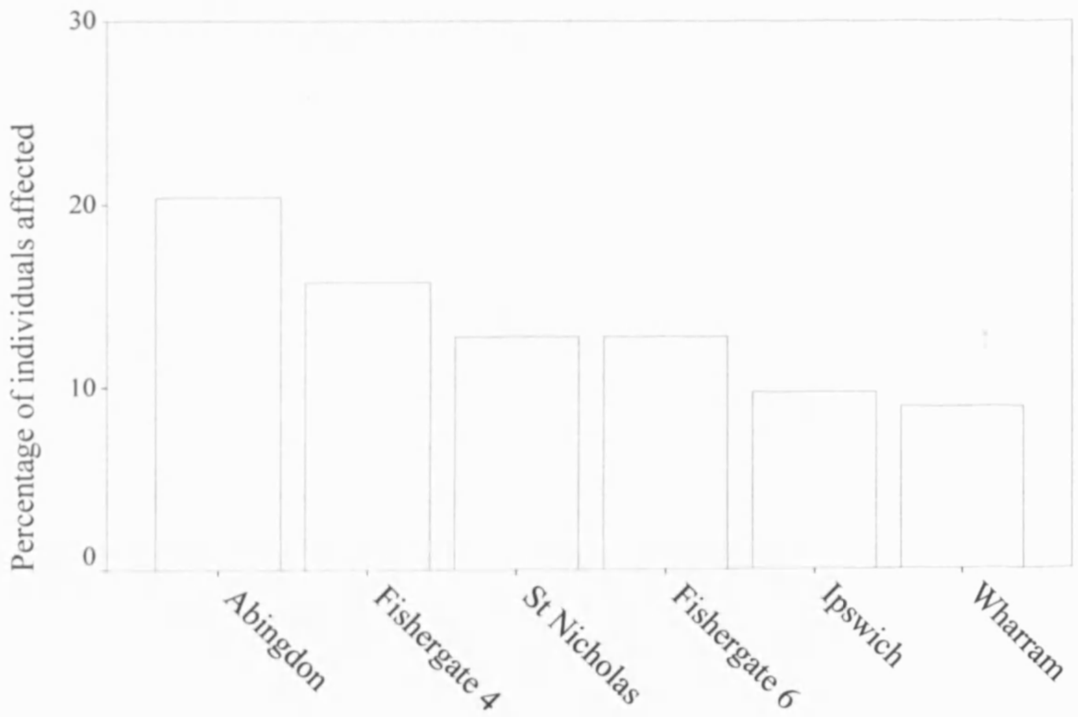
		c.18-35		c.>35	
		n_p n_t	%	n_p n_t	%
Wharram	Males Right Tibia	1/38	2.6	4/60	6.7
	Males Left Tibia	3/40	7.5	5/58	8.6
	Females Right Tibia	1/31	3.2	3/44	6.8
	Females Left Tibia	2/32	6.3	2/43	4.7
Ipswich	Males Right Tibia	6/55	10.9	6/59	10.2
	Males Left Tibia	6/58	10.3	7/62	11.3
	Females Right Tibia	4/25	16.0	1/24	4.2
	Females Left Tibia	3/26	11.5	3/24	12.5
Abingdon	Males Right Tibia	7/54	13.0	23/95	24.2
	Males Left Tibia	8/52	15.4	23/94	24.5
	Females Right Tibia	5/49	10.2	11/65	16.9
	Females Left Tibia	4/51	7.8	11/64	17.2
St Nicholas	Males Right Tibia	6/19	31.6	1/10	10.0
	Males Left Tibia	3/18	16.7	0/9	0.0
	Females Right Tibia	5/18	27.8	4/12	33.3
	Females Left Tibia	4/14	28.6	3/11	27.3
Fishergate 4	Males Right Tibia	1/25	4.0	2/10	20.0
	Males Left Tibia	1/24	4.2	4/11	36.4
	Females Right Tibia	0/6	0.0	0/10	0.0
	Females Left Tibia	1/7	14.3	0/10	0.0
Fishergate 6	Males Right Tibia	6/48	12.5	14/74	18.9
	Males Left Tibia	5/49	10.2	10/77	13.0
	Females Right Tibia	1/15	6.7	4/20	20.0
	Females Left Tibia	1/16	6.3	6/21	28.6
Pooled site data	Males Right Tibia	27/239	11.3	50/308	16.2
	Males Left Tibia	26/241	10.8	49/311	15.8
	Females Right Tibia	16/144	11.1	23/175	13.1
	Females Left Tibia	15/146	10.3	25/173	14.5

Figure 6.5a-d Bar graphs illustrating the site differences in the prevalence of tibial periostitis

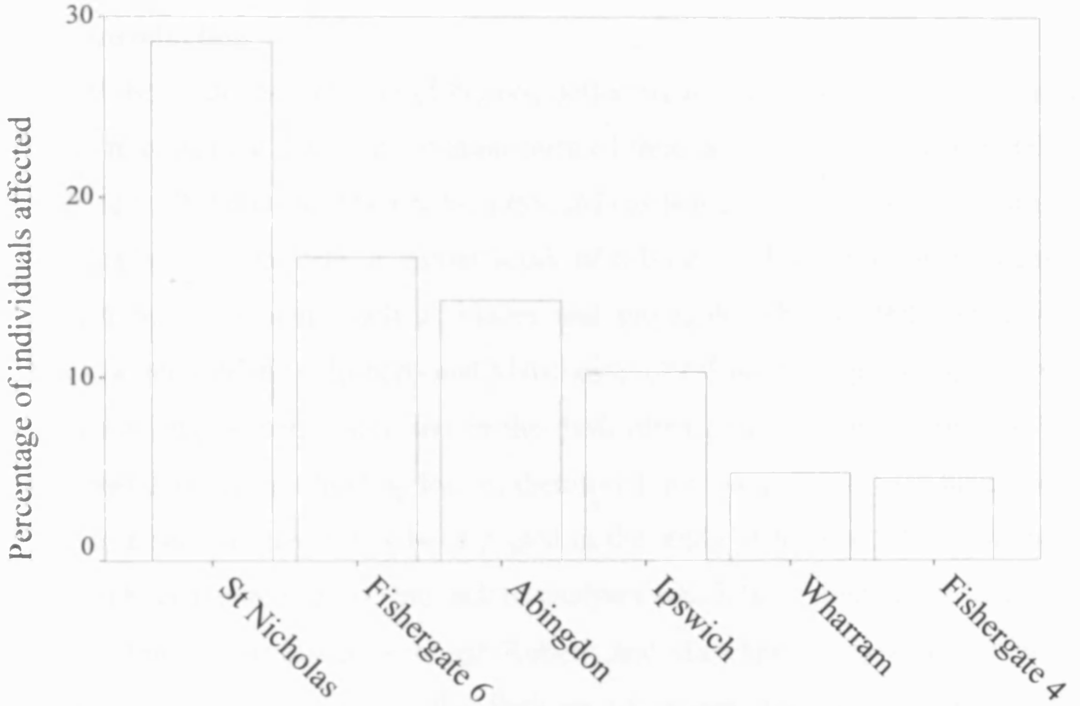
(a) Males, Right Tibia



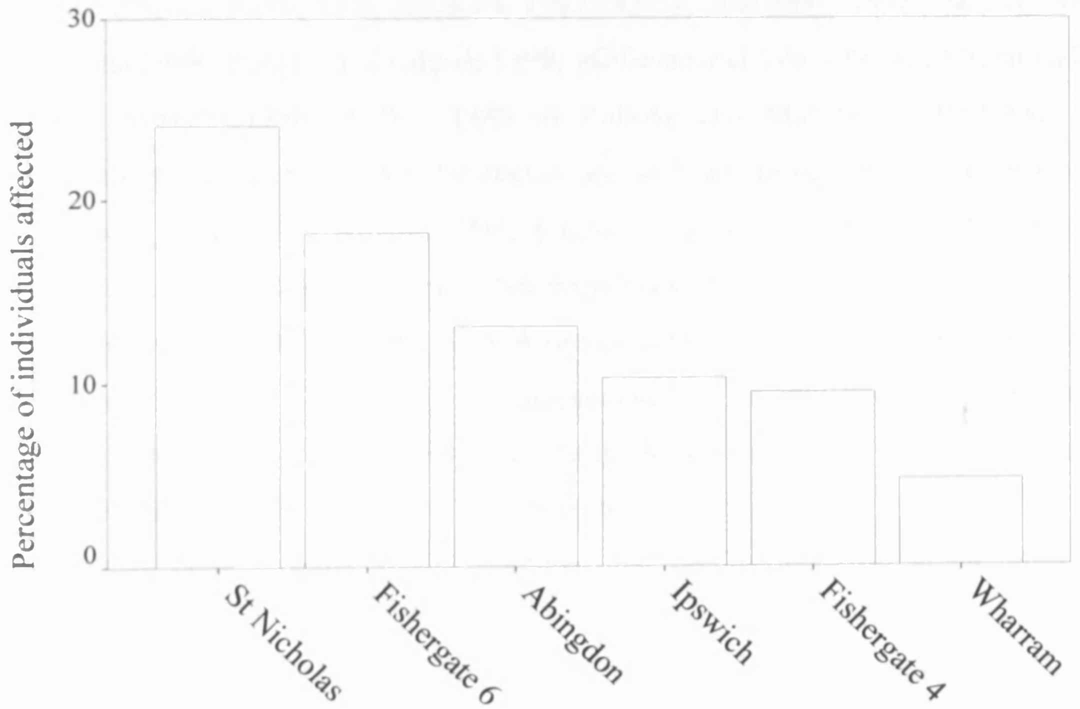
(b) Males, Left Tibia



(c) Females, Right Tibia



(d) Females, Left Tibia



7. Trauma

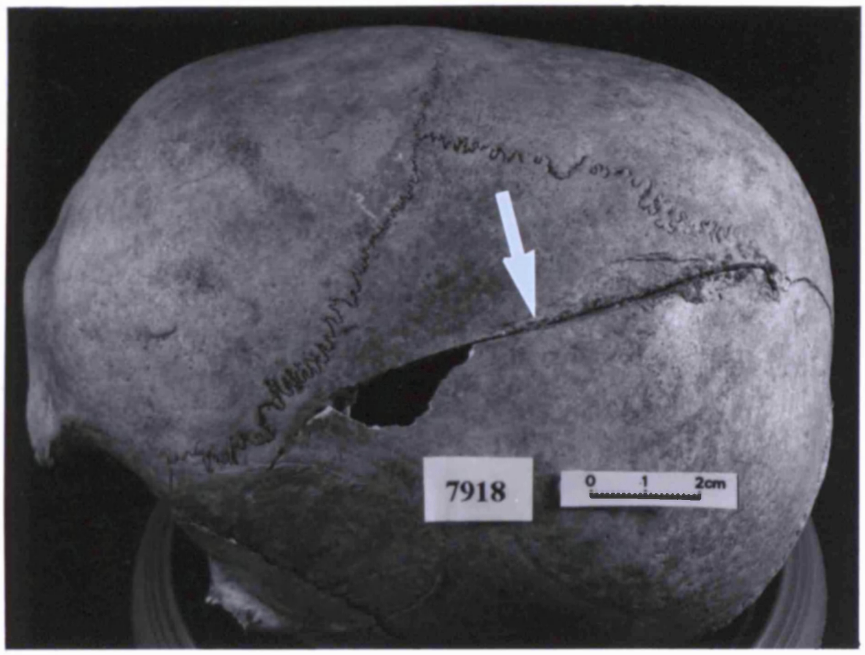
7.1 Introduction

Roberts and Manchester (1995:66) define trauma as 'any bodily injury or wound'. Bone fractures are the most common form of traumatic lesion seen in skeletal remains, defined by Roberts and Manchester (1995:67) as being 'the result of any traumatic event that leads to a complete or partial break of a bone'. This definition includes injuries caused by implements such as blades and projectiles (Mays 1998:162; Roberts and Manchester 1995:67). Roberts and Manchester (1995:80) have proposed that 'Generally speaking, males, both today and in the past, often performed heavy manual work and composed a society's fighting forces; therefore their risk of injury may have been greater and so a sex difference may be expected in the study of trauma'. Jurmain and Kilgore (1998) have commented on the lack of analyses which have specifically focused on sex-related trauma prevalence, although Roberts and Manchester's hypothesis would appear to be justified according to the findings of several previous studies. Where sex differences have been observed, males tend to display a higher prevalence of trauma, particularly cranio-facial injuries (Angel 1974 in Roberts and Manchester 1995:74 and Larsen 1997:116-117; Bennike 1985:57; Cross and Bruce 1989:130; Molleson 1993:204; Inglemark 1939 in Larsen 1997:143-145 and Mays 1998:178-181; Judd and Roberts 1998; Jurmain and Kilgore 1998; Molleson and Cox 1993:82; Stroud and Kemp 1993; Wakely 1996; Walker 1989 in Roberts and Manchester 1995:84). Some assemblages do display a similar prevalence and pattern of trauma among males and females (Jurmain and Kilgore 1998; Kilgore *et al.* 1997; Lovejoy and Heiple 1981), although samples that display a higher prevalence of trauma among females tend to be the exception (Wilkinson and Van Wagenen 1993 in Jurmain and Kilgore 1998 and Larsen 1997:122-123). Hence the purpose of this chapter was to test Roberts and Manchester's hypothesis in relation to the medieval cemeteries, through a comparative examination of male and female fracture patterns.

It is predominantly healed fractures that are recognisable in the skeleton, an example of which is shown in plate 7.1. Unhealed injuries occurring at or around the time of death, termed perimortal injuries, are difficult to identify because they are usually indistinguishable from post-depositional breakages (Larsen 1997:110; Mays 1998:165-

Plate 7.1 Healed Fracture. Arrow points to callus.

Plate 7.2 Blade Injury



167; Roberts and Manchester 1995:67). Two exceptions are blade injuries, which produce characteristic, well defined linear lesions, such as that illustrated in plate 7.2 (Mays 1998:165-167; Wenham 1989 in Mays 1998:167; Wenham and Wakely 1988 in Mays 1998:167); and depressed fractures of the skull, caused by being struck with a blunt object.

Healed fractures may be recognised in skeletal remains by the bone remodelling which takes place as part of the reparative process (Mays 1998:162-165; Merbs 1989:163-164; Roberts and Manchester 1995:70-72). This begins immediately after the fracture has occurred with the formation of a haematoma or collection of blood at the fracture site. The severing of blood vessels causes the necrosis and resorption of bone adjacent to the fracture. During the two week period following the fracture, the haematoma is absorbed as the bone ends are united by fibrous tissue. After about six weeks this is replaced by a callus of immature woven bone, and over a period of several months this is gradually consolidated by replacement with more mature lamellar bone. Further remodelling may continue for many years.

Even without treatment, fractures can heal with good alignment (Schultz 1967), although inadequate reduction may result in bone shortening and deformity, with joint degeneration and osteoarthritis as a possible consequence (Judd and Roberts 1998; Larsen 1997:152-153; Mays 1998:165; Roberts and Manchester 1995:72). As discussed in section 6.5, infection may be another complication if there is an open connection between the bone and skin surface (Judd and Roberts 1998; Roberts and Manchester 1995:67). Well aligned fractures can heal so efficiently that any evidence for the fracture is eventually obliterated. This is also true of incomplete breaks, such as those occurring in relatively resilient immature bone, termed greenstick fractures, which can heal so rapidly and efficiently that they are not even detectable on radiographs (Mays 1998:162; Roberts and Manchester 1995:69,73). However, most fractures which arise in adulthood are discernible throughout life (Mays 1998:176), although the age at which the fracture occurred cannot normally be determined (Judd and Roberts 1998).

The majority of fractures are caused by acute injury. It is not generally possible to distinguish whether a fracture was caused by an accident or was inflicted deliberately, although the location, type and direction of the break may provide some indication as to the cause (Mays 1998:162-163; Roberts and Manchester 1995:69). Blade wounds and injuries caused by projectiles, such as arrows or crossbow bolts, are usually considered to be the result of intentional violence (Kilgore *et al.* 1997; Larsen 1997:119-160; Mays 1998:162-181; Stroud and Kemp 1993:225-241). As the skull and face are often a target during interpersonal violence, cranio-facial injuries are also largely attributed to aggressive interactions (Jurmain and Kilgore 1998; Kilgore *et al.* 1997; Larsen 1997:119-160; Roberts and Manchester 1995:79-85; Smith 1996). In the postcranial skeleton, mid-shaft or distal fractures of the ulna, or radius and ulna, may be indicative of interpersonal violence as they can arise from defensive attempts to avert a blow to the head by raising the forearm; hence their descriptive classification as 'parry' fractures. However, this type of fracture may be sustained accidentally, particularly through falls, and it is now recognised that caution should be taken before interpreting this type of injury as evidence for assault, especially without corroborating evidence for aggression within a sample, primarily from cranio-facial or weapon injuries (Bennike 1985:58; Jurmain and Kilgore 1998; Kilgore *et al.* 1997; Larsen 1997:110-112; Lovejoy and Heiple 1981; Roberts and Manchester 1995:77; Smith 1996).

Fractures may be also caused by an underlying disease, such as osteoporosis which serves to weaken the bone structure. These are termed pathological fractures (Roberts and Manchester 1995:68-69). Studies of contemporary populations have revealed a typical pattern of bone involvement associated with osteoporosis, including the femoral neck, wrists, ribs, and crush fractures of the vertebrae where the vertebrae collapse in a characteristic wedge shape as a result of compressive forces. Elderly females are particularly susceptible (Larsen 1997:117; Mays 1998:176-178; Roberts and Manchester 1995:74; Snell 1973:840).

Repetitive stress may induce fractures, although stress fractures are extremely difficult to identify, even radiographically, as they are often hairline and heal without trace (Roberts and Manchester 1995:68-69). One exception is spondylolysis, a condition commonly found in skeletal remains whereby the neural arch becomes detached from the vertebral body. A congenital bone weakness may be a predisposing factor, but the primary cause is thought to be recurrent stress from strenuous bending and lifting, perhaps acting on the site of weakness (Merbs 1989:169-170). The fifth followed by the fourth lumbar vertebrae are the most frequently affected. Bony reunion does not normally take place, probably due to continuous stress at the site. Other than discomfort in the lower back, spondylolysis tends not to produce symptoms, but a serious secondary complication is spondylolisthesis in which the unstable vertebral body becomes dislocated. This is difficult to identify skeletally but may be diagnosed from the formation of bone around the edges of the slipped vertebral bodies (Roberts and Manchester 1995:79; Snell 1973:840-841).

This analysis specifically aimed to compare the overall male and female prevalence of fractures, as a general test of Roberts and Manchester's (1995:80) hypothesis; and the male and female prevalence of fractures which were probably inflicted with violent intent and those which were more likely to have been sustained accidentally, in order to distinguish whether either sex was at an elevated risk of violent injury. It also aimed to compare the elemental distribution of fractures between the sexes in order to identify any sex differences in fracture pattern, and the age-specific fracture prevalence to determine whether there was any association between fracture prevalence and age for either sex.

7.2 Method

All fractures had been identified through macroscopic examination, although radiography was used where appropriate to assist the process of diagnosis within the assemblages from Ipswich, Wharram Percy and Fishergate. Healed or healing fractures were recognised by the presence of a callus, angular deformation, or bone shortening. A minority of healed but un-united fractures were identified from remodelled fractured bone ends (Roberts and Manchester 1995:72-73). The only unhealed injuries identified were those caused by blades and projectiles. For all sites, fractures had been recorded for each individual using a qualitative description, stating the bone affected and usually the position of the lesion on the bone. The description often included additional information such as the type and direction of the break in cases where this could be inferred; and complications of the fracture such as infection, osteoarthritis, bone shortening or deformity. Occasionally the description was accompanied by a sketch, particularly the records taken for the Fishergate assemblage.

The 'crude' prevalence of individuals with fractures (number of individuals displaying a minimum of one fracture in any element/total number of individuals in the sample; see section 6.5.2) was computed for each of the adult male and female samples from the respective cemeteries, and the pooled adult data from all cemeteries combined (table 7.1). Positive identifications consisted of all fracture types, irrespective of the probable cause of injury. In order to determine whether either sex sustained a higher prevalence of injuries that were likely to have been inflicted through violence, the proportion of males and females displaying blade or projectile injuries, and the proportion of male and female crania displaying fractures to the vault or facial bones was computed for each of the samples (table 7.2 and 7.3). As skeletal inventories had not been taken for the Jewbury material, the number of crania was taken as the number of frontal bones visible on *in situ* photographs, as estimated by Brothwell and Browne (1994 in Lilley *et al.* 1994:460; see also section 6.3). Following this, the crude prevalence of individuals with fractures was recomputed for each of the male and female samples, but excluding those which exhibited solely blade or projectile injuries (table 7.4); and excluding those with only blade, projectile or cranio-facial injuries (table 7.5). The purpose of this was to determine the impact of violent injuries on the overall sex-specific trauma prevalence, and ascertain the male and female prevalence of fractures which were more likely to have been the result of unintentional injury. Chi-square tests were applied to all the above comparisons between male and female data in order to determine whether there were any statistically significant associations between sex and fracture prevalence (tables 7.1-7.5).

The limitations surrounding the use of the crude prevalence statistic were discussed in section 6.5.2. These problems have been reiterated by other authors with specific reference to the epidemiological analysis of trauma. Kilgore and colleagues (1997:106) state, 'Given the differences in quality of preservation between various osteological samples, the most useful means of data presentation is to consider prevalence by element'; i.e. the 'corrected' prevalence statistic, as discussed in section 6.5.2. Similarly, Roberts and Manchester (1995:74) believe that 'Presenting data as a percentage of individuals affected is unwise because it assumes complete survival of all the skeleton'. Instead they too recommend that fracture prevalence should be calculated as a percentage of the number of bones examined. Therefore, corrected prevalence figures were computed for each of the seven long bone types in the male and female cemetery samples: clavicle, humerus, radius, ulna, femur, tibia and fibula (tables 7.6a-g). This was with the exception of Jewbury which was excluded due to the absence of skeletal inventories. Consistent with the analysis of infectious disease (section 6.5.2), data for the right and left elements were analysed separately in order to simplify the calculations and identify any asymmetry in fracture prevalence; and incomplete long bones were included as restricting the study to complete bones would have reduced the size of the samples and complicated the epidemiological method. However, as discussed in section 6.5.2, it should be emphasised that the inclusion of incomplete elements represents a limitation of the method because it may lead to an underestimate of the actual prevalence. As Lovejoy and Heiple (1981:535) warn, incorporating incomplete bones is not ideal because 'incomplete but normal-appearing bones may have shown evidence of fracture if intact, thus skewing frequency data'.

Bennike (1985:56) has highlighted a further drawback with expressing fracture prevalence as a proportion of the number of bones examined. Owing to the low frequency of bones affected relative to the total number of bones present, the resulting prevalence figures are often extremely low, which impairs the ability to compare data. To counteract this problem, an additional method of comparing the distribution of long bone fractures between the sexes was employed, whereby all the fractured long bones were totalled, and each of the seven fractured long bone types were expressed as a proportion of this total (table 7.7a-g). Waldron (1995) describes this method as being akin to a proportional morbidity study in modern epidemiology, its advantage being that 'it avoids the problems with denominators that bedevils so much of palaeopathological work'(p.386). However, when applied to skeletal remains, it can be biased by differential preservation between long bone types and between skeletons. To minimise this source of limitation, only the most complete individuals were included in the procedure, the prerequisite for selection being that at least one long bone from each symmetrical pair should be represented.

The prevalence of rib fractures was quantified as a proportion of individuals with ribs present (table 7.8). Chi-square tests were applied to determine whether there was a statistical relationship between sex and the prevalence of rib fractures. The prevalence of vertebral compression fractures and spondylolysis/spondylolisthesis was quantified as a proportion of individuals with at least part of the spinal column represented (table 7.9 and 7.10). As with the analysis of limb bones, the inclusion of individuals lacking a full complement of ribs or vertebrae was likely to have led to an underestimate of the true prevalence, but the elimination of those in which the ribs or spine was entirely absent at least minimised this source of error. Individuals with fractures identified elsewhere in the skeleton were tallied according to the following skeletal components: sternum, scapula, pelvis, wrist, hands and feet; and quantified as a proportion of individuals with the relevant component present (table 7.11). Chi-square tests were not applied to the vertebral data, or that pertaining to other skeletal elements, owing to the comparatively low number of individuals affected.

The crude prevalence of individuals with multiple fractures was calculated for each male and female sample, defined as the proportion of individuals with two or more fractures (Kilgore *et al.* 1997) (table 7.12). Chi-square tests were applied to establish whether there was any statistical relationship between sex and multiple trauma, although it should be noted that it is not normally possible to distinguish whether multiple fractures occurred concurrently or resulted from separate traumatic events (Wakely 1996).

The age-specific prevalence of injuries caused by blades and projectiles was computed for each of the four age categories in the respective cemetery samples (table 7.13), in order to detect age cohorts which may have been at an elevated risk of violent injury. Similarly, the age-specific prevalence was computed for all other forms of fracture collectively (table 7.14). A marked rise in prevalence in a particular age category may be indicative of a group at increased risk from trauma (Larsen 1997:118; Lovejoy and Heiple 1981; Mays 1998:176), and also indicate whether other procedures may have been biased by differences in the age composition of the various samples. The age distribution of rib and vertebral compression fractures were also presented separately (tables 7.15 and 7.16) as these may be associated with the age-related condition osteoporosis. It was anticipated that their prevalence might rise among older individuals, particularly females. Only one of the subadults sexed using the tooth measurement technique (chapter 3) displayed a fracture, so no statistical analysis was applied to this age group. The individual affected was from the Fishergate assemblage and had been classified as a 'probable male', aged 14-16 years, with bilateral spondylolysis of the fifth lumbar vertebra.

7.3 Results and Discussion

The crude prevalence figures for the proportion of males and females displaying fractures of any type, presented in table 7.1, provided unequivocal evidence to support Roberts and Manchester's hypothesis that males were at a greater risk of fracture than females. The percentage of males affected surpassed that of females in every cemetery, with the exception of the sample from Jewbury in which a slightly higher percentage of females were affected. Furthermore, the chi-square tests demonstrated a statistically significant association ($p<.05$) between sex and fracture prevalence for three of the assemblages. These were Abingdon and both phases of the Fishergate cemetery. When the data from all sites were pooled, a quarter (25.9%) of all males displayed fractures compared with only 16.8% of females. The chi-square test on the pooled site data further confirmed the relationship between sex and fracture prevalence, yielding a large chi-square value (χ^2=19.597) which was statistically significant beyond the .001 level.

The results presented in table 7.2 also established that males were at greater risk of injuries which were likely to have been caused through violence. The percentage of males displaying either blade or projectile wounds exceeded the percentage of females in every cemetery, with the exception of Jewbury in which a similar proportion of males and females were affected. A statistically significant association ($p<.05$) between sex and this type of injury was identified for two of the cemeteries, Abingdon and Fishergate 4, and the chi-square value (χ^2=3.813) virtually attained statistical significance for later phase of Fishergate, with a probability of .051. All seven of the cemetery samples contained at least one male with a blade or projectile injury; yet only two of the cemeteries, Wharram Percy and Jewbury, contained females with blade wounds. None of the projectile injuries occurred in females. In total, 49 males displayed weapon injuries compared with only 4 females, which amounted to 4.6% and 0.6% of the pooled male and female samples respectively. A large chi-square value (χ^2=22.859) was obtained for the pooled cemetery data, which was statistically significant beyond the .001 level. These results not only verified that males were more often the victims of armed violence, but also suggested that this form of aggression was not generally directed at females. As blade wounds, and particularly projectile injuries, are typically inflicted by weapons during warfare (Inglemark 1939 in Larsen 1997:143-145 and Mays 1998:178-181; Stroud and Kemp 1993:225-241), the results may also imply that females tended not to be involved in this; although of course it cannot be demonstrated that the males sustained these injuries through inter-group conflict, aside from the Fishergate assemblage perhaps (see section 2.3).

A similar picture was obtained from the analysis of cranio-facial fractures, the results of which are presented in table 7.3. Although the chi-square tests did not reveal any statistically significant association between sex and cranio-facial fracture prevalence within the respective cemetery samples, a consistently higher proportion of males were affected in all cemeteries in which this type of injury was observed. Five of the cemeteries contained males with fractures to the skull or facial bones whereas only two assemblages, Abingdon and Jewbury, contained females with skull fractures. When the data from all cemeteries were pooled, the chi-square value (χ^2=3.282) approached statistical significance (p=.070), suggesting that had the sample been larger, a statistical association between sex and cranio-facial fracture prevalence may have been realised. A total of 16 males were affected, or 2.2% of the pooled male sample, compared with only four females, or 0.8% of the pooled female sample. Among the injuries observed, seven individuals had sustained fractures to the nasal bones, all of which were male. Roberts and Manchester (1995:80) believe that nasal injuries were 'no doubt . . . due to fist-fighting, an age-old and continuing method of solving minor disputes'. Therefore, these findings provided further evidence to suggest that males were more likely to have become involved in interpersonal violence whereas females were not generally targets of attack. Nevertheless, the existence of cranial fractures and blade wounds in females does indicate that they were not entirely immune from aggressive interactions. These interpretations are consistent with evidence provided by urban and rural court records, which not only testify to violence among men, but sometimes refer to brawling and fighting among women, men attacking women, and occasionally women attacking men (Shahar 1983:17, 211, 244).

The omission of individuals displaying solely blade, projectile or cranio-facial injuries did have a noticeable effect on the general trauma prevalence, as the results in tables 7.4 and 7.5 demonstrate. When those exhibiting only blade or projectile injuries were removed from the calculation of fracture prevalence (table 7.4), there was a relatively greater reduction in the prevalence of male trauma compared with female trauma, thereby lessening the difference in prevalence between the sexes. This effect became slightly more exaggerated when those exhibiting solely skull fractures were also excluded (table 7.5), resulting in a greater similarity in male and female trauma prevalence in all cemeteries. The effect can be observed most clearly within the pooled cemetery data. There was a 9.1% difference in trauma prevalence between the sexes when all fracture types were included in the calculation. When those sustaining only blade or projectile injuries were removed, the difference fell to 5.6%. The sex difference was reduced to 4.9% when those displaying only cranio-facial fractures were also omitted from the calculation, resulting in an overall trauma prevalence of 20.6% among males and 15.7% among females. The results of the chi-square tests supported these observations. Whereas a statistically significant association between sex and trauma prevalence was observed among three of the cemeteries when all forms of fracture were included in the statistics, none of the cemeteries displayed a statistically significant relationship when the individuals displaying injuries typically construed as being of violent cause were discounted as positive diagnoses. Nevertheless, despite these reductions in the magnitude of the sex difference, the sex bias in trauma prevalence remained. A higher proportion of males were affected in all cemeteries, with the exception of Jewbury which continued to display a slightly greater prevalence among females. The general consistency in bias across the cemeteries preserved the statistical association between sex and trauma prevalence in the pooled cemetery samples, albeit at a reduced, though still significant level of probability (χ^2=8.213 and p=.004 excluding blade and projectile injuries; χ^2=6.535 and p=.011 excluding blade, projectile and cranio-facial injuries). Although the cause of fractures must remain speculative, it may be surmised from these results that males were at an elevated risk of accidental fracture as well as injuries inflicted with violent intent. This is consistent with Roberts and Manchester's view that males tended to perform heavy manual work which placed them at a higher risk of trauma. Similarly, the findings are compatible with the opinion of Wakely (1996:92) that 'In a medieval community we are dealing with a society in which human muscle power, both male and female but presumably mainly male, was a major source of energy for construction, moving goods from place to place and general craft and subsistence activities', which may have placed males at an increased risk of injuries attendant with these activities. The results would also tend to support the interpretation that an increased risk of injury might have contributed to the elevated male prevalence of periostitis and osteomyelitis identified in section 6.5.3, as repeated minor injury and open fractures are thought to be important aetiological factors in their development. However, the results do imply a greater similarity between the sexes in the prevalence of fractures that were more likely to have arisen through accidental causes, compared with those normally attributed to violence. The considerable prevalence of post-cranial fractures among females therefore supports Wakely's acknowledgement that females did contribute to the 'human muscle power' required to undertake many of the arduous tasks involved in the medieval way of life.

A study of documentary evidence undertaken by Hanawalt (1977) portrays a similar picture. Hanawalt utilised coroner's inquests detailing the circumstances of fatal accidents to infer activity patterns, among other aspects of social and economic life. Two series of coroner's rolls described cases from fourteenth century London and Oxford; and a further two series, dating to the fourteenth and fifteenth centuries, detailed cases from rural Bedfordshire and Northamptonshire. The accident record implied the existence of fairly well defined gender roles. Carting was the single most dangerous operation that men were involved in, causing a quarter of all accidents among rural males. Men also encountered accidents while undertaking activities that included milling, building, masonry, carpentry, quarrying, shipping, herding animals, training horses, and heavy work in a range of crafts and shops within urban centres. Specific female tasks which emerged from the data included gathering herbs and wood, weaving, brewing, working in kitchens and running errands. The record did imply that some physically demanding tasks were undertaken by both sexes, such as reaping and stacking hay, and taking grain to the mill. Hanawalt also notes that both sexes must have engaged in a wide range of activities that were not dangerous, and so did not feature in the inquests, but concluded that 'By and large, the heavy work was done by men in both urban and rural society. In rural society men worked more outside than women and more of them died in work-related accidents. An analysis of the instruments of their death shows that men's work was more dangerous' (Hanawalt 1977:8). These findings are therefore consistent with the skeletal fracture record.

The corrected prevalence figures for long bone fractures, presented in tables 7.6a-g, provided further evidence to confirm that males experienced a higher overall frequency of fractures than females. The proportion of fractured male long bones exceeded the proportion of fractured female long bones in five of the six cemeteries examined. As predicted, the low frequency of fractured bones in relation to the number of bones available for examination did impede the ability to compare data between the sexes. The numbers of fractured bones were effectively 'lost' among the unfractured bones, often resulting in extremely low prevalence figures. For example, when the frequency of fractured bones in the pooled cemetery sample were translated into a proportion of the total number of bones present, it amounted to just 0.94% and 0.81% of the pooled male and female samples respectively. Nevertheless, the results did suggest that there were sex differences in the pattern of long bones affected. Fractures to the tibiae and fibulae were more common among males in five of the six assemblages: Ipswich, Abingdon, St Nicholas Shambles, Fishergate 4 and Fishergate 6. By contrast, of the five cemeteries which contained fractured ulnae, four displayed a higher prevalence among female bones: Ipswich, Abingdon, Fishergate 4 and Fishergate 6. No consistent sex differences were observed across the cemeteries for the remaining long bones, although further sex differences did emerge when the data from all sites were pooled (table 7.6g). There was a higher prevalence of fractures to both the right and left radius, ulna and femur among the female bones; whereas male bones displayed a higher prevalence of fractures to the right and left humerus, tibia and fibula. A similar percentage of male and female clavicles were fractured, although it was noticed that males displayed a slightly higher percentage of fractures to the right clavicle and females to the left. Aside from this observation, no consistent differences were identified in the symmetry of bones affected by fractures, suggesting that long bones from the left and right side of the skeleton were at equal risk of fracture.

The results of the fractured long bone proportional morbidity study are presented in tables 7.7a-g. Unfortunately, although this method was employed to counteract the problems associated with the use of the corrected prevalence method, the low frequency of bones displaying fractures within many of the respective cemetery samples did hamper the ability to detect sex-specific patterns in the proportion of bones affected. However, as with the corrected prevalence results, there did appear to be a general tendency for the forearm bones to be more frequently affected among females, and the tibia and fibula to be more frequently affected among males. The clavicles seemed to feature prominently for both sexes. This pattern was most pronounced among the pooled site data (table 7.7g). The tibia was the most frequently affected bone among males, comprising 22.5% of all long bone fractures. This was closely followed by the fibula which represented 21.3% of fractured male bones. These bones ranked only fourth in the female hierarchy, each of which accounted for 12.2% of the fractured sample. The radius was the most commonly affected long bone among females. Almost a quarter of all female fractures (24.4%) were in the radius, closely followed by the ulna which represented 22.0% of all bone involvement. Radial fractures were the third most affected bone among males, accounting for 17.5% of the sample, although only 12.5% of male fractures occurred in the ulna, which ranked fifth in the hierarchy of bones affected. As inferred from the respective cemetery samples, the clavicles did account for a substantial proportion of fractures in both sexes. It was the third most frequently affected bone in females, representing 17.1% of all fractures; and it accounted for a similar percentage of bone involvement among males (16.3%), though it did follow the radius as the fourth most frequently affected bone. The humerus and femur were the least commonly involved for both sexes, although their positions were transposed in the male and female rankings. Within the male sample, the humerus represented 7.5% and the femur 2.5% of bone involvement. Within the female sample, the femur represented 7.3% and the humerus 4.9% of bone involvement.

These apparent sex differences in fracture pattern point toward the existence of distinctions in male and female activity patterns. However, unlike the coroner's inquest data used by Hanawalt (1977), it is of course difficult to speculate on what these differences may have been within the confines of skeletal interpretation (Wakely 1996). One interpretation for the comparatively high proportion of fractured ulnae among females could be that this represents evidence for violence against females. Bennett (1987:103) states that 'Wife-beating, as featured in both popular and sacred literature, was considered to be a normal part of marriage'; although the rarity of spousal homicides identified in Hanawalt's (1977) court roll study indicates that this may not actually have been widespread in practice. Five of the nine fractured female ulnae, and four of the ten fractured male ulnae had been described as typical 'parry' fractures. However, these frequencies may not be reliable for the purposes of interpretation as the number of parry fractures may have been higher, judging from the descriptions of some ulna fractures on the skeletal recording forms. Nevertheless, the low frequency of cranial and weapon injuries among females would tend to point away from an argument for widespread violence directed at females. Perhaps accidental falls represent a more appropriate explanation for the relatively high prevalence of ulna fractures among females. This interpretation is supported by the relatively high prevalence of radial and clavicle fractures. Fractures to the radius often occur when falling onto an outstretched hand (Judd and Roberts 1988; Kilgore *et al.* 1997; Larsen 1997:110; Lovejoy and Heiple 1981; Roberts and Manchester 1995:77), particularly when there is also underlying osteoporosis (Roberts and Manchester 1995:77), which is perhaps one explanation for the raised prevalence of radial fractures in females compared with males. Fractures to the clavicle are also commonly sustained when falling, either onto an outstretched hand or onto the shoulder (Judd and Roberts 1988; Lovejoy and Heiple 1981; Mays 1998:175). Fractures to the tibia and fibula often result from falls caused by tripping or twisting the ankle when the foot is caught, especially when walking on rough terrain (Judd and Roberts 1998; Larsen 1997:112; Molleson and Cox 1993:82; Roberts and Manchester 1995:75). The comparatively high male prevalence of fractures in these bones therefore suggests that males were more often engaged in activities which placed them at risk from this type of accident. Falls are also a common cause of fracture to the humerus (Kilgore *et al.* 1997), again more common in males. An immediate explanation for the higher prevalence of femoral fractures among females could be that these were pathological fractures associated with osteoporosis. However, there were in total only five fractured femora in the entire medieval sample, and only three of these displayed fractures to the femoral neck, which is the typical site for fractures related to osteoporosis. Only one of these individuals was an elderly female, one was an elderly male, and the other was classified as a male aged above thirty years. The scarcity of femoral neck fractures could be associated with the relatively short medieval life-span, as today most hip fractures occur in women aged above 75 years (Mays 1998:178). Alternatively, if the medieval lifestyle was physically active, perhaps this served to protect against the development of osteoporosis and thus femoral neck fracture (Roberts and Manchester 1995:74). As hip fractures can carry a risk of death through embolism (Kilgore *et al.* 1997), a further explanation for their rarity might be that the number of femoral neck fractures was actually underenumerated because they were indistinguishable from post-mortem breaks (Mays 1998:177).

Of all skeletal elements, the ribs displayed the highest frequency of fractures, as the prevalence figures in table 7.8 demonstrate. A total of 339 fractures were identified in 139 individuals. Rib fractures tend to arise from falls or a direct blow to the ribcage (Roberts and Manchester 1995:77). They are often associated with underlying osteoporosis, and they can even be caused by coughing or sneezing, particularly in old age as the chest wall becomes increasingly rigid (Stroud and Kemp 1993:226). However, neither sex displayed a consistently higher prevalence of rib fractures across the cemeteries. A greater proportion of females were affected by rib fractures in three assemblages: Ipswich, St Nicholas Shambles and Fishergate 6. A greater percentage of males were affected among the early phase of Fishergate, and a considerably higher percentage of males were affected in the cemeteries of Wharram Percy and Abingdon. The relationship between sex and rib fractures in the latter two cemeteries was statistically significant (Wharram Percy χ^2=10.621 p=.001; Abingdon χ^2=5.499 p=.020), and the comparatively high prevalence among males from these large collections probably contributed substantially to the overall male predominance in the pooled cemetery data. The relationship between sex and rib fractures was statistically significant within the pooled sample (χ^2=5.811 p=.016), in which 14.5% of males were affected compared with 9.6% of females. The raised prevalence of rib fractures among males is consistent with their generally higher frequency of trauma, both from accidental and violent causes.

The frequency of vertebral compression fractures was low, and neither sex displayed a consistently higher prevalence across the cemeteries, as indicated by the results in table 7.9. A higher percentage of females were affected within the collections from Ipswich and Fishergate 4, and a higher percentage of males were affected within the collections from Wharram Percy, Abingdon and Fishergate 6. The male prevalence exceeded that of females when the data from all cemeteries were combined, with 4.6% and 3.2% of the pooled male and female samples affected respectively. In addition to bone weakness caused by osteoporosis, compression fractures can arise from vertical force flexion-compression injury to the spine, such as by jumping from a height or riding over rough terrain (Mays 1998:162; Merbs 1983; Roberts and Manchester 1995:78; Snell 1973:840). Again, the slightly greater percentage of males affected overall is consistent with their generally greater experience of trauma.

The male and female prevalence of spondylolysis/spondylolisthesis was also low, as indicated in table 7.10. The majority of cases exhibited spondylolysis, with only five individuals displaying spondylolisthesis, two of which were male and three female. As expected, the fifth lumbar was the vertebra most commonly affected by both variants of the condition, followed by the fourth lumbar. Neither sex showed a consistently higher prevalence throughout the respective cemetery assemblages. The percentage of males affected exceeded that of females in the cemeteries from Ipswich, Wharram Percy and Fishergate 6; and a higher percentage of females were affected in the assemblages from Abingdon and Fishergate 4. Within the pooled cemetery sample, 5.7% of males and 5.0% of females were affected. Considering that strenuous bending and lifting has been implicated as an important aetiological factor, the similarity in the percentage of males and females affected suggests that both sexes were likely to have engaged in this type of activity. The similarity in prevalence may also have arisen from a similar genetic predisposition for the condition.

The frequency of fractures occurring in other skeletal components was too low to draw further inferences about the distribution of fractures in males and females, as illustrated by the results in table 7.11. As with the dearth of femoral neck fractures, the lack of wrist fractures was notable, with only one case, a male, identified in the entire medieval sample.

As the results in table 7.12 demonstrate, neither sex displayed a consistently higher prevalence of individuals with multiple fractures across the respective cemetery collections. An equally low percentage of males and females were affected in the Jewbury assemblage. A higher percentage of females had sustained multiple fractures in the collections from Ipswich, Fishergate 4 and St Nicholas Shambles, whereas a higher percentage of males were affected from Wharram Percy, Fishergate 6 and Abingdon. None of these sex differences were statistically significant, except that observed within the assemblage from Wharram Percy (χ^2=6.828 p=.009). A statistically significant relationship between sex and multiple trauma was also identified when the data from all cemeteries were pooled (χ^2=4.573 p=.032); 10.1% of all males were affected compared with 7.1% of females. The higher male prevalence in the three largest assemblages probably contributed to this overall predominance in the pooled sample. During the analysis, it also became apparent that males exhibited a greater number of fractures per individual. For example, of those displaying five or more fractures, 23 were male and only five were female. The greater prevalence of multiple trauma among males either suggests that males were more prone to repeated injury, or were more likely to be involved in serious traumatic events which caused the simultaneous breakage of more than one bone.

The age-specific trauma prevalence figures are presented in tables 7.13-7.16. With regard to the age distribution of injuries caused by blades and projectiles (table 7.13), the majority identified within the assemblage from Fishergate occurred among males aged between 18 and 35. Most of these injuries were fatal, suggesting that it was mostly young males who engaged in armed conflict. The blade injuries evident in the other cemeteries were scattered across all four age groups. Many of these wounds had healed, so it was not possible to draw conclusions about the age at which the injuries were sustained.

The age distribution of fractures which were not inflicted by blades or projectiles displayed a fairly similar pattern in virtually all the male and female samples (table 7.14). Although the trend was somewhat erratic among some of the cemeteries, perhaps due to the relatively low frequency of individuals affected, a general rise in prevalence was observed with increasing age. This probably reflects the cumulative nature of the skeletal fracture record. Fractures occurring in adulthood tend to leave a permanent lesion, and the longer the lifespan, the longer the opportunity for encountering traumatic events. Thus a higher trauma prevalence may be expected with advancing age (Judd and Roberts 1998; Larsen 1997:118; Lovejoy and Heiple 1981; Mays 1998:176). This factor may also have contributed to the overall higher prevalence of fractures observed among males, since the typical age at death among males slightly exceeded that of females (see chapter 5); although the male bias in trauma prevalence was corroborated by the age-specific analysis, as males tended to display a higher prevalence of trauma in the majority of cohorts.

Despite the fairly erratic age rise in the percent affected by fractures in some samples, a marked rise in fracture prevalence was not detected among any of the male or female age categories from the respective cemeteries which may have been suggestive of a group at particular risk of injury. However, a slight sex difference was noted in the pattern of the age increase within the pooled site data, perhaps only apparent due to its larger size. Males displayed a steady increment in the percent affected by fractures, rising by approximately 8% with each successive age category. This steady accumulation with age suggests that the male risk of fracture was fairly constant in each cohort (Lovejoy and Heiple 1981; Mays 1998:176). The females, however, displayed a more exponential-type rise in fracture prevalence. A 3.6% increment was observed among females aged *c.*25-35 compared with those aged *c.*18-25. The difference rose by 6.8% in the following age category, and there was a 10.3% increase in the percentage exhibiting fractures in the eldest group (>*c.*45 years) compared with those aged *c.*35-45. This suggests that females were at an increased risk of fracture with advancing age. One possible explanation could be that females were more susceptible to fractures associated with the age-related reduction in bone mass.

These variations between the male and female rise in fracture prevalence had an effect on the sex difference in fracture prevalence within the respective age groups of the pooled site data. The sexes displayed an almost identical prevalence in the youngest group, comprised of skeletons estimated to be between *c.*18-25 years. Approximately 8% of males and females were affected. This was somewhat surprising as it might have been expected that the male bias in trauma would be most distinct in this age group, if it is assumed that young males were among the most physically active. One possible explanation could be that young females experienced a similarly arduous lifestyle which placed them at an equivalent risk of trauma. This interpretation would tend to support Goldberg's argument for a companionate late marriage regime, discussed in section 5.3, in which he contends that females as well as males often remained single until their mid-twenties, following a period of active participation in the labour force and financial independence. Continuing this argument, it might tentatively be inferred that after marriage, and presumably parenthood, the female role in the most physically demanding occupations diminished relative to that of males. If males did take on a greater proportion of the most strenuous activities, they may have been placed at an increased risk of injury. This is in fact consistent with the pooled site trauma data. The sex difference in the percentage affected by fractures became increasingly divergent in the two succeeding age classes. Among those aged *c.*25-35, 16.7% of males and 11.9% of females displayed fractures, which amounted to a sex difference of 4.8%. Among those aged *c.*35-45, 24.3% of males and 18.7% of females displayed fractures, giving a sex difference of 5.6%. The age rise in fractures among females does nevertheless indicate that females continued to be involved in activities which carried a substantial risk of injury. The comparatively large rise in female fractures in the most elderly group, aged over *c*.45, served to close the gap between the percentage of males and females affected: 31.3% of males and 29.0% of females displayed fractures, giving a sex difference of just 2.3%. This could either suggest that females resumed higher risk activities with advancing age, or that they were at an increased risk of pathological fractures associated with osteoporosis. The age distribution of vertebral compression fractures provided a little evidence to support the latter interpretation (table 7.16), as despite the overall higher prevalence of vertebral compression fractures in males, a fractionally higher percentage of females were affected in the eldest group of the pooled site data, and three of the four cemeteries in which this type of fracture was identified in the most elderly. However, the age distribution of rib fractures, which may also occur in association with reduced bone mass, did not display this pattern, the proportion of males affected being greater in most age groups of the respective cemetery samples and the pooled site data (table 7.15). This could either be taken as evidence to diminish the importance of reduced bone mass on female fracture prevalence, or it may be that males were at a substantially increased risk of rib fracture from violent or accidental causes which served to obscure any potential sex difference in pathological rib fractures. The fact that the prevalence of fractures among elderly females did not actually surpass that of males, perhaps suggests that the influence of osteoporosis on fracture rate should not be overplayed. This is supported by the general lack of femoral neck and wrist fractures. Commenting on the lack of femoral neck fractures among the Wharram Percy collection compared with the relatively high prevalence today, Mays (1998:177) has suggested that the 'consequences of osteoporosis would have been much less serious for the medieval people'. However, it should be emphasised that the observations, and hence interpretations, drawn from the pooled site data may be unique to the composition of the sample. Further research would be necessary to determine whether they are a general characteristic of medieval material.

The virtual absence of broken bones among the sexed subadults from Abingdon and Fishergate need not necessarily imply that these individuals escaped bone fractures. They may have sustained greenstick fractures, characteristic of immature bone, which tend to heal without trace (Roberts and Manchester 1995:73). Alternatively, if the lack of fractures is a true reflection of the subadult experience, it could either testify to the greater resilience of immature bone to fracture, or more likely, imply that subadults were exposed to a lower risk of fracture than their adult counterparts. The latter interpretation would indicate that subadults were protected from many of the rigours of adult life, at least in terms of workload. This would tend to repudiate Ariès' thesis that 'In medieval society the idea of childhood did not exist' (Ariès 1962:125); and that of his supporters such as Shorter (1977:169), Stone (1979:57, 65, 82-83) and to a certain extent Schultz (1991). Instead, it would lend support to the majority who believe that medieval society viewed childhood, and probably adolescence, as developmental phases that were distinct from adulthood (e.g. DeMaitre 1976-7; Forsyth 1976-7; Hanawalt 1986:187; 1993:7-8, 89; Herlihy 1995; Holmes 1968-9; Maddern 1996; McLaughlin 1976; Nicholas 1985:109, 208; Orme 1995; Shahar 1992:1; Stuard 1992; Wilson 1984). It would also tend to support the view that physical abuse was not widely inflicted upon children (Kroll and Bachrach 1986). This is consistent with the general lack of evidence for infanticide (see section 5.3). However, the lack of skeletal trauma does not negate the probability that subadults sustained injuries. Soft tissue injury, whether deliberate or accidental, largely evades the skeletal record, but historical evidence may provide some insight into the trauma patterns sustained by subadults.

There is ample anecdotal evidence to suggest that male and female children were exposed to different trauma risks. Contemporary sources refer to boys partaking in energetic games and mock battles, committing vandalism, hunting for birds, cockfighting, and training for apprenticeships (Forsyth 1976-7; Orme 1995; Shahar 1992:26, 238). Bernard Gordon, a fourteenth century scholar, comments on how boys aged between seven and fourteen 'begin to run and jump and to hit each other' and therefore describes this phase as 'the age of concussion' (DeMaitre 1976-7; Shahar 1992:26). However, Orme (1995) urges caution over the use of contemporary references for inferring gender-related activity patterns because the sources frequently overlook the activities of girls. Even when the inclusive term *pueri* (children) is used, the writer is often really only referring to boys. Furthermore, adults' descriptions of children are often biased by their own pre-conceived ideas, with boys tending to be described in terms of their behaviour and activities, and girls by their character and physical traits

(Orme 1995; Shahar 1992:26). Orme (1995:50) commends coroners' records as providing the most 'dispassionate accounts' of boys' and girls' activities, and cites Hanawalt's research.

As with the accident record for adults, Hanawalt's (1977) coroners' roll study suggests that there were sex differences in the subadult trauma experience, even though this has eluded the skeletal record. The sex difference was even apparent among children aged between just one and three years. For example, 27% of the girls in Hanawalt's sample died in accidents while playing with pots or cauldrons compared with only 14% of boys; whereas 64% of boys were involved in water related accidents outside the home compared with 44% of girls. Hanawalt draws parallels with modern data which show that male children predominate in drownings and fatal accidents during ventures outside the home. Hanawalt notes that most of the accidents occurring in this age group arose through an inquisitive interest in the environment combined with inadequate motor skills, but suggests that the gender differences indicate children identified with the gender roles of their parents from a very young age, girls tending to imitate their mothers by cooking, and boys following their fathers about their tasks.

The number of accidents fell markedly among both girls and boys aged between four and seven. Hanawalt attributes this to greater child mobility which enabled children to accompany their parents and so receive more adult supervision. However, Hanawalt emphasises that 'Contrary to Ariès' assumption that the children suddenly became productive, their accident pattern indicates that they were doing little work. Their misadventures were still almost entirely related to playing children's games. The work which they did perform must have been rather minimal: some herding, babysitting, and perhaps some work in the family gardens' (p.18). It was in the cohort aged eight to twelve that the accident pattern of boys and girls started to resemble that of their adult counterparts, as they grew independent from adults and were assigned their own tasks. The accident record suggests that girls took care of children, gathered wood and worked in the fields at harvest. Boys acted as shepherds and assisted with milling and reaping. In urban society, boys sold goods in the street and took up apprenticeships. Hanawalt states that 'their tasks show that they were moving into adult life and were being trained for the work they would eventually perform as men'. However, Hanawalt's study indicates that children only began to assume an adult workload gradually, and this is consistent with the scarcity of trauma in the subadult skeletal record. It might be expected that fractures would become more prevalent with increasing age, especially in the teenage years, although the sexed skeletal sample was particularly small for this age group and perhaps insufficient for a trauma pattern to emerge.

It was apparent from this study that differences existed between the trauma patterns of the various cemetery collections. Males from the pre-monastic phase of Fishergate displayed by far the greatest prevalence of weapon injuries (table 7.2). Kemp (1993:127) has suggested that the affected individuals may have been casualties of a battle, especially as several had been interred in double graves. The highest prevalence of non-weapon injuries, including cranio-facial, long-bone, rib and multiple fractures, occurred in the Abingdon assemblage (tables 7.1, 7.3-7.6, 7.8, 7.9, 7.11, 7.12). Males from Abingdon displayed a higher non-weapon trauma prevalence than any other group, and the female prevalence surpassed that of all the male and female samples from the other cemeteries (table 7.4). Wakely (1996; pers. comm) has remarked on the high prevalence of trauma within the Abingdon collection, including individuals with multiple fractures, and considered the possibility that it may be related to two historically documented incidents of major civil rioting which took place in Abingdon during 1327 and 1431 (Townsend 1910:31-36). However, Wakely emphasises that without further evidence to connect the material to specific historical events, and in the absence of widespread trauma blatantly attributable to violence, such as the weapon injuries observed within the Fishergate assemblage, it is not possible to demonstrate that violence was an important contributory factor in the Abingdon trauma pattern, let alone named conflicts. As the cemetery received burials from the rural manors surrounding Abingdon (see section 2.5), Wakely has suggested that the high trauma prevalence could be a reflection a physically arduous lifestyle, perhaps characteristic of a rural society, and contrasts Abingdon with the scarcity of trauma evident among the assemblage from St Nicholas Shambles, London. White (1988:44) proposes that the lack of trauma at St Nicholas Shambles 'may reflect the advantages of urban life' compared with the 'higher risk activities of rural areas'. The crude prevalence results for non-weapon injuries in this study confirm the disparity in trauma prevalence between Abingdon and St Nicholas Shambles: 35.4% of males and 28.1% of females from Abingdon displayed fractures compared with only 9.9% of males and 6.8% of females from St Nicholas Shambles (table 7.4). St Nicholas

Shambles displayed the second lowest crude prevalence of trauma of all the medieval collections. The crude prevalence of non-weapon injuries at Wharram Percy lends further support to the idea that rural communities were at an elevated risk of trauma. Wharram Percy followed Abingdon in the proportion of individuals affected by non-weapon injuries: 24.5% of males and 18.6% of females displayed lesions (table 7.4). Males and females from Abingdon and Wharram Percy also displayed a comparatively high prevalence of spondylolysis/spondylolisthesis (table 7.10), which could be interpreted as further evidence for a physically demanding rural lifestyle.

However, closer examination of the data reveals inconsistencies in this apparent urban/rural dichotomy. Firstly, the percentage of males and females affected by non-weapon injuries from Ipswich and both phases of Fishergate approached that of Wharram Percy, yet these collections were not derived from rural cemeteries (table 7.4). Secondly, the cemetery hierarchy for the proportion of fractured long bones differed from that of the crude prevalence (tables 7.6a-g). While Abingdon prevailed as the site with the highest proportion of fractured long bones, the position of Wharram Percy was inverted, displaying the lowest proportion of fractured long bones of all the cemeteries. Male long bones from St Nicholas Shambles displayed the third highest fracture prevalence, although the percentage of fractured female bones remained low, displaying the second lowest prevalence. These results suggest that the crude prevalence figures may have been influenced by sample preservation. Like the results of the periostitis analysis, discussed in section 6.5.3, this would confirm the value of computing the corrected prevalence statistic. The disparities in the results also indicate that the observed differences between the cemeteries may have been a product of a complex of factors, so it may not be possible to attribute the differences to a single, broad cause such as an urban/rural divide.

A further observation concerning the inter-site differences was that Jewbury appeared to deviate from the other cemeteries in its pattern of trauma. The crude trauma prevalence was particularly low (table 7.1). Only nine males and eleven females displayed fractures, which amounted to just 5.6% and 7.3% of the male and female samples respectively. These frequencies fell to four males and six females, or 2.5% and 4.0% of the male and female samples, when those exhibiting solely blade or cranial injuries were excluded from the calculation (table 7.5). One possible explanation could be that the material was not examined as rigorously as the other assemblages owing to the haste with which it had to be reburied, and this may have led to an underestimate of the true prevalence. The published cemetery report does state that rib fractures were not recorded (Lilley *et al.* 1994:486), presumably due to a lack of time, and rib fractures constituted a considerable proportion of trauma in most of the other collections. Nevertheless, the report does comment on the 'surprisingly low number of fractured bones in the Jewbury sample' (Lilley *et al.* 1994:486), which conveys the impression that the actual prevalence was relatively low. This would suggest that the individuals buried at Jewbury were exposed to a reduced risk of trauma compared with those interred in the other cemeteries. It may be of relevance that one of the many restrictions imposed upon the Jews of medieval England was prohibition from most occupations. Mitchell and Leys (1967:159) explain that 'Membership of a gild and the holding of any municipal office was dependent upon an oath that no Jew could take, so he was automatically ruled out from every form of trade, and his only means of livelihood was to finance building and other enterprises for those who had no capital'. Mitchell and Leys (1967:162) concede that 'Not every Jew was a money-lender; some dealt in jewellery and precious stones, occasionally we find a scribe, and there were physicians of Jewish race in both London and King's Lynn, but the very large majority of Jews in England were usurers or pawnbrokers or both'. In an overview of the development of Jewish settlement in York prior to the massacre of 1190 (see sections 2.4 and 5.3), Dobson (1974:14) is also of the opinion that the Jewish community was 'dominated by a small and closely integrated elite of money-lenders and dealers in bonds'. Indeed, Dobson contends that much of the anti-Semitic fervour which developed at the time did not originate on religious grounds *per se*, but was stirred up by the aristocracy because they could not, or would not, honour their debts. Dobson assents that from the reign of Henry II (1154-1189) onwards, some Jews in York were probably involved in other professions, acting as pedlars, physicians and landlords for example, but believes that 'it seems highly unlikely that any activity other than that of money-lending on a massive scale could account for the emergence of a really substantial Jewish community' in York (Dobson 1974:7). It is therefore tempting to suggest that the employment restrictions imposed on the Jewish community may actually have afforded some protection against the hazards which accompanied many of the more physically strenuous occupations, and this may have contributed to the low prevalence of trauma within the Jewbury cemetery. It might also explain why Jewbury was the only cemetery in which the percentage of males displaying fractures was actually lower than the percentage of females, as the exclusion of males from high risk occupations may have resulted in a disproportionate reduction in male trauma. Jewbury was also the only cemetery to contain a similar frequency of males and females with blade injuries. Three females and two males had sustained blade injuries to the skull and another male exhibited multiple cuts to the left tibia. Again, it is tempting to suggest that these wounds might in some way be related to the historically documented acts of anti-Semitism that were perpetrated against females as well as males (Dobson 1974; Mitchell and Leys 1967:158-162). However, it must of course be emphasised that all these connections between archaeological and historical evidence are no more than pure speculation. Furthermore, as with the other cemeteries, it may be too simplistic to attempt to attribute the trauma pattern observed within the Jewbury assemblage to a single, and perhaps the most obvious cause, such as its Jewish heritage.

Table 7.1 Proportion of individuals displaying fractures within the male and female cemetery samples (crude prevalence)

n_f number of individuals displaying fractures (all types) n_t total number of individuals in sample
% percentage of sample displaying fractures χ^2 chi-square statistic p probability

	Males		Females			
	n_f n_t	%	n_f n_t	%	χ^2	p
Wharram	53/212	25.0	25/129	19.4	1.436	.231
Ipswich	38/146	26.3	12/64	18.8	1.299	.254
Abingdon	85/223	38.1	48/171	28.1	4.368	.037
St Nicholas	10/91	11.0	5/74	6.8	.885	.347
Fishergate 4	26/47	55.3	5/33	15.2	13.179	.000
Fishergate 6	52/176	29.6	7/53	13.2	5.685	.017
Jewbury	9/161	5.6	11/150	7.3	.392	.531
Pooled site data	273/1056	25.9	113/674	16.8	19.597	.000

Table 7.2 Proportion of individuals displaying blade or projectile injuries within the male and female cemetery samples

n_f number of individuals displaying blade or projectile injuries n_t total number of individuals in sample
% percentage of sample displaying blade or projectile injuries χ^2 chi-square statistic p probability

	Males		Females			
	n_f n_t	%	n_f/n_t	%	χ^2	p
Wharram	3/212	1.4	1/129	0.8	.283	.595
Ipswich	5/146	3.4	0/64	0.0	2.245	.134
Abingdon	7/223	3.1	0/171	0.0	5.465	.019
St Nicholas	1/91	1.1	0/74	0.0	.818	.366
Fishergate 4	18/47	38.3	0/33	0.0	16.307	.000
Fishergate 6	12/176	6.8	0/53	0.0	3.813	.051
Jewbury	3/161	1.9	3/150	2.0	.008	.930
Pooled site data	49/1056	4.6	4/674	0.6	22.859	.000

Table 7.3 Proportion of individuals with crania displaying cranio-facial fractures (not caused by blades or projectiles) within the male and female cemetery samples

n_f number of individuals displaying cranio-facial fractures n_t total number of individuals with crania in the sample % percentage of sample displaying fractures χ^2 chi-square statistic p probability

	Males		Females			
	n_f n_t	%	n_f/n_t	%	χ^2	p
Wharram	4/166	2.4	0/113	0.0	2.762	.096
Ipswich	2/126	1.6	0/54	0.0	.867	.352
Abingdon	7/126	5.6	3/98	3.1	.804	.370
St Nicholas	0/33	0.0	0/44	0.0	-	-
Fishergate 4	1/35	2.9	0/23	0.0	.669	.414
Fishergate 6	0/118	0.0	0/38	0.0	-	-
Jewbury	2/122	1.6	1/107	0.9	.219	.640
Pooled site data	16/726	2.2	4/477	0.8	3.282	.070

Table 7.4 Proportion of individuals within the male and female cemetery samples displaying fractures which were not inflicted using blades or projectiles

n_f number of individuals displaying fractures n_t total number of individuals in sample
% percentage of sample displaying fractures χ^2 chi-square statistic p probability

	Males		Females			
	n_f n_t	%	n_f n_t	%	χ^2	p
Wharram	52/212	24.5	24/129	18.6	1.625	.202
Ipswich	33/146	22.6	12/64	18.8	.392	.531
Abingdon	79/223	35.4	48/171	28.1	2.397	.122
St Nicholas	9/91	9.9	5/74	6.8	.516	.473
Fishergate 4	10/47	21.3	5/33	15.2	.477	.490
Fishergate 6	41/176	23.3	7/53	13.2	2.502	.114
Jewbury	6/161	3.7	8/150	5.3	.466	.495
Pooled site data	230/1056	21.8	109/674	16.2	8.213	.004

Table 7.5 Proportion of individuals displaying fractures within the male and female cemetery samples, excluding weapon injuries and/or cranio-facial injuries as positive identifications

n_f number of individuals displaying fractures n_t total number of individuals in sample
% percentage of sample displaying fractures χ^2 chi-square statistic p probability

	Males		Females			
	n_f n_t	%	n_f n_t	%	χ^2	p
Wharram	50/212	23.6	24/129	18.6	1.171	.279
Ipswich	31/146	21.2	12/64	18.8	.168	.681
Abingdon	74/223	33.2	47/171	27.5	1.477	.224
St Nicholas	9/91	9.9	5/74	6.8	.516	.473
Fishergate 4	9/47	19.2	5/33	15.2	.215	.643
Fishergate 6	41/176	23.3	7/53	13.2	2.502	.114
Jewbury	4/161	2.5	6/150	4.0	.573	.449
Pooled site data	218/1056	20.6	106/674	15.7	6.535	.011

Tables 7.6a-g Corrected prevalence of fractures among male and female long bones

(a) Wharram Percy

n_f number of long bones displaying fractures n_t total number of long bones in sample
% percentage of long bones displaying fractures

	Males		Females	
	n_f n_t	%	n_f n_t	%
Right Clavicle	1/120	0.8	0/93	0.0
Left Clavicle	4/125	3.2	1/93	1.1
Right Humerus	0/139	0.0	1/101	1.0
Left Humerus	0/128	0.0	0/106	0.0
Right Radius	0/126	0.0	0/93	0.0
Left Radius	0/128	0.0	0/97	0.0
Right Ulna	0/134	0.0	0/91	0.0
Left Ulna	2/130	1.5	0/98	0.0
Right Femur	0/138	0.0	0/95	0.0
Left Femur	0/146	0.0	0/92	0.0
Right Tibia	1/128	0.8	0/84	0.0
Left Tibia	0/123	0.0	1/84	1.2
Right Fibula	1/119	0.8	0/78	0.0
Left Fibula	2/113	1.8	2/80	2.5
Total long bones	11/1797	0.6	5/1285	0.4

(b) Ipswich Blackfriars

n_f number of long bones displaying fractures n_t total number of long bones in sample
% percentage of long bones displaying fractures

	Males		Females	
	n_f n_t	%	n_f n_t	%
Right Clavicle	0/113	0.0	0/52	0.0
Left Clavicle	0/113	0.0	1/52	1.9
Right Humerus	1/122	0.8	0/54	0.0
Left Humerus	1/121	0.8	0/55	0.0
Right Radius	2/121	1.7	1/56	1.8
Left Radius	2/120	1.7	1/57	1.8
Right Ulna	0/126	0.0	0/54	0.0
Left Ulna	0/122	0.0	1/53	1.9
Right Femur	2/129	1.6	0/59	0.0
Left Femur	0/130	0.0	0/58	0.0
Right Tibia	1/128	0.8	0/58	0.0
Left Tibia	1/134	0.7	0/58	0.0
Right Fibula	0/119	0.0	0/53	0.0
Left Fibula	1/122	0.8	0/52	0.0
Total long bones	11/1720	0.6	4/771	0.5

(c) Abingdon

n_f number of long bones displaying fractures n_t total number of long bones in sample
% percentage of long bones displaying fractures

	Males		Females	
	n_f n_t	%	n_f n_t	%
Right Clavicle	5/140	3.6	2/103	1.9
Left Clavicle	1/140	0.7	1/102	1.0
Right Humerus	1/154	0.6	0/108	0.0
Left Humerus	1/153	0.7	0/118	0.0
Right Radius	1/158	0.6	1/105	1.0
Left Radius	5/157	3.2	3/117	2.6
Right Ulna	3/157	1.9	2/110	1.8
Left Ulna	3/160	1.9	4/120	3.3
Right Femur	0/162	0.0	3/116	2.6
Left Femur	0/168	0.0	0/131	0.0
Right Tibia	5/159	3.1	2/119	1.7
Left Tibia	3/157	1.9	1/122	0.8
Right Fibula	4/150	2.7	1/114	0.9
Left Fibula	3/153	2.0	1/121	0.8
Total long bones	35/2168	1.6	21/1606	1.3

(d) St Nicholas

n_f number of long bones displaying fractures n_t total number of long bones in sample
% percentage of long bones displaying fractures

	Males		Females	
	n_f n_t	%	n_f n_t	%
Right Clavicle	1/38	2.6	0/43	0.0
Left Clavicle	0/36	0.0	1/37	2.7
Right Humerus	0/51	0.0	0/46	0.0
Left Humerus	0/41	0.0	1/39	2.6
Right Radius	2/45	4.4	1/45	2.2
Left Radius	0/41	0.0	0/39	0.0
Right Ulna	0/47	0.0	0/48	0.0
Left Ulna	0/40	0.0	0/40	0.0
Right Femur	0/53	0.0	0/49	0.0
Left Femur	0/47	0.0	0/39	0.0
Right Tibia	2/39	5.1	0/35	0.0
Left Tibia	0/39	0.0	0/29	0.0
Right Fibula	0/36	0.0	0/31	0.0
Left Fibula	0/36	0.0	0/27	0.0
Total long bones	5/589	0.8	3/547	0.5

(e) Fishergate 4

n_f number of long bones displaying fractures n_t total number of long bones in sample
% percentage of long bones displaying fractures

	Males		Females	
	n_f n_t	%	n_f n_t	%
Right Clavicle	0/36	0.0	0/22	0.0
Left Clavicle	0/36	0.0	0/20	0.0
Right Humerus	0/40	0.0	0/23	0.0
Left Humerus	0/38	0.0	0/25	0.0
Right Radius	0/40	0.0	1/24	4.2
Left Radius	0/38	0.0	2/24	8.3
Right Ulna	0/39	0.0	0/26	0.0
Left Ulna	0/38	0.0	1/26	3.8
Right Femur	0/40	0.0	0/22	0.0
Left Femur	0/42	0.0	0/23	0.0
Right Tibia	0/38	0.0	0/22	0.0
Left Tibia	0/38	0.0	0/21	0.0
Right Fibula	0/39	0.0	0/18	0.0
Left Fibula	2/36	5.6	0/21	0.0
Total long bones	2/538	0.4	4/317	1.3

(f) Fishergate 6

n_f number of long bones displaying fractures n_t total number of long bones in sample
% percentage of long bones displaying fractures

	Males		Females	
	n_f n_t	%	n_f n_t	%
Right Clavicle	0/119	0.0	1/40	2.5
Left Clavicle	1/124	0.8	0/39	0.0
Right Humerus	0/127	0.0	0/38	0.0
Left Humerus	2/136	1.5	0/38	0.0
Right Radius	0/135	0.0	0/36	0.0
Left Radius	2/139	1.4	0/38	0.0
Right Ulna	2/128	1.6	1/36	2.8
Left Ulna	0/140	0.0	0/38	0.0
Right Femur	0/150	0.0	0/43	0.0
Left Femur	0/146	0.0	0/44	0.0
Right Tibia	3/138	2.2	0/42	0.0
Left Tibia	2/141	1.4	1/44	2.3
Right Fibula	3/131	2.3	0/41	0.0
Left Fibula	3/136	2.2	1/43	2.3
Total long bones	18/1890	1.0	4/560	0.7

(g) Pooled Site Data

n_f number of long bones displaying fractures n_t total number of long bones in sample
% percentage of long bones displaying fractures

	Males		Females	
	n_f/n_t	%	n_f/n_t	%
Right Clavicle	7/566	1.2	3/353	0.8
Left Clavicle	6/574	1.0	4/343	1.7
Right Humerus	2/633	0.3	1/370	0.3
Left Humerus	4/617	0.6	1/381	0.3
Right Radius	5/625	0.8	4/359	1.1
Left Radius	9/623	1.4	6/372	1.6
Right Ulna	5/631	0.8	3/365	0.8
Left Ulna	5/630	0.8	6/375	1.6
Right Femur	2/672	0.3	3/384	0.8
Left Femur	0/679	0.0	0/387	0.0
Right Tibia	12/630	1.9	2/360	0.6
Left Tibia	6/632	0.9	3/358	0.8
Right Fibula	8/594	1.3	1/335	0.3
Left Fibula	11/596	1.8	4/344	1.2
Total long bones	82/8702	0.9	41/5086	0.8

Tables 7.7a-g Proportional morbidity study for long bone fractures

(a) Wharram Percy

Bone, rank order of long bones displaying fractures *f* frequency of long bones displaying fractures
% proportion of the total number of fractured long bones in the sample, expressed as a percentage

Males			Females		
Bone$_r$	*f*	%	Bone$_r$	*f*	%
Clavicle	5	45.5	Fibula	2	40.0
Fibula	3	27.3	Clavicle	1	20.0
Ulna	2	18.2	Humerus	1	20.0
Tibia	1	9.1	Tibia	1	20.0
Humerus	0	0.0	Radius	0	0.0
Radius	0	0.0	Ulna	0	0.0
Femur	0	0.0	Femur	0	0.0

(b) Ipswich Blackfriars

Bone, rank order of long bones displaying fractures *f* frequency of long bones displaying fractures
% proportion of the total number of fractured long bones in the sample, expressed as a percentage

Males			Females		
Bone$_r$	*f*	%	Bone$_r$	*f*	%
Radius	4	36.4	Radius	2	50.0
Humerus	2	18.2	Clavicle	1	25.0
Femur	2	18.2	Ulna	1	25.0
Tibia	2	18.2	Humerus	0	0.0
Fibula	1	9.1	Femur	0	0.0
Clavicle	0	0.0	Tibia	0	0.0
Ulna	0	0.0	Fibula	0	0.0

(c) Abingdon

Bone, rank order of long bones displaying fractures *f* frequency of long bones displaying fractures
% proportion of the total number of fractured long bones in the sample, expressed as a percentage

Males			Females		
Bone$_r$	*f*	%	Bone$_r$	*f*	%
Tibia	8	22.9	Ulna	6	28.6
Fibula	7	20.0	Radius	4	19.1
Clavicle	6	17.1	Clavicle	3	14.3
Radius	6	17.1	Femur	3	14.3
Ulna	6	17.1	Tibia	3	14.3
Humerus	2	5.7	Fibula	2	9.5
Femur	0	0.0	Humerus	0	0.0

(d) St Nicholas Shambles

Bone, rank order of long bones displaying fractures *f* frequency of long bones displaying fractures
% proportion of the total number of fractured long bones in the sample, expressed as a percentage

Males			Females		
Bone,	*f*	%	Bone,	*f*	%
Radius	2	40.0	Clavicle	1	33.3
Tibia	2	40.0	Humerus	1	33.3
Clavicle	1	20.0	Radius	1	33.3
Humerus	0	0.0	Ulna	0	0.0
Ulna	0	0.0	Femur	0	0.0
Femur	0	0.0	Tibia	0	0.0
Fibula	0	0.0	Fibula	0	0.0

(e) Fishergate 4

Bone, rank order of long bones displaying fractures *f* frequency of long bones displaying fractures
% proportion of the total number of fractured long bones in the sample, expressed as a percentage

Males			Females		
Bone,	*f*	%	Bone,	*f*	%
Fibula	2	100.0	Radius	3	75.0
Clavicle	0	0.0	Ulna	1	25.0
Humerus	0	0.0	Clavicle	0	0.0
Radius	0	0.0	Humerus	0	0.0
Ulna	0	0.0	Femur	0	0.0
Femur	0	0.0	Tibia	0	0.0
Tibia	0	0.0	Fibula	0	0.0

(f) Fishergate 6

Bone, rank order of long bones displaying fractures *f* frequency of long bones displaying fractures
% proportion of the total number of fractured long bones in the sample, expressed as a percentage

Males			Females		
Bone,	*f*	%	Bone,	*f*	%
Fibula	6	33.3	Clavicle	1	25.0
Tibia	5	27.8	Ulna	1	25.0
Humerus	2	11.1	Tibia	1	25.0
Radius	2	11.1	Fibula	1	25.0
Ulna	2	11.1	Humerus	0	0.0
Clavicle	1	5.6	Radius	0	0.0
Femur	0	0.0	Femur	0	0.0

(g) Pooled site data

Bone, rank order of long bones displaying fractures *f* frequency of long bones displaying fractures
% proportion of the total number of fractured long bones in the sample, expressed as a percentage

Males			Females		
Bone,	*f*	%	Bone,	*f*	%
Tibia	18	22.0	Radius	10	24.4
Fibula	19	23.2	Ulna	9	22.0
Radius	14	17.1	Clavicle	7	17.1
Clavicle	13	15.9	Tibia	5	12.2
Ulna	10	12.2	Fibula	5	12.2
Humerus	6	7.3	Femur	3	7.3
Femur	2	2.4	Humerus	2	4.9

Table 7.8 Proportion of individuals with ribs displaying rib fractures within the male and female cemetery samples

n_f number of individuals displaying rib fractures (bracketed figures represent the number of fractures identified) n_t total number of individuals with ribs in the sample
% percentage of sample with ribs displaying rib fractures χ^2 chi-square statistic p probability

	Males		Females			
	n_f n_t	%	n_f n_t	%	χ^2	p
Wharram	25/156 (50)	16.0	4/113 (7)	3.5	10.621	.001
Ipswich	7/115 (20)	6.1	5/50 (11)	10.0	.791	.374
Abingdon	46/159 (135)	28.9	22/128 (54)	17.2	5.499	.020
St Nicholas	2/64 (2)	3.1	2/58 (2)	3.5	.010	.920
Fishergate 4	4/42 (7)	9.5	1/27 (1)	3.7	.828	.363
Fishergate 6	15/146 (38)	10.3	6/43 (12)	14.0	.455	.500
Pooled site data	99/682 (252)	14.5	40/419 (87)	9.6	5.811	.016

Table 7.9 Proportion of individuals with vertebrae displaying vertebral compression fractures within the male and female cemetery samples

n_f number of individuals displaying compression fractures (bracketed figures represent the number of vertebrae affected) n_t total number of individuals with vertebrae in the sample
% percentage of sample with vertebrae displaying compression fractures

	Males		Females	
	n_f n_t	%	n_f n_t	%
Wharram	7/175 (15)	4.0	3/123 (5)	2.4
Ipswich	6/128 (11)	4.7	4/60 (6)	6.7
Abingdon	11/175 (19)	6.3	6/133 (8)	4.5
St Nicholas	0/57	0.0	0/55	0.0
Fishergate 4	1/40 (2)	2.5	1/27 (1)	3.7
Fishergate 6	8/147 (8)	5.4	0/41	0.0
Pooled site data	33/722 (55)	4.6	14/439 (20)	3.2

Table 7.10 Proportion of individuals with vertebrae displaying spondylolysis/spondylolisthesis within the male and female cemetery samples

n_f number of individuals displaying spondylolysis/spondylolisthesis n_t total number of individuals with vertebrae in sample % percentage of sample with vertebrae displaying spondylolysis/spondylolisthesis

	Males		Females	
	n_f n_t	%	n_f/n_t	%
Wharram	17/175	9.7	8/123	6.5
Ipswich	11/128	8.6	3/60	5.0
Abingdon	8/175	4.6	10/133	7.5
St Nicholas	0/57	0.0	0/55	0.0
Fishergate 4	0/40	0.0	1/27	3.7
Fishergate 6	5/147	3.4	0/41	0.0
Pooled site data	41/722	5.7	22/439	5.0

Table 7.11 Proportion of individuals displaying fractures in other skeletal components

n_f number of individuals displaying fractures n_t total number of individuals with the relevant skeletal component represented % percentage of sample with the relevant skeletal component displaying fractures

		Males		Females	
		n_f n_t	%	n_f n_t	%
Wharram	Sternum	0/131	0.0	0/95	0.0
	Hands	5/148	3.4	4/112	3.6
	Pelvis	0/119	0.0	0/85	0.0
	Feet	6/114	5.3	3/82	3.7
Ipswich	Sternum	1/91	1.1	0/43	0.0
	Hands	2/146	1.4	1/64	1.6
	Pelvis	1/118	0.8	0/52	0.0
	Feet	2/129	1.6	0/60	0.0
Abingdon	Sternum	1/134	0.7	0/107	0.0
	Scapulae	3/157	1.9	0/114	0.0
	Wrists	1/167	0.6	0/128	0.0
	Hands	4/161	2.5	2/125	1.6
	Pelvis	1/169	0.6	1/128	0.8
	Feet	2/146	1.4	1/117	0.9
St Nicholas	Feet	1/32	3.1	1/19	5.3
Fishergate 4	Scapulae	0/30	0.0	1/19	5.3
	Hands	2/40	5.0	2/23	8.7
	Feet	2/37	5.4	1/19	5.3
Fishergate 6	Scapulae	1/107	0.9	1/27	3.7
	Hands	2/141	1.4	0/40	0.0
	Pelvis	1/145	0.7	0/42	0.0
	Feet	6/129	4.7	0/47	0.0

Table 7.12 Proportion of individuals displaying multiple fractures within the male and female cemetery samples (≥ 2 fractures, excluding weapon injuries)

n_f number of individuals displaying multiple (≥2) fractures n_t total number of individuals in the sample
% percentage of sample displaying multiple (≥2) fractures

	Males		Females			
	n_f/n_t	%	n_f/n_t	%	χ^2	p
Wharram	26/212	12.3	5/129	3.9	6.828	.009
Ipswich	12/146	8.2	8/64	12.5	.946	.331
Abingdon	43/223	19.3	25/171	14.6	1.473	.225
St Nicholas	0/91	0.0	1/74	1.4	1.237	.266
Fishergate 4	2/47	4.3	3/33	9.1	.774	.379
Fishergate 6	22/176	12.5	4/53	7.6	.993	.319
Jewbury	2/161	1.2	2/150	1.3	.005	.943
Pooled site data	107/1056	10.1	48/674	7.1	4.573	.032

Table 7.13 Age-specific prevalence of blade/projectile injuries within the male and female cemetery samples

n_f number of individuals in age group displaying blade or projectile injuries n_t total number of individuals in age group
% percentage of age group displaying blade or projectile injuries

		c.18-25		c.25-35		c.35-45		c.>45	
		n_f n_t	%	n_f n_t	%	n_f n_t	%	n_f n_t	%
Wharram	Males	0/31	0.0	1/31	3.2	0/35	0.0	2/75	2.7
	Females	0/24	0.0	0/24	0.0	1/24	4.2	0/43	0.0
Ipswich	Males	0/26	0.0	4/36	11.1	0/33	0.0	1/33	3.0
	Females	0/11	0.0	0/18	0.0	0/8	0.0	0/17	0.0
Abingdon	Males	0/28	0.0	3/47	6.4	2/61	3.3	1/71	1.4
	Females	0/25	0.0	0/47	0.0	0/42	0.0	0/43	0.0
St Nicholas	Males	1/21	4.8	0/21	0.0	0/18	0.0	0/8	0.0
	Females	0/12	0.0	0/28	0.0	0/17	0.0	0/5	0.0
Fishergate 4	Males	9/19	47.4	6/12	50.0	3/9	33.3	0/4	0.0
	Females	0/6	0.0	0/6	0.0	0/10	0.0	0/3	0.0
Fishergate 6	Males	6/24	25.0	4/37	10.8	1/43	2.3	0/50	0.0
	Females	0/3	0.0	0/13	0.0	0/14	0.0	0/13	0.0
Jewbury	Males	1/33	3.0	0/31	0.0	0/40	0.0	2/40	5.0
	Females	1/39	2.6	0/24	0.0	0/35	0.0	1/28	3.6
Pooled site data	Males	17/182	9.3	0/215	0.0	0/239	0.0	6/281	2.1
	Females	1/120	0.8	18/160	11.3	6/150	4.0	1/152	0.7

Table 7.14 Age-specific prevalence of fractures (excluding weapon injuries) within the male and female cemetery samples

n_f number of individuals in age group displaying fractures n_t total number of individuals in age group   % percentage of age group displaying fractures

		c.18-25		c.25-35		c.35-45		c.>45	
		n_f/n_t	%	n_f/n_t	%	n_f/n_t	%	n_f/n_t	%
Wharram	Males	4/31	12.9	4/31	12.9	9/35	25.7	28/75	37.3
	Females	5/24	20.8	3/24	12.5	3/24	12.5	12/43	27.9
Ipswich	Males	1/26	3.8	5/36	13.9	7/33	21.2	7/33	21.2
	Females	2/11	18.2	0/18	0.0	3/8	37.5	5/17	29.4
Abingdon	Males	5/28	17.9	16/47	34.4	23/61	37.7	32/71	45.2
	Females	1/25	4.0	12/47	25.5	13/42	31.0	20/43	46.5
St Nicholas	Males	2/21	9.5	0/21	0.0	2/18	11.1	1/8	12.5
	Females	0/12	0.0	2/28	7.1	2/17	11.8	1/5	20.0
Fishergate 4	Males	1/19	5.3	2/12	16.7	5/9	55.6	1/4	25.0
	Females	0/6	0.0	0/6	0.0	4/10	40.0	1/3	33.3
Fishergate 6	Males	1/24	4.2	9/37	24.3	11/43	25.6	16/50	32.0
	Females	0/3	0.0	1/13	7.7	3/14	21.4	3/13	23.1
Jewbury	Males	1/33	3.0	0/31	0.0	1/40	2.5	3/40	7.5
	Females	2/39	5.1	1/24	4.2	0/35	0.0	2/28	7.1
Pooled site data	Males	15/182	8.2	36/215	16.7	58/239	24.3	88/281	31.3
	Females	10/120	8.3	19/160	11.9	28/150	18.7	44/152	28.9

Table 7.15 Age-specific prevalence of rib fractures among individuals with ribs in the male and female cemetery samples

n_f number of individuals in age group displaying rib fractures n_t total number of individuals with ribs in age group
% percentage of age group with ribs displaying rib fractures

		c.18-25		c.25-35		c.35-45		c.>45	
		n_f n_t	%	n_f n_t	%	n_f n_t	%	n_f n_t	%
Wharram	Males	0/25	0.0	2/21	9.5	2/28	7.1	18/61	29.5
	Females	1/21	4.8	0/19	0.0	0/22	0.0	3/38	7.9
Ipswich	Males	1/22	4.5	2/29	6.9	2/26	7.7	2/26	7.7
	Females	1/10	10.0	0/13	0.0	1/6	16.7	3/12	25.0
Abingdon	Males	2/24	8.3	7/31	22.6	17/41	41.5	20/61	32.8
	Females	1/20	5.0	5/30	16.7	7/36	19.4	9/36	25.0
St Nicholas	Males	1/15	6.7	0/16	0.0	0/13	0.0	0/6	0.0
	Females	0/8	0.0	0/24	0.0	0/14	0.0	0/4	0.0
Fishergate 4	Males	0/19	0.0	1/12	8.3	3/8	37.5	0/3	0.0
	Females	0/6	0.0	0/6	0.0	0/10	0.0	1/2	50.0
Fishergate 6	Males	0/19	0.0	1/34	2.9	3/39	7.7	11/47	23.4
	Females	0/3	0.0	0/13	0.0	3/13	23.1	3/13	23.1
Pooled site data	Males	4/124	3.2	13/143	9.1	27/155	17.4	51/204	25.0
	Females	3/68	4.4	5/105	4.7	11/101	10.9	19/105	18.1

Table 7.16 Age-specific prevalence of vertebral compression fractures among individuals with vertebrae in the male and female cemetery samples

n_f number of individuals in age group displaying compression fractures n_t total number of individuals with vertebrae in age group
% percentage of age group with vertebrae displaying compression fractures

		c.18-25		*c*.25-35		*c*.35-45		*c*.>45	
		n_f n_t	%	n_f n_t	%	n_f n_t	%	n_f n_t	%
Wharram	Males	0/28	0.0	0/27	0.0	1/30	3.3	3/68	4.4
	Females	0/24	0.0	0/23	0.0	0/24	0.0	3/41	7.3
Ipswich	Males	0/23	0.0	0/35	0.0	3/31	9.7	2/27	7.4
	Females	1/11	9.1	0/17	0.0	1/8	12.5	2/16	12.5
Abingdon	Males	0/21	0.0	2/37	5.4	4/48	8.3	5/67	7.5
	Females	0/20	0.0	1/34	2.9	1/33	3.0	4/40	10.0
St Nicholas	Males	0/15	0.0	0/14	0.0	0/14	0.0	0/4	0.0
	Females	0/8	0.0	0/21	0.0	0/16	0.0	0/4	0.0
Fishergate 4	Males	0/17	0.0	0/12	0.0	1/8	12.5	0/3	0.0
	Females	0/6	0.0	0/6	0.0	1/10	10.0	0/3	0.0
Fishergate 6	Males	0/20	0.0	2/32	6.3	1/42	2.4	3/47	6.4
	Females	0/3	0.0	0/13	0.0	0/13	0.0	0/11	0.0
Pooled site data	Males	0/124	0.0	4/157	2.5	10/173	5.8	13/216	6.0
	Females	1/72	1.4	1/114	0.9	3/104	2.9	9/115	7.8

8. Joint Disease

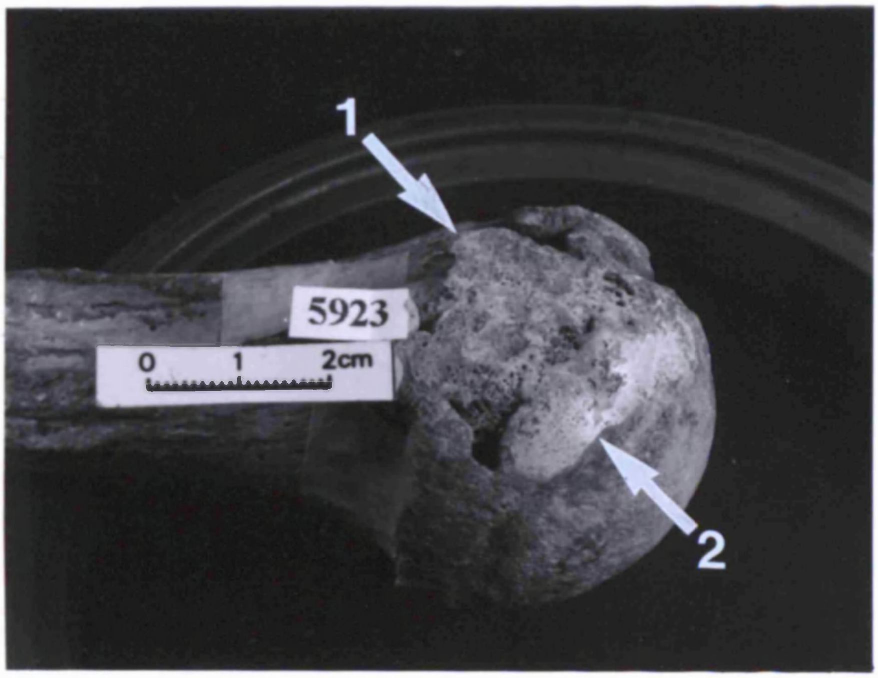
8.1 Introduction

This chapter aimed to compare the male and female prevalence of joint disease, primarily to determine whether there was any evidence to suggest differences in activity patterns between the sexes, especially following the results obtained from the fracture analysis. Osteoarthritis was the only form of joint disease examined in the appendicular skeleton. In the vertebral column, the analysis included osteoarthritis of the articular processes, osteophytosis of the vertebral bodies, and Schmorl's nodes. No other forms of joint disease were considered because their frequencies were generally too low to permit a comparative study between the sexes. Similarly, the analysis was confined to adult skeletons as joint disease was an extremely rare occurrence among the subadult material.

Osteoarthritis affects the synovial joints and involves the degeneration of the cartilage which covers the articular surfaces (Gardner 1983; Jurmain and Kilgore 1995; Larsen 1997:161-194; Roberts and Manchester 1995:99-123; Rogers *et al.* 1981; Rogers *et al.* 1987; Rogers and Waldron 1995:32-46). Plate 8.1 illustrates some of the characteristics of the disease that are visible in archaeological remains. Cartilage disintegration and the associated failure of the reparative process in the subchondral bone may result in cyst formation, rarefaction and pitting of the joint surfaces. Total loss of cartilage causes friction during movement between the exposed bone surfaces, which can become polished, or eburnated, as a result. Irregular outgrowths of new bone, termed osteophytes, may develop around the joint margins, which represent an attempt to redistribute load. In extreme cases, remodelling of the joint contours may occur. The clinical manifestations of osteoarthritis include joint deformity, pain, and limitation of function. However, the severity of an individual's symptoms do not necessarily bear any correlation with the degree of joint involvement (Rogers *et al.* 1990).

The aetiology of osteoarthritis is multifactorial, including advancing age, heredity, obesity and trauma. Mechanical stress is also a major contributory factor although Rogers and Waldron (1995:33) state that 'the mechanical element probably acts to determine which joints are involved in an otherwise predisposed individual'. Some modern epidemiological studies have observed an association between certain

Plate 8.1 Osteoarthritis. Eburnation (2), Osteophytes (1).



occupations and the distribution of joints affected by osteoarthritis (Larsen 1997:163-164; Stirland 1988; Waldron 1994:93-95). This has led to patterns of osteoarthritis in the skeleton being used to infer the practice of specific, repetitive physical activities. However, Rogers and Waldron (Rogers and Waldron 1995:105-107; Waldron 1994:92-101) strongly condemn this approach on the grounds that no activity produces a unique or consistent pattern of joint involvement, and because the development of osteoarthritis in a given individual is dependent upon a combination of factors, making it impossible to attribute an ultimate cause for joint changes evident in a single skeleton. Nevertheless, they do suggest that it may be feasible to make general inferences about activity at the population level, such as different patterns of osteoarthritis exhibited by urban and rural groups, a view which is shared by Jurmain (1990). Larsen (1997:194) concludes, 'generally, the more mechanically demanding the lifeway, the greater the prevalence of osteoarthritis . . . conversely, less demanding work repertoires result in a relatively lower prevalence'.

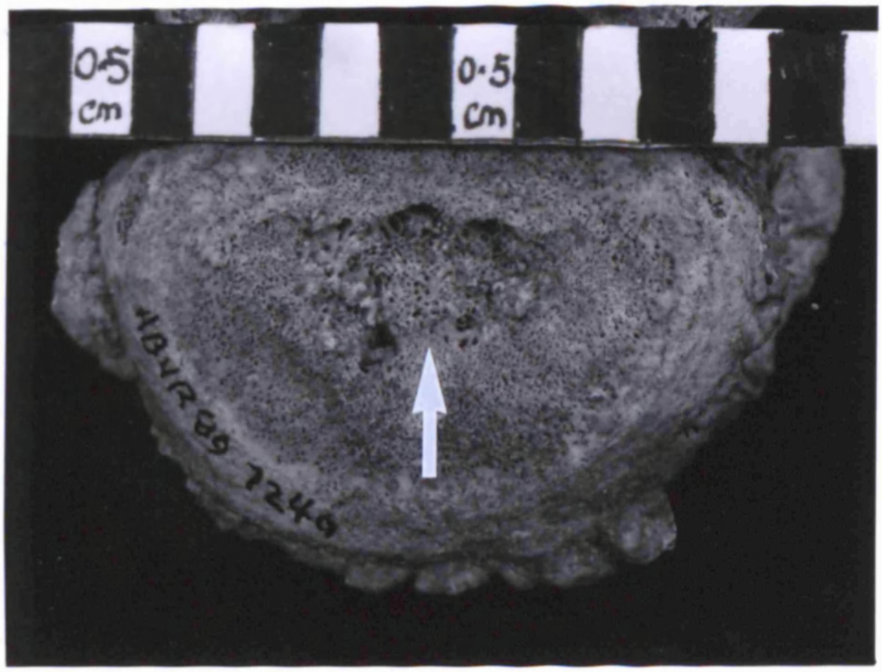
Studies made on populations in the developed world indicate that osteoarthritis tends to be more prevalent among women than men, particularly in later middle-age, leading to the view that there may be a hormonal influence in the development of the condition (Larsen 1997:163; Spector *et al.* 1994; Rogers and Waldron 1995:32; Waldron 1997); although perhaps this interpretation assumes preconceptions about male and female physical work loads (O'Sullivan pers. comm.). By contrast, where sex differences have been identified among archaeological assemblages, there is a tendency for males to be more frequently affected (Jurmain 1990; Larsen 1997:176-178; Waldron 1997; Walker and Hollimon 1989). This has usually been interpreted as evidence for contrasting patterns of physical activity between the sexes, particularly sex division in labour, with more physically demanding work repertoires among males.

Spinal osteophytosis is the term used to describe the development of osteophytes around the margins of the vertebral bodies, usually concomitant with the ageing process, illustrated in plate 8.2 (Rogers *et al.* 1981; 1985). Following an examination of 400 modern specimens, Nathan (1962) found the earliest age of onset to be in the second decade, with all individuals displaying osteophytes by the fourth decade. The new bone growth acts as a defence mechanism against the increase in compressional forces on the vertebrae subsequent to the deterioration of the intervertebral discs, which normally function as a spinal shock absorber. The osteophytes serve to broaden the vertebral surfaces, thus reducing the force per unit area acting on the vertebrae. Osteophyte development tends to be greatest at the points of maximum pressure along the vertebral column. The fifth cervical, eighth to tenth thoracic, and third to fourth lumbar vertebrae are particularly susceptible (Nathan 1962) and these approximately coincide with the greatest curvatures in the bipedal posture (Bridges 1994; Jurmain and Kilgore 1995; Knüsel *et al.* 1997; Manchester 1983:65-67). Both Nathan (1962) and Roberts and Manchester (1995:107) have suggested that osteophytosis may be initiated as a response to the excessive pressure imposed by heavy manual labour. Although not statistically significant, Nathan (1962) identified a preponderance of osteophytosis among the males in his sample. He attributed this to 'the greater pressure exerted on the vertebral columns of men because of their greater body weight and harder physical work' (p.261).

Schmorl's nodes are depressions on the vertebral surfaces, as shown on plate 8.3, which result from the pressure exerted by herniated intervertebral discs (Rogers and

Plate 8.2 Osteophytosis

Plate 8.3 Schmorl's Node



Waldron 1995:27). Young individuals tend to be most susceptible because the spine is still able to grow and adapt to the shape of a herniated disc. Schmorl's nodes occur most commonly in the lower thoracic and lumbar vertebrae (Ellis 1975:315; Oliver and Middleditch 1991:24). Trauma has been suggested as the primary aetiological factor, particularly that associated with weight bearing, such as sudden stress when lifting heavy loads; although other conditions which serve to weaken the bone structure, such as infection, osteoporosis or neoplasia, may contribute to their development (Roberts and Manchester 1995:107; White 1988:43).

8.2 Method

8.2.1 Appendicular Skeleton

The methods which had been used to score osteoarthritis differed among the medieval cemeteries. The operational definition devised by Rogers and Waldron (1995:43-44) had been adopted to record osteoarthritis in joints from the Abingdon assemblage. This primarily depends on the presence of eburnation. If eburnation is absent, a positive classification rests on a minimum of two of the following criteria being present:

- marginal osteophytes and/or new bone on the joint surface;
- pitting on the joint surface;
- alteration in the bony contour of the joint.

The material from Ipswich and Wharram was scored using the method presented by Brothwell (1981:150), whereby osteoarthritic changes in each joint are graded according to severity:

Grade 0 = Normal bone surface

Grade I = Intermittent osteophytes

Grade II = Osteophytes continuous, some porotic changes

Grade III = Osteophytic lipping, extensive porosis and possible eburnation

A similar system was applied to the collection from St Nicholas Shambles, except joint changes were described as being 'mild', 'moderate', or 'severe'; classifications which were analogous to grades I-III of the Brothwell system respectively. Osteoarthritic changes evident in the Fishergate material had been recorded qualitatively, with a detailed description and frequently an illustration of changes present on each articular surface of every joint affected. Osteoarthritis had not been routinely recorded in the Jewbury assemblage owing to the time limits imposed on the examination of the material. As skeletal inventories had not been recorded either, which largely precluded the calculation of prevalence figures, the Jewbury assemblage was excluded from further analysis.

This type of variation in recording method has been the subject of much discussion and concern (Larsen 1997:170). Although it presents little problem when making comparisons between sub-samples of data collected by the same author, it has greatly impeded the reliable comparison of results between published studies. Larsen (1997:70) notes that the problem could be circumvented by comparing populations using data collected by a single researcher. Such an approach would have been impractical for this study, given the large number of individuals included and because joint disease was only one of several aspects of pathology under consideration. However, since the raw data for each individual skeleton was at least available, rather than the simple summary statistics which are normally presented in published reports, it was the intention to enter the data onto the database in a format which made the data from each of the cemeteries as comparable as possible.

The following joints were included in the analysis: sterno-clavicular, acromio-clavicular, shoulder, elbow, wrist, hand, hip, knee, ankle and foot (Bass 1987; Brothwell 1981). It will be noted that the so-called 'joints' of the extremities, such as the hands and feet, are actually comprised of several small synovial joints. These were treated collectively as a single joint for the purposes of analysis because they represent a single functional unit. However, this approach did raise the problem of how to deal with incomplete 'joints'. In fact, this problem applied to all the joints as by definition, each comprised of at least two articular surfaces. As discussed in section 6.5.2, incomplete bone preservation can severely impede the analysis of data. Furthermore, the separate components which constitute a joint do not necessarily display the same propensity for developing osteoarthritis. For example, the patello-femoral compartment in the knee has been found to exhibit osteoarthritis more frequently than the tibio-femoral compartment (Cooper *et al.* 1994; Rogers and Waldron 1995:42; Stroud and Kemp 1993:211; Waldron 1995). One possible solution would have been to analyse the different components of each joint separately. However, this would have complicated the statistical analysis, confused the interpretation of results, and detracted from the principle that the components of a joint function collectively as a single biological unit (Waldron 1994:59). In addition, osteoarthritis had not always been scored for the separate components. An alternative solution would have been to include only complete joints in the analysis, but this would have created the problem of a radically reduced sample size owing to the fragmentary nature of the archaeological material. Thus it was decided that a joint would be included in the analysis if represented by a minimum of one articular surface, though it was accepted that this did represent a source of limitation in the method. This limitation was likely to have the most serious implications with regard to the comparison of data between cemeteries or the pooled site data, owing to the site differences in preservation (see chapter 5).

Only joints displaying changes which met the criteria of Rogers and Waldron's (1995:43-44) operational definition were treated as positive diagnoses of osteoarthritis in the analysis. This excluded joints which had been classed below grade II using Brothwell's scheme because Rogers and Waldron state categorically that the presence of osteophytes alone is an insufficient criterion on which to base a palaeopathological diagnosis of osteoarthritis: osteophytes may develop simply as a product of the ageing process. In fact, Waldron (1994:39) states that 'little would be lost, and indeed there would be less ambiguity if the classification were to rely *solely* on the presence of eburnation', a pathognomonic sign of osteoarthritis. However, this recommendation could not have been implemented in the present study because joints displaying eburnation had not always been differentiated from those which did not. No attempt was made to grade the osteoarthritic changes according to severity, partly because it is a subjective measure and partly because it was not always explicit in the description provided. It is also a practice strongly denounced by Rogers and Waldron (1995:101-105), for two reasons. Firstly, since the morphology of joint change does not necessarily correlate with the magnitude of clinical symptoms, it does not provide a reliable indication of the impact that the osteoarthritis would have had on the individual. Secondly, the severity of a lesion is related to its speed of progression, a factor which varies between individuals. Since the rate of progress and the stage of disease development at the point of death cannot be determined for skeletal populations, the measure of lesion severity is almost a meaningless concept.

These measures helped to rationalise the data into a more comparable format for statistical purposes. Nevertheless, a study by Waldron and Rogers (1991) has drawn attention to the considerable degree of inter-observer variation which may exist in the scoring of osteoarthritis, even if the same recording criteria are used. Thirty-eight participants took part in the study who had varying levels of expertise. Ten specimens were presented to the participants, who were instructed to score the specimens according to the same criteria. Eburnation and new bone formation on the joint surfaces were the criteria scored most consistently. However, although all of the specimens were considered by Rogers and Waldron to display osteoarthritis, the most experienced participants agreed on a diagnosis for only three specimens and the novices, just one. These results illustrate how inter-observer variation remained an important limitation of the method in this study, despite the precautions taken.

The crude prevalence of osteoarthritis (number of individuals displaying osteoarthritis in any joint/total number of individuals with a minimum of one joint present; see section 6.5.2) was computed for males and females from each cemetery and the pooled data from all cemeteries combined (table 8.1). Since the prevalence of osteoarthritis increases with age, comparisons made between population samples may be biased by dissimilarities in their age structure. In an attempt to control this confounding factor, age-specific prevalence figures were also computed for each of the four age classes in the samples (table 8.1). Chi-square tests were applied in order to determine whether there was any statistical association between sex and the prevalence of osteoarthritis in any of the respective age categories, or the total samples with all ages combined (table 8.1). One drawback with using age-specific prevalence figures to control confounding is that it involves a large number of comparisons, particularly when several cemetery samples are being considered, which can complicate the interpretation of results (Waldron 1994:61). It also fragments the data into samples which are sometimes too small to permit meaningful comparisons. To provide an alternative method, the common odds ratio for each cemetery sample and the pooled cemetery data was computed using the Mantel-Haenszel estimate (table 8.1) (Breslow and Day 1980:140-141). This relates the age-specific prevalence figures for the male and female samples being compared in a single summary statistic which indicates whether either sex displayed a higher prevalence of osteoarthritis overall, taking account of any differences in the age composition of the respective samples (Waldron 1995:61-63).

In addition to investigating the prevalence of osteoarthritis in the entire skeleton, it was necessary to examine the distribution of joints affected among males and females. Aside from the drawbacks associated with the use of the crude prevalence statistic discussed in section 6.5.2, Rogers and Waldron (1995:32) point out that there seem to be distinct entities of osteoarthritis with different aetiologies, including sex differences in joint involvement, and it is important to focus attention on the specific patterning of joints affected. Therefore, the corrected prevalence (number of joints displaying osteoarthritis/total number of joints present; see section 6.5.2) and age-specific corrected prevalence of osteoarthritis was computed for each of the appendicular joints within the male and female cemetery samples, and the pooled site data (table 8.2a-g). The right and left joints were analysed separately, partly to simplify the procedure and also to enable the identification of any asymmetry in prevalence, which may be suggestive of an activity-related cause.

A disadvantage of this approach was that by splitting the data by joint type, the numerator in the prevalence ratio (i.e. the number of joints affected by osteoarthritis) was reduced disproportionately to the denominator (i.e. the number of joints present), often generating extremely low prevalence figures on which to base comparisons. A similar problem was encountered during the analysis of long bone fractures, discussed in chapter 7. Fragmenting the data in such a way also made the use of statistical tests for association or the calculation of odds ratios largely inappropriate due to the small number of affected joints, although odds ratios were computed for the large sample of pooled cemetery data (table 8.2g). To counteract this problem, a proportional morbidity study was applied to compare the male and female distribution of osteoarthritis, similar to that used to compare the distribution of long bone fractures. The number of each anatomical site displaying osteoarthritis was expressed as a percentage of the total number of sites displaying the condition (table 8.3a-g). As there may be differential preservation between joint types, for example the small bones of the hands and feet tend to be more prone to decay than other parts of the skeleton, only the most complete individuals were included in this procedure, otherwise the proportions of joint types affected by osteoarthritis may have been biased by the proportions of joint types preserved. The prerequisite for selection was the possession of a minimum of one side of every joint pair.

8.2.2 Vertebral Column

Spinal joint disease had been recorded in considerable detail among the collections from Abingdon and Fishergate. Brothwell's (1981:150) method had been used to score the severity of osteoarthritis on the superior and inferior aspects of each articular process, and the costal and costo-transverse facets of the thoracic vertebrae. Brothwell's method had also been applied to record the severity of osteophytosis on the right, left, anterior and posterior margins of both the superior and inferior surfaces of each vertebral body. Schmorl's nodes were recorded as being either present or absent on the inferior and superior surfaces of each vertebral body. This data was frequently accompanied by further observations about each vertebra. Osteophytosis and osteoarthritis among the assemblages from Wharram Percy and Ipswich had also been scored according to Brothwell's criteria, though in less anatomical detail than that of Abingdon and Fishergate. The total number of cervical, thoracic and lumbar vertebrae displaying each grade of osteoarthritis and osteophytosis severity were noted, but without reference to the specific articular processes or vertebral bodies affected. In cases where vertebrae displayed different grades of osteoarthritis severity in the right and left articular processes, the maximum grade of bone change had been used for the purposes of classification. Similarly, the total number of cervical, thoracic and lumbar vertebrae displaying Schmorl's nodes were noted, including the total number of affected superior and inferior surfaces for each type of vertebra and the total number of nodes visible, but the particular vertebrae or surfaces affected were not specified. Vertebral osteoarthritis present in the cervical, thoracic, lumbar and first sacral segments of skeletons from St Nicholas Shambles was described as being 'mild', 'moderate' or 'severe'. As with the appendicular joints, these classifications corresponded with the three grades of Brothwell's scheme. Osteophytosis of the vertebral bodies was not recorded specifically. The existence of Schmorl's nodes was noted with respect to the cervical, thoracic, lumbar and first sacral segments, though like the material from Wharram Percy and Ipswich, the data did not detail which vertebral surfaces were affected. As with the appendicular joints, vertebral joint disease had not been routinely recorded within the assemblage from Jewbury owing to the time limits on examination, so this cemetery was omitted from the analysis.

The male and female prevalence of osteoarthritis in the articular processes was initially computed with respect to the entire vertebral column (number of individuals displaying osteoarthritis in the minimum of one articular process/total number of individuals with a minimum of one articular process present). These figures were computed for each cemetery sample, the pooled cemetery data, and the respective age groups within these samples owing to the tendency for osteoarthritis to increase with advancing age (table 8.5). As with the appendicular joints, only joints displaying changes which met the criteria of Rogers and Waldron's (1995:43-44) operational definition were classified as positive cases of osteoarthritis for the purposes of analysis. This broadly equates with severity grade II or above of Brothwell's scheme. No attempt was made to investigate potential sex differences in the severity of joint change, for the same reasons stated for the peripheral joints.

Two limitations of investigating osteoarthritis with respect to the entire vertebral column are that the results may be biased by variations in vertebral preservation between samples (see section 6.5.2), and the approach may obscure sex differences in the vertebrae affected. Predisposition to osteoarthritis varies along the length of the vertebral column due to changes in stress and weight transmission through the spinal curvatures (Knüsel *et al.* 1997). Thus ideally, prevalence figures should also have been computed for each articular process, or at least each vertebra. However, not only was this data not available for all the cemeteries, but such a detailed investigation was beyond the time constraints of this study. Nevertheless, the prevalence figures that were computed for the entire spine were recalculated for the cervical, thoracic and lumbar segments, and first sacral vertebra for cemeteries where this data were available, with the intention that this might refine the results to a certain extent (table 8.6a-g).

The same statistics that were computed for osteoarthritis were generated to compare the male and female prevalence of osteophytosis (tables 8.7 and 8.8a-f) and Schmorl's nodes (table 8.9 and 8.10a-g). However, unlike osteoarthritis, all grades of osteophytosis development were included as positive classifications for the purposes of analysis.

8.3 Results and Discussion

8.3.1 Appendicular Skeleton

The crude prevalence figures for the total population samples are presented in table 8.1. The figures for the total cemetery samples, irrespective of age, indicated that a higher proportion of males than females were affected by osteoarthritis from Wharram Percy, Abingdon and Fishergate 6; whereas a higher percentage of females were affected from Ipswich. An approximately equal percentage of each sex displayed osteoarthritis in the samples from St Nicholas Shambles and Fishergate 4. However, none of the cemeteries displayed a statistically significant association between sex and osteoarthritis prevalence according to the chi-square tests, with the possible exception of Wharram Percy which did approach significance (χ^2=3.514 p=.061). The higher prevalence of osteoarthritis among males within three of the larger collections contributed to a higher male prevalence in the pooled sample; 32.3% of all males were affected compared with 27.1% of all females. The association between sex and osteoarthritis prevalence in the pooled cemetery sample was statistically significant at the 5% probability level (χ^2=4.212 p=.040).

However, the age-specific prevalence figures for both sexes, also presented in table 8.1, confirmed the expected tendency for osteoarthritis to increase with each successive age class. The percentage of individuals affected by osteoarthritis in the youngest age category (*c.*18-25 years) ranged from between 0-14% across the cemeteries; which compares with a range of 36-88% affected among the eldest group (*c.*>45 years). This indicated that the above results for the total male and female samples were probably influenced by any sex differences in their age structure. On the basis of the common odds ratios, which adjusted for this potential limitation, four of the six cemetery samples displayed a predominance of osteoarthritis among males, as detailed in table 8.1. Wharram Percy and the monastic phase of the Fishergate collection displayed the heaviest male bias, followed by the preceding phase from Fishergate, and then Abingdon. The common odds ratios indicated that osteoarthritis was more common among females within the assemblages from St Nicholas Shambles and Ipswich Blackfriars. The pooled cemetery data displayed an overall bias toward males.

The results therefore appeared to suggest a general tendency for males to display a higher prevalence of osteoarthritis, though this was not exclusively the case for all the cemeteries. One explanation for this apparent trend may be that males were habitually involved in more physically arduous activities. Further evidence which might support this interpretation was found upon closer observation of the age-specific prevalence figures. Within three of the assemblages, St Nicholas Shambles, Abingdon and Fishergate 4, males displayed a greater prevalence of osteoarthritis among younger individuals, but the female prevalence surpassed that of males in the eldest groups. Following a similar pattern, the disparity in male and female prevalence became increasingly biased toward males through the three youngest age groups of the Wharram Percy and pooled cemetery samples, but the sex difference diminished among those over *c.*45 years due to a comparatively large rise in female prevalence in the eldest age group. Although these sex differences were not statistically significant (perhaps due to the smaller sample sizes having split the data into age groups), the pattern may imply an earlier age of onset among males with an increase in prevalence among females in later middle age. Roberts and Manchester (1995:109) contend that for occupationally induced changes to become manifest in the skeleton, the activity must be undertaken from a young age, and that an elevated prevalence of osteoarthritis among young individuals may be indicative of an occupationally induced cause. The age distribution of male prevalence could therefore be interpreted in these terms. The higher prevalence among older females concords with the findings of modern studies, and may support the hypothesis that there is a hormonal component in the development of osteoarthritis. However, the considerable prevalence of osteoarthritis among females of all ages should not be overlooked, suggesting that females would also have been habitually engaged in physically demanding activity.

The results in table 8.1 also indicated that there were differences in prevalence between the cemeteries. Of the male samples, Fishergate 6 displayed the highest crude prevalence, with 46.6% of the sample affected. The lowest prevalence was observed within the Ipswich collection, in which 23.3% of males were affected. The samples from Abingdon, Wharram Percy, Fishergate 4 and St Nicholas Shambles all displayed a similar prevalence; approximately 30% of males from each sample displayed osteoarthritis. Like the males, the females from Fishergate 6 displayed the highest prevalence of osteoarthritis of all the female samples, with almost 40% of individuals affected. This was followed by Ipswich (34.4%), Fishergate 4 (30.3%), St Nicholas

Shambles (28.4%) and Abingdon (24.0%). In contrast to the males, the female sample from Wharram Percy displayed the lowest prevalence of osteoarthritis, with 20.9% of individuals affected. It is difficult to speculate on possible interpretations for these observed differences between cemeteries, especially as the male and female cemetery samples presented different prevalence rankings, which would tend to undermine the possibility of attributing the differences to a general common cause, such as potential differences in lifestyle between population samples or inter-observer differences in recording method. Disparities in the age structure of the samples were probably a factor, as the investigation into age at death in chapter 5 revealed substantial differences in the age profiles of the respective cemetery samples. Furthermore, comparison of the age-specific prevalence figures indicated further differences between the samples. This would suggest that other, perhaps indeterminable factors may have contributed toward the apparent differences in osteoarthritis prevalence between the cemetery samples.

The results presented in table 8.2a-g show the male and female prevalence of osteoarthritis in each joint. These revealed sex differences in the distribution joints affected. Splitting the data by joint type did make it difficult to draw conclusions, especially when the data were subdivided into age groups, as the resulting number of joints affected were frequently below double figures. The poor preservation of the assemblage from St Nicholas Shambles, and the small size of the sample from Fishergate 4 combined with its young age profile made the data from these cemeteries particularly sparse (table 8.2d/e). Nevertheless, the following patterns were identified. In four of the cemetery collections, Abingdon, Ipswich, Fishergate 4 and Wharram Percy, osteoarthritis of the right and left knees was more common among females of all age groups (table 8.2a,b,c,e). This was even more apparent in each age class of the pooled cemetery sample, and confirmed by the common odds ratios which showed a clear bias toward a greater female prevalence of osteoarthritis in both knee joints (table 8.2g). By contrast, a higher male prevalence of osteoarthritis was evident in both acromio-clavicular joints for most age groups in the collections from Wharram Percy, Fishergate 4, Fishergate 6 and St Nicholas Shambles (table 8.2a,d,e,f). Again, the aggregated cemetery data accentuated this sex difference, with both the age-specific prevalence figures and the common odds ratios confirming the greater prevalence of osteoarthritis in the acromio-clavicular joints of males (table 8.2g). The pooled cemetery data also indicated a male bias in the prevalence of osteoarthritis in the sterno-clavicular joints, particularly for the right side which was almost twice as commonly affected in males as in females. However, this sex difference was not really discernible in the data from the individual cemeteries, possibly owing to the generally low prevalence of osteoarthritis in the sterno-clavicular joints, at least by comparison to the acromio-clavicular joints. No clear sex differences were perceptible in the remaining joints with regard to the data from the respective assemblages, although the pooled site data indicated a tendency for males to display a slightly greater prevalence of osteoarthritis in the majority of joints. This concords with the findings in table 8.1 which pointed toward a generally higher prevalence of osteoarthritis among males.

The results of the proportional morbidity study, presented in tables 8.3a-g, mainly served to confirm the inferences drawn from the study of corrected prevalence (tables 8.2a-g). The relatively small number of complete individuals which qualified for inclusion to the proportional morbidity study from Fishergate 4 and St Nicholas Shambles reduced the reliability of the results from these cemeteries. Nevertheless, a similar pattern of joint involvement emerged from most of the cemeteries, which was effectively amplified when the data were aggregated (table 8.3g). Chi-square tests on the pooled cemetery data confirmed that there were differences in the distribution of osteoarthritis across the various joint types which were statistically significant beyond the .001 probability level, for both males (χ^2=103.420) and females (χ^2=31.632) respectively. The acromio-clavicular joint was the site most frequently involved in both sexes, but it accounted for a comparatively greater proportion of all joint involvement in males. A total of 79 male joints displayed osteoarthritis in this location, which was equivalent to 21.3% of the pooled sample. This represents a substantially greater lead on the second most commonly affected site in males, the hip, which was affected in 49 cases and accounted for 13.2% of all joint involvement. By comparison, only 15% of the female sample displayed osteoarthritis in the acromio-clavicular joint, which was a similar proportion to that exhibited by four other sites: the knee, hip, hand and wrist. The most striking sex difference was observed in the proportion of joints exhibiting osteoarthritis in the knee. It was the second most frequently affected joint in females, accounting for 14.5% of all joint involvement. By contrast, the knee was the second least commonly affected joint in males. It accounted for just 4.9% of all joint involvement, approximately a third of the proportion of female cases affected. As indicated by the corrected prevalence study (table 8.2a-g), there were also sex differences in sterno-clavicular joint involvement. Eleven percent of male joints exhibited osteoarthritis in this, the fourth most frequently affected site. This compared with 6.4% of all female joints, which ranked only eighth out of all joint types. The rank order of the remaining joints was similar between the sexes and the percentage affected was close to unity. Osteoarthritis of the hip, wrist and hand each contributed to approximately 13% of all joint involvement. Approximately 9.5% of osteoarthritis occurred in the feet, followed by the elbows and shoulders. The ankle was the joint least affected in both sexes, comprising just 2% of all sites involved.

The proportional morbidity study therefore supported the findings of the corrected prevalence study. The expression of osteoarthritis differed between the sexes, the acromio-clavicular and sterno-clavicular joints being more frequently affected in males whereas the knee joints were more frequently affected in females. The greater acromio-clavicular and sterno-clavicular involvement in males could imply that males undertook a greater physical workload with the upper body. Both joints are involved in arm-swinging movements and the acromio-clavicular is a weight bearing joint, so although it is not possible to attribute the comparatively high prevalence of osteoarthritis in the joints to a particular activity, the results could indicate the more habitually strenuous use of the upper limbs among males. White (1988:43) also noted the comparatively high prevalence of osteoarthritic changes in the distal end of the clavicle among males from St Nicholas Shambles, and suggested that carrying heavy weights on the shoulder could be a causative factor. These interpretations are supported by the results of a study by Mays (1999) into humeral robusticity within a sample of skeletons from the Fishergate cemetery. Bone robusticity increases in response to increased mechanical stress, such as weight bearing or muscular tension. Mays found that males displayed greater humeral asymmetry than females, indicating that they habitually undertook activities which entailed greater differential loading of the right and left upper limbs, an activity pattern which is consistent with heavier occupations. As discussed in chapter 1, the occupational life of males tended to be more stable and consistent than females, which tended to be more varied and intermittent, and Mays suggests that this may have 'facilitated the imprinting of repetitive, stereotyped tasks on the male skeleton' (Mays

1999:72). This factor may also have contributed to the sex difference in osteoarthritis prevalence identified within the acromio-clavicular and sterno-clavicular joints in this study.

There are several possible interpretations for the comparatively high female prevalence of osteoarthritis in the knee. In modern populations, obesity is the most important aetiological factor in the development of osteoarthritis of the knee (Spector *et al.* 1994), so the results could indicate a greater prevalence of obesity among females. However, obesity was presumably less common than it is today, particularly among the poorer strata of medieval society, owing to the more physically active lifestyle and less opulent diet. Perhaps weight gained during repeated pregnancies could have imposed a similar stress on this weight-bearing joint. Mechanical stress is also an important risk factor. A recent study of contemporary British men and women found a significant association between the development of knee osteoarthritis and occupational activities which involved prolonged or repeated knee bending through squatting, kneeling or climbing stairs (Cooper *et al.* 1994). Prolonged walking, standing or sitting were not found to contribute to the development of the disease but the results did indicate that mechanical loading through heavy lifting might augment the other risk factors. The results of this study could therefore suggest that females were more frequently involved in activities which entailed knee bending and mechanical loading. A further possible explanation for the higher female prevalence of osteoarthritis in the knee could originate in anatomical differences between the sexes. The lower limbs in males tend to be positioned more vertically than females, which tend to be more inwardly angled as a result of the wider pelvis (Brothwell 1981:32), so this perhaps causes differences in the stress imposed on the joint.

A further pattern identified from the corrected prevalence results in table 8.2a-g was an inclination for the joints on the right side of the skeleton to display a higher prevalence of osteoarthritis than those on the left. Only two of the respective cemetery samples did not display this propensity, Fishergate 4 and Ipswich. The number of joints displaying osteoarthritis in the Fishergate 4 assemblage were too few to permit any identification of asymmetry in osteoarthritis patterning (table 8.2e). A slightly higher proportion of left joints were affected among the males and females from Ipswich (table 8.2b). Despite this exception, the predilection for osteoarthritis to occur on the right side was most apparent in the pooled cemetery data (table 8.2g). Among the pooled male sample, the proportion of right joints affected by osteoarthritis exceeded the proportion of left joints for nine of the ten joint types; and among the females, a higher proportion of right joints were affected for seven of the ten joint types examined. To confirm that the observed pattern was not influenced by the age structure of the samples, common odds ratios were computed to relate the age-specific prevalence between the right and left sides for the pooled cemetery data. The results, presented in table 8.4, corroborated the observed bias. Of the ten joint types, only the left ankle in males and the left hip and sterno-clavicular joints in females displayed an osteoarthritis prevalence which exceeded that of the corresponding right joint. The most obvious explanation for this right side dominance in osteoarthritis is the predominance of right-handedness among the general population, resulting in greater mechanical stress on the right side (Larsen 1997:173). Support for this interpretation may be derived from a study of upper limb asymmetry in a sample of adult skeletons from Wharram Percy, by Steele and Mays (1995). Behavioural handedness in load bearing tasks may be manifest in a slight lengthening of bones in the dominant arm (Larsen 1997:210). Steele and Mays identified a statistically significant directional asymmetry in bone length which indicated that the majority of the sample, around 80%, were right handed and approximately 15% were left handed. Directional asymmetry was also identified in a similar study of the clavicle within a sample from Wharram Percy, by Mays, Steele and Ford (1999). Why the lower limbs should also tend to display a higher prevalence of osteoarthritis on the right side is unclear, though it is possible that the results indicate the existence of right-sided dominance in the lower limbs, with an attendant increase in mechanical stress. Perhaps this could be clarified through a study of asymmetry in the lower limb bones. Another possibility could be that habitual weight-bearing on the right upper limb transmits stress via the spine to the pelvis and the right lower limb, and vice versa. If right-sided bias in behaviour is the primary factor contributing to the right-sided bias in osteoarthritis, it would also tend to confirm that osteoarthritis can be used as a general marker for inferring activity-related stress in the skeleton, despite its multifactorial aetiology.

8.3.2 Vertebral Column

As the results in table 8.5 illustrate, the prevalence of osteoarthritis in the articular processes for the entire vertebral column showed the predicted tendency to increase with each successive age category. This pattern was evident among both male and female samples from virtually all the cemeteries and the pooled cemetery data. However, unlike the joints of the appendicular skeleton, no consistent pattern of sex differences in prevalence were observed. In fact, the proportions of each sex affected were generally alike. The similarity between the sexes was such that tests of statistical significance were not applied to the data because from a visual inspection of the figures, it was obvious that any potential sex differences would not be statistically significant. Where slight variations were perceived in the percentage affected, neither sex displayed a consistently higher prevalence in any age group or among the total samples in which the data for all age groups were pooled. Similar results were obtained for the cervical, thoracic, lumbar and sacral segments, as shown in table 8.6a-g. The results in table 8.6a-g did reveal that the thoracic vertebrae displayed the highest prevalence of osteoarthritis among both males and females in the majority of age classes, from the majority of cemeteries. Without a more detailed study, it is not possible to determine whether the increased prevalence in this region could be associated with anatomical factors or perhaps patterns of physical activity; although the most immediate explanation could simply be that this region of the spine contains the greatest number of vertebrae and so was more likely to produce positive classifications for osteoarthritis using the crude method of prevalence assessment applied (see section 6.5.2), primarily through the increased chance of preservation. The lumbar vertebrae tended to be the second most affected region in the cemeteries of St Nicholas Shambles, Fishergate 6 and Abingdon (table 8.6c,d,f), whereas the cervical vertebrae were the second most affected vertebrae in the assemblages from Wharram Percy, Ipswich and Fishergate 4 (table 8.6a,b,e). The first sacral vertebra displayed the lowest prevalence among those cemeteries for which joint changes in this vertebra had been recorded.

Like osteoarthritis of the articular facets, the prevalence of spinal osteophytosis also tended to increase within each consecutive age group, and again, neither sex displayed a consistently higher prevalence in any of the samples examined, as demonstrated by the results in tables 8.7 and 8.8a-f. As with the articular facets, the thoracic vertebrae displayed the highest prevalence of osteophytosis among both sexes. This was followed by the lumbar, cervical, then first sacral vertebrae in the majority of samples.

These results could be taken as evidence to suggest a lack of sex differences in activity patterns. However, this interpretation would contradict that derived from the analysis of osteoarthritis in the appendicular skeleton, which did reveal sex differences in joint disease prevalence. Alternatively, they may support the view of Knüsel, Göggel and Lucy (1997), who propose that joint disease of the vertebral column, including osteoarthritis of the articular processes and osteophytosis, does not provide a very effective indicator of activity-related stress. Knüsel and colleagues drew this conclusion following a study of 81 male skeletons from the monastic phase of the Fishergate cemetery. The sample consisted of individuals derived from three areas of the cemetery. As discussed in section 2.3, it is believed that these differ according to social class: the resident canons; the lay brethren who were employed by the priory as the workforce; and wealthy benefactors and canons of high status. On the basis of documentary and other skeletal evidence, Knüsel and co-workers postulated that the resident canons were likely to have followed a fairly sedentary life-style, whereas the lay brethren would have experienced a physically active life. They hypothesised that these two groups would display different patterns of vertebral joint disease as a result, the third group serving as a control, comprising high status but non-ecclesiastical burials. However, no differences in vertebral joint disease were identified between the three burial groups, leading to the conclusion that joint disease in the vertebral column is a poor indicator of activity-related stress.

Furthermore, Knüsel and colleagues actually identified a consistent pattern of joint disease among all three burial groups. The articular processes and the joints between the vertebral bodies displayed an approximately inverse pattern of involvement. The fifth to sixth cervical, eight to tenth thoracic, and second to third lumbar were the most severely affected joints between the vertebral bodies; the least affected being between the seventh cervical and first thoracic, the twelfth thoracic and first lumbar, and the fifth lumbar and first sacral vertebrae. By contrast, the greatest level of osteoarthritis in the articular processes was identified between the second cervical through to the fourth cervical vertebrae, between the seventh cervical and first thoracic, the tenth thoracic, and the third through fifth lumbar vertebrae. The lowest level of apophyseal osteoarthritis was found between the occipital condyles and the first cervical vertebra, the fifth to sixth cervical, and from the first to the ninth thoracic vertebrae. A progressive increase in osteoarthritis severity was also observed in the lower thoracic and lumbar articular facets. Knüsel and colleagues cited several other studies (Bridges 1994; Roberts and Manchester 1995; Nathan 1962; Sager 1969) which have produced a similar pattern of results. The authors attributed the inverse pattern of joint disease between the articular processes and vertebral bodies to their differences in function, which together provide the spine with the support and movement necessary to maintain upright posture, bipedal locomotion and weight transmission to the lower limbs. The joints between the vertebral bodies provide support yet permit minimal movement; whereas although the joints formed by the articular processes do provide support, they allow varying amounts of movement. Knüsel and co-workers interpreted the pattern of joint disease as being an adaptation to the stresses sustained in maintaining this support and movement. They suggest that the pattern of osteoarthritis in the articular facets reflects stress produced by movement through accentuating or reducing the spinal curvatures; and the pattern identified in the joints between the vertebral bodies reflects the spinal curvatures, the lowest severity occurring where the spine passes through the line of gravity and the highest severity occurring where the curvatures are furthest from it. They conclude that these biological factors obscure the expression of activity-related stress, and recommend that other joints which are not usually involved in body-weight bearing, postural support and locomotion, such as in the upper limbs and pectoral girdle, are more suitable structures for investigating activity-related stress.

However, while Knüsel and colleagues do acknowledge that for differences in vertebral pathology to be observed between skeletal samples, differences in activity patterns would have to be of a 'considerable magnitude' (p.494), it might be argued that this factor represents an important limitation of the method from which their conclusions were drawn. The original hypothesis was based on the assumption that the three skeletal groups from the Fishergate cemetery were drawn from three distinct social classes. While this is probably a valid inference on the basis of the archaeological and documentary evidence available, it may not be possible to determine how reliable the distinctions really are; or more importantly, the integrity of then using those groupings as a foundation upon which to make preconceptions about activity patterns between the groups. As has been discussed in previous chapters (section 2.8, 5.3 and 6.2.3), in reality, virtually nothing is known about the composition, nature or characteristics of individuals derived from archaeological contexts, let alone their lifestyle or level of physical activity (Molleson and Cox 1993:213; Waldron 1994:10-27). Even if the three social classes defined did experience general differences in lifestyle, it is also not possible to determine how representative the skeletons were from a collective sample of 81 individuals, all of which were male. Thus it could be argued that the lack of differences in vertebral pathology was not wholly due to the overriding biological constraints on vertebral function, but a lack of distinct differences in physical activity between the three groups.

Therefore, it may be rash to negate the value of the vertebral column as a structure for investigating activity-related stress on the basis of the Fishergate study alone. The results of Knüsel and co-workers study do provide compelling evidence to suggest that biological factors play an important role in determining vertebral pathology, but they may not necessarily obscure patterns in joint disease produced by activity-related stress. Thus a further interpretation for the lack of sex differences observed in this study could simply be that the results are inconclusive. Sex differences in activity-related stress may have been present yet not detectable owing to inadequacies in the methodology used in this study. By basing the sex comparisons on the entire vertebral column and large segments of it, the method may not have been sensitive enough to take into account the important effect of biological determinants on vertebral joint disease. Had the approach focused on joint changes in the respective vertebrae, it may have been possible to distinguish joint changes resulting from biological factors, and identify potential sex differences resulting through differences in activity patterns. Support for this interpretation may be derived from research by Chapman (pers. comm.) which is currently progress. Chapman is conducting a detailed study of vertebral joint disease, and early results point toward the existence of sex differences in vertebral osteoarthritis patterning. Although beyond the scope of this study, this suggests that future sex comparative studies should focus on the detailed examination of the respective vertebrae and avoid general comparisons between large segments of it.

The results of the Schmorl's node analysis are presented in table 8.9 and 8.10a-g. As with the results obtained for vertebral osteoarthritis and osteophytosis, the prevalence of Schmorl's nodes tended to rise with each successive age class, and the thoracic region displayed the highest prevalence, followed by the lumbar, cervical and lastly the first sacral vertebra. Again, the high prevalence of Schmorl's nodes in the thoracic region may simply have occurred because this region contains the greatest number of vertebrae, rather than being of any further significance. However, in contrast to the results obtained for osteoarthritis and osteophytosis, the prevalence of Schmorl's nodes did show a consistent difference between the sexes, with males displaying the greatest prevalence. This was less obvious among the results for the separate spinal regions (table 8.10a-g), although these did show a tendency for males to be more affected in the majority of age classes. It was in the figures relating to the complete spine that the sex difference was most apparent (table 8.9). The percentage of males affected exceeded the percentage of females in virtually every age class from every cemetery. As the pattern was so consistent, chi-square tests were applied to determine whether any of the sex differences were statistically significant, the results of which are included in table 8.9. These revealed that none of the sex differences within the respective cemeteries were statistically significant, with the exception of the age group *c.*25-35 from Abingdon, in which 67.6% of males displayed Schmorl's nodes compared with only 44.1% of females. However, the general lack of statistically significant sex differences within the respective cemetery samples may have been due to their comparatively small size, because when the data from all the sites were pooled, not only did the proportion of males affected exceed the proportion of females in all age classes, but the sex difference was significant within two of the four age groups, those aged between *c.*25-35 (χ^2=10.128 p=.001) and *c.*35-45 (χ^2=4.924 p=.026). Furthermore, the overall sex difference, with all age classes combined, yielded a chi-square value of 15.970, which was statistically significant beyond the .001 probability level. In percentage terms, 51.3% of all males displayed Schmorl's nodes compared with only 39.2% of all females.

The prominent sex difference in Schmorl's node prevalence may imply that Schmorl's nodes provide a better indication of activity-related stress than vertebral osteoarthritis and osteophytosis. One possible explanation could derive from the earlier age of Schmorl's node development. They frequently occur in young adults as the vertebrae are able to adapt to the shape of the herniated disc. This may enable the nodes to become manifest through sex differences in patterns of physical activity from a young age; whereas vertebral osteoarthritis and osteophytosis tend to develop with advancing age, and as the study by Knüsel and colleagues (1997) demonstrated, are likely to be influenced by biological factors. Wakely (pers. comm.) has commented on the lack of emphasis that is generally placed on examining subadult skeletons for Schmorl's nodes, and suggests that perhaps greater emphasis should be placed on this as a method of detecting activity-related stress among subadults.

As the most important aetiological factor in Schmorl's node development is traumatic stress, commonly through the strain of heavy lifting for example, the results of this study indicate that males were more frequently involved in this type of activity. This concords with the picture borne out by the analysis of osteoarthritis in the appendicular joints, which revealed a generally elevated prevalence among males, and a higher male prevalence in the acromio-clavicular and sterno-clavicular joints, suggestive of more strenuous physical activity with the upper limbs, such as that involved in carrying heavy weights.

Table 8.1 Proportion of individuals displaying osteoarthritis in the total male and female cemetery samples and the respective age categories (crude prevalence)

n_{oa} number of individuals displaying osteoarthritis n_t total number of individuals in sample
% percentage of sample displaying osteoarthritis χ^2 chi-square statistic p probability
ψ common odds ratio (a ratio exceeding the value of 1.00 indicates a higher prevalence of osteoarthritis among males, and a ratio of less than 1.00 indicates a higher prevalence of osteoarthritis among females)

		Males		Females				
	Age group	n_{oa} n_t	%	n_{oa} n_t	%	χ^2	p	ψ
Wharram	*c*.18-25	0/31	0.0	0/24	0.0	-	-	
	c.25-35	4/31	12.9	1/24	4.2	1.249	.264	
	c.35-45	14/35	40.0	5/24	20.8	2.396	.122	
	c.>45	38/75	50.7	19/43	44.2	.460	.498	
	Adult	8/40	20.0	2/14	14.3			
	Total	64/212	30.2	27/129	20.9	3.514	.061	1.69
Ipswich	*c*.18-25	1/26	3.9	1/11	9.1	.416	.519	
	c.25-35	5/36	13.9	7/18	38.9	4.339	.037	
	c.35-45	13/33	39.4	3/8	37.5	.010	.922	
	c.>45	12/33	36.4	9/17	52.9	1.266	.261	
	Adult	3/18	16.7	2/10	20.0			
	Total	34/146	23.3	22/64	34.4	2.797	.094	0.48
Abingdon	*c*.18-25	0/28	0.0	0/25	0.0	-	-	
	c.25-35	11/47	23.4	5/47	10.6	2.712	.100	
	c.35-45	15/61	24.6	10/42	23.8	.008	.928	
	c.>45	41/71	57.8	25/43	58.1	.002	.967	
	Adult	2/16	12.5	1/14	7.1			
	Total	69/223	30.9	41/171	24.0	2.333	.127	1.24

Table 8.1 contd. . . /

Table 8.1 (contd.)

	Age group	Males n_{oa}/n_t	Males %	Females n_{oa}/n_t	Females %	χ^2	p	ψ
St Nicholas	*c.*18-25	3/21	14.3	0/12	0.0	1.886	.170	
	*c.*25-35	5/21	23.8	6/28	21.4	.039	.843	
	*c.*35-45	8/18	44.4	8/17	47.1	.024	.877	
	c.>45	3/8	37.5	4/5	80.0	2.236	.135	
	Adult	7/23	30.4	3/12	25.0			
	Total	26/91	28.6	21/74	28.4	.001	.978	0.70
Fishergate 4	*c.*18-25	2/19	10.5	0/6	0.0	.686	.407	
	*c.*25-35	2/12	16.7	0/6	0.0	1.125	.289	
	*c.*35-45	6/9	66.7	7/10	70.0	.024	.876	
	c.>45	2/4	50.0	2/3	66.7	.194	.659	
	Adult	2/3	66.7	1/8	12.5			
	Total	14/47	29.8	10/33	30.3	.002	.960	1.42
Fishergate 6	*c.*18-25	0/24	0.0	0/3	0.0	-	-	
	*c.*25-35	6/37	16.2	1/13	7.7	.581	.446	
	*c.*35-45	25/43	58.1	8/14	57.1	.004	.948	
	c.>45	44/50	88.0	9/13	69.2	2.722	.099	
	Adult	7/22	31.8	3/10	30.0			
	Total	82/176	46.6	21/53	39.6	.799	.371	1.71
Pooled Site Data	*c.*18-25	6/149	4.0	1/81	1.2	1.386	.239	
	*c.*25-35	33/184	17.9	20/136	14.7	.590	.442	
	*c.*35-45	81/199	40.7	41/115	35.7	.783	.376	
	c.>45	140/241	58.1	68/124	54.8	.353	.552	
	Adult	29/122	23.8	12/68	17.7			
	Total	289/895	32.3	142/524	27.1	4.212	.040	1.23

Table 8.2a-g Proportion of male and female joints displaying osteoarthritis within the total cemetery samples and the respective age categories (corrected prevalence)

(a) Wharram Percy

n_{oa} number of joints in sample displaying osteoarthritis n_t total number of joints in sample
% percentage of sample displaying osteoarthritis

		Males		Females	
	Age group	n_{oa}/n_t	%	n_{oa}/n_t	%
Right Sterno-clavicular	*c.*18-25	0/21	0.0	0/18	0.0
	*c.*25-35	0/19	0.0	0/18	0.0
	*c.*35-45	0/25	0.0	0/22	0.0
	c.>45	2/52	3.8	2/37	5.4
	Adult	1/11	9.1	0/8	0.0
	Total	3/128	2.3	2/103	1.9
Left Sterno-clavicular	*c.*18-25	0/21	0.0	0/16	0.0
	*c.*25-35	0/20	0.0	0/17	0.0
	*c.*35-45	1/26	3.8	0/20	0.0
	c.>45	1/54	1.8	2/34	5.9
	Adult	1/11	9.1	0/8	0.0
	Total	3/132	2.3	2/95	2.1
Right Acromio-clavicular	*c.*18-25	0/6	0.0	0/9	0.0
	*c.*25-35	0/16	0.0	0/16	0.0
	*c.*35-45	8/23	34.8	2/14	14.3
	c.>45	15/46	32.6	7/26	26.9
	Adult	0/11	0.0	0/3	0.0
	Total	23/102	22.5	9/68	13.2
Left Acromio-clavicular	*c.*18-25	0/7	0.0	0/8	0.0
	*c.*25-35	0/19	0.0	0/17	0.0
	*c.*35-45	5/24	20.8	2/19	10.5
	c.>45	13/47	27.7	5/26	19.2
	Adult	0/9	0.0	0/7	0.0
	Total	18/106	17.0	7/77	9.1
Right Shoulder	*c.*18-25	0/21	0.0	0/19	0.0
	*c.*25-35	0/18	0.0	0/17	0.0
	*c.*35-45	0/26	0.0	0/20	0.0
	c.>45	2/55	3.6	1/37	2.7
	Adult	0/12	0.0	0/7	0.0
	Total	2/132	1.5	1/100	1.0

Table 8.2a contd. . . /

Table 8.2a (contd.)

	Age group	Males n_{oa}/n_t	Males %	Females n_{oa}/n_t	Females %
Left Shoulder	*c.* 18-25	0/20	0.0	0/17	0.0
	c. 25-35	0/21	0.0	0/20	0.0
	c. 35-45	0/25	0.0	0/21	0.0
	c. >45	2/54	3.7	0/33	0.0
	Adult	0/13	0.0	0/9	0.0
	Total	2/133	1.5	0/100	0.0
Right Elbow	*c.* 18-25	0/18	0.0	0/19	0.0
	c. 25-35	0/25	0.0	0/20	0.0
	c. 35-45	1/26	3.8	0/18	0.0
	c. >45	4/53	7.5	2/36	5.6
	Adult	0/20	0.0	0/8	0.0
	Total	5/142	3.5	2/101	2.0
Left Elbow	*c.* 18-25	0/19	0.0	0/17	0.0
	c. 25-35	0/25	0.0	0/19	0.0
	c. 35-45	1/27	3.7	0/23	0.0
	c. >45	2/48	4.2	1/36	2.8
	Adult	0/15	0.0	0/10	0.0
	Total	3/134	2.2	1/105	1.0
Right Wrist	*c.* 18-25	0/20	0.0	0/19	0.0
	c. 25-35	1/23	4.3	0/17	0.0
	c. 35-45	0/22	0.0	0/17	0.0
	c. >45	7/54	13.0	4/38	10.5
	Adult	2/25	8.0	0/9	0.0
	Total	10/144	6.9	4/100	4.0
Left Wrist	*c.* 18-25	0/23	0.0	0/20	0.0
	c. 25-35	0/21	0.0	0/20	0.0
	c. 35-45	1/24	4.2	0/18	0.0
	c. >45	8/52	15.4	4/39	10.3
	Adult	1/23	4.3	0/10	0.0
	Total	10/143	7.0	4/107	3.7
Right Hand	*c.* 18-25	0/23	0.0	0/20	0.0
	c. 25-35	1/23	4.3	0/19	0.0
	c. 35-45	2/24	8.3	3/16	18.8
	c. >45	7/51	13.7	5/38	13.2
	Adult	0/27	0.0	1/7	14.3
	Total	10/148	6.8	9/100	9.0

Table 8.2a contd. . . /

Table 8.2a (contd.)

	Age group	Males		Females	
		n_{oa}/n_t	%	n_{oa}/n_t	%
Left Hand	c.18-25	0/22	0.0	0/22	0.0
	c.25-35	2/22	9.1	0/20	0.0
	c.35-45	2/22	9.1	0/21	0.0
	c.>45	5/55	9.1	4/39	10.3
	Adult	0/26	0.0	0/10	0.0
	Total	9/147	6.1	4/112	3.6
Right Hip	c.18-25	0/20	0.0	0/21	0.0
	c.25-35	0/22	0.0	0/17	0.0
	c.35-45	3/24	12.5	0/17	0.0
	c.>45	9/54	16.7	6/38	15.8
	Adult	3/28	10.7	1/11	9.1
	Total	15/148	10.1	7/104	6.7
Left Hip	c.18-25	0/20	0.0	0/20	0.0
	c.25-35	1/25	4.0	0/16	0.0
	c.35-45	2/26	7.7	0/19	0.0
	c.>45	3/53	5.7	7/38	18.4
	Adult	3/28	10.7	1/11	9.1
	Total	9/152	5.9	8/104	7.7
Right Knee	c.18-25	0/19	0.0	0/17	0.0
	c.25-35	0/23	0.0	1/17	5.9
	c.35-45	0/20	0.0	0/15	0.0
	c.>45	0/49	0.0	3/34	8.8
	Adult	1/31	3.2	0/9	0.0
	Total	1/142	0.7	4/92	4.3
Left Knee	c.18-25	0/19	0.0	0/17	0.0
	c.25-35	0/25	0.0	0/17	0.0
	c.35-45	0/21	0.0	0/12	0.0
	c.>45	0/50	0.0	2/35	5.7
	Adult	1/32	3.1	1/9	11.1
	Total	1/147	0.7	3/90	3.3
Right Ankle	c.18-25	0/20	0.0	0/15	0.0
	c.25-35	0/22	0.0	0/16	0.0
	c.35-45	0/15	0.0	0/11	0.0
	c.>45	0/41	0.0	0/31	0.0
	Adult	0/28	0.0	0/7	0.0
	Total	0/126	0.0	0/80	0.0

Table 8.2a contd. . . /

Table 8.2a (contd.)

	Age group	Males n_{oa}/n_t	Males %	Females n_{oa}/n_t	Females %
Left Ankle	c.18-25	0/18	0.0	0/16	0.0
	c.25-35	0/21	0.0	0/17	0.0
	c.35-45	1/17	5.9	0/11	0.0
	c.>45	0/42	0.0	0/33	0.0
	Adult	1/24	4.2	0/4	0.0
	Total	2/122	1.6	0/81	0.0
Right Foot	c.18-25	0/19	0.0	0/17	0.0
	c.25-35	0/19	0.0	0/17	0.0
	c.35-45	0/16	0.0	0/11	0.0
	c.>45	4/35	11.4	1/33	3.0
	Adult	1/25	4.0	0/4	0.0
	Total	5/114	4.4	1/82	1.2
Left Foot	c.18-25	0/18	0.0	0/16	0.0
	c.25-35	0/21	0.0	0/17	0.0
	c.35-45	1/15	6.7	0/11	0.0
	c.>45	2/36	5.6	2/33	6.1
	Adult	1/20	5.0	0/5	0.0
	Total	4/110	3.6	2/82	2.4

(b) Ipswich Blackfriars

n_{oa} number of joints in sample displaying osteoarthritis n_t total number of joints in sample
% percentage of sample displaying osteoarthritis

	Age group	Males n_{oa}/n_t	Males %	Females n_{oa}/n_t	Females %
Right Sterno-clavicular	c.18-25	0/22	0.0	0/9	0.0
	c.25-35	0/27	0.0	0/13	0.0
	c.35-45	1/21	4.8	0/7	0.0
	c.>45	2/20	10.0	0/9	0.0
	Adult	0/8	0.0	0/5	0.0
	Total	3/98	3.1	0/43	0.0
Left Sterno-clavicular	c.18-25	0/20	0.0	0/10	0.0
	c.25-35	0/29	0.0	0/13	0.0
	c.35-45	1/24	4.2	1/7	14.3
	c.>45	3/22	13.6	0/10	0.0
	Adult	0/7	0.0	0/7	0.0
	Total	4/102	3.9	1/47	2.1

Table 8.2b contd. . . /

Table 8.2b (contd.)

	Age group	Males n_{oa}/n_t	Males %	Females n_{oa}/n_t	Females %
Right Acromio-clavicular	c.18-25	0/17	0.0	0/9	0.0
	c.25-35	0/23	0.0	3/10	30.0
	c.35-45	5/21	23.8	1/4	25.0
	c.>45	5/18	27.8	1/8	12.5
	Adult	0/2	0.0	1/3	33.3
	Total	10/81	12.3	6/34	17.6
Left Acromio-clavicular	c.18-25	0/17	0.0	0/6	0.0
	c.25-35	0/21	0.0	2/9	22.2
	c.35-45	2/17	11.8	1/6	16.7
	c.>45	7/20	35.0	1/7	14.3
	Adult	1/5	20.0	1/5	20.0
	Total	10/80	12.5	5/33	15.2
Right Shoulder	c.18-25	0/22	0.0	0/10	0.0
	c.25-35	0/31	0.0	0/13	0.0
	c.35-45	1/27	3.7	0/7	0.0
	c.>45	2/25	8.0	1/14	7.1
	Adult	0/7	0.0	1/6	16.7
	Total	3/112	2.7	2/50	4.0
Left Shoulder	c.18-25	1/21	4.8	0/10	0.0
	c.25-35	0/30	0.0	0/13	0.0
	c.35-45	1/26	3.9	0/8	0.0
	c.>45	2/26	7.7	0/14	0.0
	Adult	0/9	0.0	0/7	0.0
	Total	4/112	3.6	0/52	0.0
Right Elbow	c.18-25	0/22	0.0	0/10	0.0
	c.25-35	0/32	0.0	0/14	0.0
	c.35-45	1/30	3.3	0/8	0.0
	c.>45	2/27	7.4	1/13	7.7
	Adult	0/12	0.0	1/7	14.3
	Total	3/123	2.4	2/52	3.8
Left Elbow	c.18-25	0/20	0.0	0/10	0.0
	c.25-35	0/31	0.0	0/14	0.0
	c.35-45	0/26	0.0	0/7	0.0
	c.>45	2/27	7.4	2/15	13.3
	Adult	0/12	0.0	2/8	25.0
	Total	2/116	1.7	4/54	7.4

Table 8.2b contd. . . /

Table 8.2b (contd.)

	Age group	Males n_{oa}/n_t	Males %	Females n_{oa}/n_t	Females %
Right Wrist	*c.* 18-25	0/24	0.0	0/10	0.0
	c. 25-35	0/31	0.0	0/14	0.0
	c. 35-45	1/27	3.7	1/8	12.5
	c. >45	2/27	7.4	1/16	6.3
	Adult	0/12	0.0	1/9	11.1
	Total	3/121	2.5	3/57	5.3
Left Wrist	*c.* 18-25	0/22	0.0	0/11	0.0
	c. 25-35	1/32	3.1	0/14	0.0
	c. 35-45	0/30	0.0	0/8	0.0
	c. >45	4/27	14.8	3/16	18.8
	Adult	1/12	8.3	3/8	37.5
	Total	6/123	4.9	6/57	10.5
Right Hand	*c.* 18-25	0/26	0.0	0/11	0.0
	c. 25-35	1/36	2.8	0/18	0.0
	c. 35-45	0/33	0.0	1/8	12.5
	c. >45	2/33	6.1	3/17	17.6
	Adult	1/18	5.6	3/10	30.0
	Total	4/146	2.7	7/64	10.9
Left Hand	*c.* 18-25	0/22	0.0	0/10	0.0
	c. 25-35	0/31	0.0	1/14	7.1
	c. 35-45	1/30	3.3	0/8	0.0
	c. >45	5/25	20.0	3/16	18.8
	Adult	0/12	0.0	3/7	42.9
	Total	6/120	5.0	7/55	12.7
Right Hip	*c.* 18-25	0/23	0.0	0/10	0.0
	c. 25-35	0/31	0.0	1/16	6.3
	c. 35-45	1/30	3.3	0/8	0.0
	c. >45	4/30	13.3	0/15	0.0
	Adult	1/12	8.3	0/9	0.0
	Total	6/126	4.8	1/58	1.7
Left Hip	*c.* 18-25	0/24	0.0	0/11	0.0
	c. 25-35	0/32	0.0	0/15	0.0
	c. 35-45	0/30	0.0	0/8	0.0
	c. >45	4/28	14.3	2/15	13.3
	Adult	2/13	15.4	2/8	25.0
	Total	6/127	4.7	4/57	7.0

Table 8.2b contd. . . /

Table 8.2b (contd.)

	Age group	Males n_{oa}/n_t	Males %	Females n_{oa}/n_t	Females %
Right Knee	c.18-25	0/26	0.0	1/11	9.1
	c.25-35	0/31	0.0	0/15	0.0
	c.35-45	1/30	3.3	1/7	14.3
	c.>45	0/29	0.0	0/16	0.0
	Adult	0/12	0.0	0/9	0.0
	Total	1/128	0.8	2/58	3.4
Left Knee	c.18-25	0/21	0.0	1/11	9.1
	c.25-35	0/34	0.0	0/15	0.0
	c.35-45	2/29	6.9	2/7	28.6
	c.>45	0/28	0.0	2/17	11.8
	Adult	0/12	0.0	2/8	25.0
	Total	2/124	1.6	7/58	12.1
Right Ankle	c.18-25	0/25	0.0	0/11	0.0
	c.25-35	0/31	0.0	0/14	0.0
	c.35-45	0/31	0.0	1/8	12.5
	c.>45	0/30	0.0	1/17	5.9
	Adult	0/14	0.0	1/9	11.1
	Total	0/131	0.0	3/59	5.1
Left Ankle	c.18-25	0/24	0.0	0/11	0.0
	c.25-35	1/34	2.9	0/14	0.0
	c.35-45	0/31	0.0	0/8	0.0
	c.>45	1/30	3.3	0/17	0.0
	Adult	0/13	0.0	0/9	0.0
	Total	2/132	1.5	0/59	0.0
Right Foot	c.18-25	0/26	0.0	0/11	0.0
	c.25-35	1/30	3.3	2/15	13.3
	c.35-45	3/30	10.0	0/8	0.0
	c.>45	5/28	17.9	3/17	17.6
	Adult	1/13	7.7	3/9	33.3
	Total	10/127	7.9	8/60	13.3
Left Foot	c.18-25	0/24	0.0	0/11	0.0
	c.25-35	0/32	0.0	1/14	7.1
	c.35-45	1/31	3.2	0/8	0.0
	c.>45	2/29	6.9	3/17	17.6
	Adult	0/13	0.0	3/9	33.3
	Total	3/129	2.3	7/59	11.9

(c) Abingdon

n_{oa} number of joints in sample displaying osteoarthritis n_t total number of joints in sample
% percentage of sample displaying osteoarthritis

	Age group	Males n_{oa}/n_t	Males %	Females n_{oa}/n_t	Females %
Right Sterno-clavicular	c.18-25	0/19	0.0	0/18	0.0
	c.25-35	0/31	0.0	0/26	0.0
	c.35-45	3/32	9.3	2/23	8.7
	c.>45	16/56	28.6	8/35	22.9
	Adult	0/1	0.0	0/4	0.0
	Total	19/139	13.7	10/106	9.4
Left Sterno-clavicular	c.18-25	0/20	0.0	0/18	0.0
	c.25-35	0/30	0.0	0/25	0.0
	c.35-45	2/32	6.3	2/21	9.5
	c.>45	12/58	20.7	9/34	26.5
	Adult	0/1	0.0	0/4	0.0
	Total	14/141	9.9	11/102	10.8
Right Acromio-clavicular	c.18-25	0/19	0.0	0/18	0.0
	c.25-35	1/31	3.2	1/26	3.8
	c.35-45	2/32	6.3	2/23	8.7
	c.>45	15/56	26.8	6/35	17.1
	Adult	0/1	0.0	1/4	25.0
	Total	18/139	12.9	10/106	9.4
Left Acromio-clavicular	c.18-25	0/20	0.0	0/18	0.0
	c.25-35	1/30	3.3	0/25	0.0
	c.35-45	2/32	6.3	2/21	9.5
	c.>45	11/58	19.0	8/34	23.5
	Adult	0/1	0.0	0/4	0.0
	Total	14/141	9.9	10/102	9.8
Right Shoulder	c.18-25	0/18	0.0	0/17	0.0
	c.25-35	0/30	0.0	2/28	7.1
	c.35-45	2/29	6.9	1/22	4.5
	c.>45	7/60	11.7	3/37	8.1
	Adult	0/2	0.0	0/4	0.0
	Total	9/139	6.5	6/108	5.6
Left Shoulder	c.18-25	0/19	0.0	0/19	0.0
	c.25-35	1/33	3.0	1/29	3.4
	c.35-45	1/36	2.8	1/23	4.3
	c.>45	5/60	8.3	2/33	6.1
	Adult	0/1	0.0	0/4	0.0
	Total	7/149	4.7	4/108	3.7

Table 8.2c contd. . . /

Table 8.2c (contd.)

	Age group	Males n_{oa}/n_t	Males %	Females n_{oa}/n_t	Females %
Right Elbow	c.18-25	0/22	0.0	0/17	0.0
	c.25-35	3/34	8.8	2/29	6.9
	c.35-45	3/40	7.5	3/29	10.3
	c.>45	4/66	6.1	3/37	8.1
	Adult	1/5	20.0	0/5	0.0
	Total	11/167	6.6	8/117	6.8
Left Elbow	c.18-25	0/21	0.0	0/18	0.0
	c.25-35	2/38	5.3	1/33	3.0
	c.35-45	3/45	6.7	3/31	9.7
	c.>45	2/63	3.2	1/37	2.7
	Adult	0/1	0.0	0/6	0.0
	Total	7/168	4.2	5/125	4.0
Right Wrist	c.18-25	0/21	0.0	0/17	0.0
	c.25-35	1/35	2.9	2/31	6.4
	c.35-45	2/38	5.3	1/31	3.2
	c.>45	10/64	15.6	6/35	17.1
	Adult	0/6	0.0	0/4	0.0
	Total	13/164	7.9	9/118	7.6
Left Wrist	c.18-25	0/18	0.0	0/17	0.0
	c.25-35	2/38	5.3	1/37	2.7
	c.35-45	0/46	0.0	2/32	6.3
	c.>45	7/62	11.3	5/38	13.2
	Adult	1/3	33.3	0/4	0.0
	Total	10/167	6.0	8/128	6.3
Right Hand	c.18-25	0/19	0.0	0/16	0.0
	c.25-35	0/32	0.0	2/32	6.3
	c.35-45	3/40	7.5	0/29	0.0
	c.>45	7/64	10.9	4/37	10.8
	Adult	0/5	0.0	0/5	0.0
	Total	10/160	6.3	6/119	5.0
Left Hand	c.18-25	0/18	0.0	0/17	0.0
	c.25-35	1/35	2.9	1/37	2.7
	c.35-45	2/46	4.3	0/31	0.0
	c.>45	4/58	6.9	3/37	8.1
	Adult	0/4	0.0	0/3	0.0
	Total	7/161	4.3	4/125	3.2

Table 8.2c contd. . . /

Table 8.2c (contd.)

	Age group	Males n_{oa}/n_t	Males %	Females n_{oa}/n_t	Females %
Right Hip	*c.*18-25	0/19	0.0	0/15	0.0
	*c.*25-35	0/35	0.0	2/33	6.1
	*c.*35-45	4/45	8.9	2/32	6.3
	c.>45	8/65	12.3	8/38	21.1
	Adult	1/3	33.3	0/4	0.0
	Total	13/167	7.8	12/122	9.8
Left Hip	*c.*18-25	0/19	0.0	0/18	0.0
	*c.*25-35	1/34	2.9	2/35	5.7
	*c.*35-45	4/48	8.3	2/33	6.1
	c.>45	12/64	18.8	6/37	16.2
	Adult	1/4	25.0	0/5	0.0
	Total	18/169	10.7	10/128	7.8
Right Knee	*c.*18-25	0/17	0.0	0/17	0.0
	*c.*25-35	0/36	0.0	1/34	2.9
	*c.*35-45	1/44	2.3	5/32	15.6
	c.>45	4/59	6.8	6/35	17.1
	Adult	0/5	0.0	0/5	0.0
	Total	5/161	3.1	12/123	9.8
Left Knee	*c.*18-25	0/17	0.0	0/19	0.0
	*c.*25-35	0/33	0.0	0/35	0.0
	*c.*35-45	2/48	4.2	5/33	15.2
	c.>45	4/62	6.4	6/36	16.7
	Adult	0/6	0.0	0/6	0.0
	Total	6/166	3.6	11/129	8.5
Right Ankle	*c.*18-25	0/17	0.0	0/16	0.0
	*c.*25-35	0/31	0.0	0/32	0.0
	*c.*35-45	1/43	2.3	1/30	3.3
	c.>45	1/55	1.8	1/33	3.0
	Adult	0/7	0.0	0/5	0.0
	Total	2/153	1.3	2/116	1.7
Left Ankle	*c.*18-25	0/15	0.0	0/17	0.0
	*c.*25-35	0/34	0.0	0/34	0.0
	*c.*35-45	0/42	0.0	1/31	3.2
	c.>45	2/56	3.6	1/33	3.0
	Adult	0/8	0.0	0/5	0.0
	Total	2/155	1.3	2/120	1.7

Table 8.2c contd. . . /

Table 8.2c (contd.)

	Age group	Males n_{oa}/n_t	Males %	Females n_{oa}/n_t	Females %
Right Foot	c.18-25	0/16	0.0	0/16	0.0
	c.25-35	0/30	0.0	0/32	0.0
	c.35-45	0/38	0.0	2/30	6.7
	c.>45	1/54	1.9	2/33	6.1
	Adult	0/8	0.0	0/6	0.0
	Total	1/146	0.7	4/117	3.4
Left Foot	c.18-25	0/15	0.0	0/18	0.0
	c.25-35	1/32	3.1	0/31	0.0
	c.35-45	0/41	0.0	2/30	6.7
	c.>45	2/50	4.0	1/32	3.1
	Adult	0/7	0.0	0/6	0.0
	Total	3/145	2.1	3/117	2.6

(d) St Nicholas Shambles

n_{oa} number of joints in sample displaying osteoarthritis n_t total number of joints in sample
% percentage of sample displaying osteoarthritis

	Age group	Males n_{oa}/n_t	Males %	Females n_{oa}/n_t	Females %
Right Sterno-clavicular	c.18-25	0/5	0.0	0/4	0.0
	c.25-35	0/5	0.0	0/11	0.0
	c.35-45	0/10	0.0	0/12	0.0
	c.>45	0/2	0.0	0/4	0.0
	Adult	0/5	0.0	0/1	0.0
	Total	0/27	0.0	0/32	0.0
Left Sterno-clavicular	c.18-25	0/6	0.0	0/3	0.0
	c.25-35	0/5	0.0	0/9	0.0
	c.35-45	0/10	0.0	0/8	0.0
	c.>45	0/2	0.0	0/3	0.0
	Adult	0/2	0.0	0/1	0.0
	Total	0/25	0.0	0/24	0.0
Right Acromio-clavicular	c.18-25	0/6	0.0	0/5	0.0
	c.25-35	1/5	20.0	0/9	0.0
	c.35-45	2/10	20.0	0/10	0.0
	c.>45	1/2	50.0	1/4	25.0
	Adult	1/5	20.0	0/2	0.0
	Total	5/28	17.9	1/30	3.3

Table 8.2d contd. . . /

Table 8.2d (contd.)

	Age group	Males n_{oa}/n_t	Males %	Females n_{oa}/n_t	Females %
Left Acromio-clavicular	c.18-25	2/7	28.6	0/4	0.0
	c.25-35	1/4	25.0	1/8	12.5
	c.35-45	0/10	0.0	0/8	0.0
	c.>45	1/2	50.0	1/3	33.3
	Adult	0/1	0.0	1/3	33.3
	Total	4/24	16.7	3/26	11.5
Right Shoulder	c.18-25	0/9	0.0	0/5	0.0
	c.25-35	0/6	0.0	0/8	0.0
	c.35-45	1/6	16.7	0/8	0.0
	c.>45	0/2	0.0	0/3	0.0
	Adult	0/5	0.0	0/4	0.0
	Total	1/28	3.6	0/28	0.0
Left Shoulder	c.18-25	0/7	0.0	0/3	0.0
	c.25-35	0/7	0.0	0/10	0.0
	c.35-45	0/11	0.0	0/8	0.0
	c.>45	0/1	0.0	0/3	0.0
	Adult	0/2	0.0	0/5	0.0
	Total	0/28	0.0	0/29	0.0
Right Elbow	c.18-25	0/12	0.0	0/5	0.0
	c.25-35	0/10	0.0	1/17	5.9
	c.35-45	1/11	9.1	0/13	0.0
	c.>45	0/1	0.0	0/3	0.0
	Adult	0/6	0.0	0/6	0.0
	Total	1/40	2.5	1/44	2.3
Left Elbow	c.18-25	0/9	0.0	0/3	0.0
	c.25-35	0/12	0.0	0/14	0.0
	c.35-45	0/9	0.0	0/10	0.0
	c.>45	0/3	0.0	0/3	0.0
	Adult	1/4	25.0	0/4	0.0
	Total	1/37	2.7	0/34	0.0
Right Wrist	c.18-25	0/6	0.0	0/7	0.0
	c.25-35	0/9	0.0	0/14	0.0
	c.35-45	0/11	0.0	0/12	0.0
	c.>45	0/0	0.0	0/4	0.0
	Adult	0/8	0.0	0/1	0.0
	Total	0/34	0.0	0/38	0.0

Table 8.2d contd. . . /

Table 8.2d (contd.)

	Age group	Males n_{oa}/n_t	Males %	Females n_{oa}/n_t	Females %
Left Wrist	*c.*18-25	0/9	0.0	0/5	0.0
	*c.*25-35	0/10	0.0	0/13	0.0
	*c.*35-45	0/12	0.0	0/9	0.0
	c.>45	0/0	0.0	0/3	0.0
	Adult	0/5	0.0	0/5	0.0
	Total	0/36	0.0	0/35	0.0
Right Hand	*c.*18-25	0/11	0.0	0/7	0.0
	*c.*25-35	0/11	0.0	0/13	0.0
	*c.*35-45	0/11	0.0	0/12	0.0
	c.>45	0/1	0.0	0/4	0.0
	Adult	0/8	0.0	1/4	25.0
	Total	0/42	0.0	1/40	2.5
Left Hand	*c.*18-25	0/10	0.0	0/4	0.0
	*c.*25-35	0/12	0.0	0/14	0.0
	*c.*35-45	0/12	0.0	0/10	0.0
	c.>45	0/1	0.0	0/3	0.0
	Adult	0/8	0.0	0/3	0.0
	Total	0/43	0.0	0/34	0.0
Right Hip	*c.*18-25	0/12	0.0	0/8	0.0
	*c.*25-35	0/13	0.0	0/18	0.0
	*c.*35-45	3/9	33.3	1/9	11.1
	c.>45	0/0	0.0	0/4	0.0
	Adult	0/10	0.0	0/7	0.0
	Total	3/44	6.8	1/46	2.2
Left Hip	*c.*18-25	0/9	0.0	0/6	0.0
	*c.*25-35	0/12	0.0	1/17	5.9
	*c.*35-45	1/11	9.1	1/10	10.0
	c.>45	0/1	0.0	0/4	0.0
	Adult	1/9	11.1	0/2	0.0
	Total	2/42	4.8	2/39	5.1
Right Knee	*c.*18-25	0/7	0.0	0/5	0.0
	*c.*25-35	1/12	8.3	0/13	0.0
	*c.*35-45	1/9	11.1	0/8	0.0
	c.>45	0/1	0.0	0/4	0.0
	Adult	0/11	0.0	0/5	0.0
	Total	2/40	5.0	0/35	0.0

Table 8.2d contd. . . /

Table 8.2d (contd.)

	Age group	Males n_{oa}/n_t	Males %	Females n_{oa}/n_t	Females %
Left Knee	*c.* 18-25	0/8	0.0	0/0	0.0
	c. 25-35	0/11	0.0	0/11	0.0
	c. 35-45	1/9	11.1	0/8	0.0
	c. >45	0/1	0.0	0/3	0.0
	Adult	1/11	9.1	0/6	0.0
	Total	2/40	5.0	0/28	0.0
Right Ankle	*c.* 18-25	0/8	0.0	0/1	0.0
	c. 25-35	1/9	11.1	1/10	10.0
	c. 35-45	1/8	12.5	0/7	0.0
	c. >45	0/1	0.0	0/3	0.0
	Adult	1/11	9.1	0/4	0.0
	Total	3/37	8.1	1/25	4.0
Left Ankle	*c.* 18-25	0/7	0.0	0/1	0.0
	c. 25-35	0/8	0.0	0/9	0.0
	c. 35-45	1/8	12.5	0/7	0.0
	c. >45	0/1	0.0	0/3	0.0
	Adult	2/11	18.2	0/4	0.0
	Total	3/35	8.6	0/24	0.0
Right Foot	*c.* 18-25	0/6	0.0	0/1	0.0
	c. 25-35	0/8	0.0	0/6	0.0
	c. 35-45	0/7	0.0	0/7	0.0
	c. >45	0/1	0.0	0/2	0.0
	Adult	1/10	10.0	0/3	0.0
	Total	1/32	3.1	0/19	0.0
Left Foot	*c.* 18-25	0/6	0.0	0/1	0.0
	c. 25-35	0/7	0.0	0/6	0.0
	c. 35-45	0/8	0.0	0/6	0.0
	c. >45	0/1	0.0	0/2	0.0
	Adult	0/9	0.0	0/3	0.0
	Total	0/31	0.0	0/18	0.0

(e) Fishergate 4

n_{oa} number of joints in sample displaying osteoarthritis n_t total number of joints in sample
% percentage of sample displaying osteoarthritis

	Age group	Males		Females	
		n_{oa}/n_t	%	n_{oa}/n_t	%
Right Sterno-clavicular	*c.* 18-25	0/12	0.0	0/3	0.0
	c. 25-35	0/11	0.0	0/5	0.0
	c. 35-45	0/6	0.0	0/7	0.0
	c. >45	0/2	0.0	0/2	0.0
	Adult	0/0	0.0	0/1	0.0
	Total	0/31	0.0	0/18	0.0
Left Sterno-clavicular	*c.* 18-25	0/11	0.0	0/4	0.0
	c. 25-35	0/11	0.0	0/6	0.0
	c. 35-45	0/6	0.0	0/6	0.0
	c. >45	0/2	0.0	0/3	0.0
	Adult	0/0	0.0	0/1	0.0
	Total	0/30	0.0	0/20	0.0
Right Acromio-clavicular	*c.* 18-25	0/11	0.0	0/2	0.0
	c. 25-35	0/11	0.0	0/5	0.0
	c. 35-45	2/5	40.0	1/8	12.5
	c. >45	2/3	66.7	1/2	50.0
	Adult	0/0	0.0	0/1	0.0
	Total	4/30	13.3	2/18	11.1
Left Acromio-clavicular	*c.* 18-25	0/13	0.0	0/4	0.0
	c. 25-35	0/10	0.0	0/5	0.0
	c. 35-45	1/6	16.7	0/7	0.0
	c. >45	0/2	0.0	1/3	33.3
	Adult	0/0	0.0	0/0	0.0
	Total	1/31	3.2	1/19	5.3
Right Shoulder	*c.* 18-25	0/14	0.0	0/2	0.0
	c. 25-35	0/10	0.0	0/5	0.0
	c. 35-45	0/6	0.0	0/7	0.0
	c. >45	0/2	0.0	0/2	0.0
	Adult	0/0	0.0	0/3	0.0
	Total	0/32	0.0	0/19	0.0
Left Shoulder	*c.* 18-25	0/13	0.0	0/5	0.0
	c. 25-35	0/10	0.0	0/6	0.0
	c. 35-45	0/6	0.0	0/8	0.0
	c. >45	0/2	0.0	0/3	0.0
	Adult	0/1	0.0	0/0	0.0
	Total	0/32	0.0	0/22	0.0

Table 8.2e contd. . . /

Table 8.2e (contd.)

	Age group	Males n_{oa}/n_t	Males %	Females n_{oa}/n_t	Females %
Right Elbow	*c.* 18-25	0/17	0.0	0/3	0.0
	c. 25-35	0/11	0.0	0/3	0.0
	c. 35-45	0/9	0.0	1/10	10.0
	c. >45	0/3	0.0	1/2	50.0
	Adult	0/0	0.0	0/3	0.0
	Total	0/40	0.0	2/21	9.5
Left Elbow	*c.* 18-25	0/16	0.0	0/6	0.0
	c. 25-35	0/11	0.0	0/6	0.0
	c. 35-45	0/8	0.0	0/9	0.0
	c. >45	0/3	0.0	0/3	0.0
	Adult	0/1	0.0	0/3	0.0
	Total	0/39	0.0	0/27	0.0
Right Wrist	*c.* 18-25	0/17	0.0	0/5	0.0
	c. 25-35	1/10	10.0	0/5	0.0
	c. 35-45	1/9	11.1	0/10	0.0
	c. >45	0/2	0.0	0/3	0.0
	Adult	0/0	0.0	0/2	0.0
	Total	2/38	5.3	0/25	0.0
Left Wrist	*c.* 18-25	0/13	0.0	0/4	0.0
	c. 25-35	0/11	0.0	0/5	0.0
	c. 35-45	1/8	12.5	0/10	0.0
	c. >45	0/2	0.0	0/3	0.0
	Adult	0/1	0.0	0/2	0.0
	Total	1/35	2.9	0/24	0.0
Right Hand	*c.* 18-25	0/16	0.0	0/4	0.0
	c. 25-35	0/11	0.0	0/5	0.0
	c. 35-45	0/8	0.0	1/9	11.1
	c. >45	0/3	0.0	0/3	0.0
	Adult	0/2	0.0	0/2	0.0
	Total	0/40	0.0	1/23	4.3
Left Hand	*c.* 18-25	0/14	0.0	0/4	0.0
	c. 25-35	1/10	10.0	0/4	0.0
	c. 35-45	1/8	12.5	1/10	10.0
	c. >45	0/3	0.0	0/3	0.0
	Adult	0/2	0.0	0/1	0.0
	Total	2/37	5.4	1/22	4.5

Table 8.2e contd. . . /

Table 8.2e (contd.)

	Age group	Males n_{oa}/n_t	Males %	Females n_{oa}/n_t	Females %
Right Hip	c.18-25	0/18	0.0	0/3	0.0
	c.25-35	0/10	0.0	0/3	0.0
	c.35-45	1/9	11.1	0/10	0.0
	c.>45	0/4	0.0	0/2	0.0
	Adult	0/1	0.0	0/2	0.0
	Total	1/42	2.4	0/20	0.0
Left Hip	c.18-25	0/16	0.0	0/4	0.0
	c.25-35	0/10	0.0	0/4	0.0
	c.35-45	1/8	12.5	0/9	0.0
	c.>45	0/3	0.0	0/3	0.0
	Adult	0/2	0.0	0/1	0.0
	Total	1/39	2.6	0/21	0.0
Right Knee	c.18-25	0/17	0.0	0/3	0.0
	c.25-35	0/10	0.0	0/4	0.0
	c.35-45	0/9	0.0	1/7	14.3
	c.>45	0/2	0.0	0/2	0.0
	Adult	1/3	33.3	1/3	33.3
	Total	1/41	2.4	2/19	10.5
Left Knee	c.18-25	0/15	0.0	0/3	0.0
	c.25-35	0/10	0.0	0/5	0.0
	c.35-45	1/9	11.1	1/8	12.5
	c.>45	0/3	0.0	0/2	0.0
	Adult	1/3	33.3	0/2	0.0
	Total	2/40	5.0	1/20	5.0
Right Ankle	c.18-25	0/15	0.0	0/1	0.0
	c.25-35	0/8	0.0	0/4	0.0
	c.35-45	1/8	12.5	0/7	0.0
	c.>45	0/2	0.0	0/2	0.0
	Adult	0/3	0.0	0/6	0.0
	Total	1/36	2.8	0/20	0.0
Left Ankle	c.18-25	0/15	0.0	0/2	0.0
	c.25-35	0/8	0.0	0/5	0.0
	c.35-45	0/8	0.0	0/7	0.0
	c.>45	0/3	0.0	0/2	0.0
	Adult	0/3	0.0	0/3	0.0
	Total	0/37	0.0	0/19	0.0

Table 8.2e contd. . . /

Table 8.2e (contd.)

	Age group	Males n_{oa}/n_t	Males %	Females n_{oa}/n_t	Females %
Right Foot	c.18-25	0/15	0.0	0/1	0.0
	c.25-35	0/8	0.0	0/4	0.0
	c.35-45	1/8	12.5	1/7	14.3
	c.>45	0/2	0.0	1/2	50.0
	Adult	2/3	66.7	0/5	0.0
	Total	3/36	8.3	2/19	10.5
Left Foot	c.18-25	0/15	0.0	0/2	0.0
	c.25-35	0/8	0.0	0/5	0.0
	c.35-45	0/8	0.0	1/6	16.7
	c.>45	0/3	0.0	0/2	0.0
	Adult	0/3	0.0	0/3	0.0
	Total	0/37	0.0	1/18	5.6

(f) Fishergate 6

n_{oa} number of joints in sample displaying osteoarthritis n_t total number of joints in sample
% percentage of sample displaying osteoarthritis

	Age group	Males n_{oa}/n_t	Males %	Females n_{oa}/n_t	Females %
Right Sterno-clavicular	c.18-25	0/15	0.0	0/3	0.0
	c.25-35	1/20	5.0	0/10	0.0
	c.35-45	1/28	3.6	1/11	9.1
	c.>45	18/38	47.4	1/5	20.0
	Adult	1/2	50.0	0/1	0.0
	Total	21/103	20.4	2/30	6.7
Left Sterno-clavicular	c.18-25	0/14	0.0	0/2	0.0
	c.25-35	0/22	0.0	0/9	0.0
	c.35-45	1/31	3.2	0/8	0.0
	c.>45	12/36	33.3	1/6	16.7
	Adult	1/4	25.0	0/2	0.0
	Total	14/107	13.1	1/27	3.7
Right Acromio-clavicular	c.18-25	0/16	0.0	0/2	0.0
	c.25-35	0/23	0.0	0/9	0.00
	c.35-45	7/29	24.1	3/8	37.5
	c.>45	20/38	52.6	1/7	14.3
	Adult	0/3	0.0	0/1	0.0
	Total	27/109	24.8	4/27	14.8

Table 8.2f contd. . . /

Table 8.2f (contd.)

	Age group	Males		Females	
		n_{oa}/n_t	%	n_{oa}/n_t	%
Left Acromio-clavicular	c.18-25	0/15	0.0	0/1	0.0
	c.25-35	0/22	0.0	0/10	0.0
	c.35-45	7/29	24.1	1/7	14.3
	c.>45	17/37	45.9	2/7	28.6
	Adult	0/1	0.0	0/1	0.0
	Total	24/104	23.1	3/26	11.5
Right Shoulder	c.18-25	0/17	0.0	0/3	0.0
	c.25-35	0/23	0.0	0/11	0.0
	c.35-45	1/31	3.2	0/11	0.0
	c.>45	4/38	10.5	2/8	25.0
	Adult	0/6	0.0	0/0	0.0
	Total	5/115	4.3	2/33	6.1
Left Shoulder	c.18-25	0/17	0.0	0/2	0.0
	c.25-35	0/22	0.0	0/12	0.0
	c.35-45	1/31	3.2	0/9	0.0
	c.>45	6/44	13.6	2/6	33.3
	Adult	0/4	0.0	0/1	0.0
	Total	7/118	5.9	2/30	6.7
Right Elbow	c.18-25	0/19	0.0	0/3	0.0
	c.25-35	0/30	0.0	1/12	8.3
	c.35-45	2/37	5.4	0/10	0.0
	c.>45	4/41	9.8	3/12	25.0
	Adult	0/8	0.0	0/0	0.0
	Total	6/135	4.4	4/37	10.8
Left Elbow	c.18-25	0/19	0.0	0/1	0.0
	c.25-35	0/29	0.0	0/12	0.0
	c.35-45	3/36	8.3	0/10	0.0
	c.>45	1/47	2.1	0/11	0.0
	Adult	1/6	16.7	0/2	0.0
	Total	5/137	3.6	0/36	0.0
Right Wrist	c.18-25	0/19	0.0	0/3	0.0
	c.25-35	0/31	0.0	0/12	0.0
	c.35-45	3/38	7.9	1/10	10.0
	c.>45	13/45	28.9	3/9	33.3
	Adult	1/6	16.7	1/3	33.3
	Total	17/139	12.2	5/37	13.5

Table 8.2f contd. . . /

Table 8.2f (contd.)

	Age group	Males n_{oa}/n_t	Males %	Females n_{oa}/n_t	Females %
Left Wrist	c.18-25	0/19	0.0	0/3	0.0
	c.25-35	0/30	0.0	0/12	0.0
	c.35-45	2/38	5.3	1/12	8.3
	c.>45	11/47	23.4	2/9	22.2
	Adult	2/7	28.6	1/3	33.3
	Total	15/141	10.6	4/39	10.3
Right Hand	c.18-25	0/20	0.0	0/3	0.0
	c.25-35	0/32	0.0	0/12	0.0
	c.35-45	6/38	15.8	1/11	9.1
	c.>45	15/45	33.3	2/11	18.2
	Adult	2/6	33.3	0/3	0.0
	Total	23/141	16.3	3/40	7.5
Left Hand	c.18-25	0/17	0.0	0/2	0.0
	c.25-35	0/28	0.0	0/12	0.0
	c.35-45	3/41	7.3	1/13	7.7
	c.>45	13/45	28.9	2/9	22.2
	Adult	1/6	16.7	1/3	33.3
	Total	17/137	12.4	4/39	10.3
Right Hip	c.18-25	0/21	0.0	0/3	0.0
	c.25-35	2/32	6.3	0/12	0.0
	c.35-45	1/39	2.6	1/10	10.0
	c.>45	10/45	22.2	3/12	25.0
	Adult	0/8	0.0	0/5	0.0
	Total	13/145	9.0	4/42	9.5
Left Hip	c.18-25	0/19	0.0	0/2	0.0
	c.25-35	1/30	3.3	0/13	0.0
	c.35-45	1/41	2.4	2/12	16.7
	c.>45	12/47	25.5	3/12	25.0
	Adult	0/7	0.0	0/3	0.0
	Total	14/144	9.7	5/42	11.9
Right Knee	c.18-25	0/19	0.0	0/3	0.0
	c.25-35	1/31	3.2	0/12	0.0
	c.35-45	6/40	15.0	0/10	0.0
	c.>45	8/41	19.5	3/10	30.0
	Adult	2/14	14.3	1/3	33.3
	Total	17/145	11.7	4/38	10.5

Table 8.2f contd. . . /

Table 8.2f (contd.)

	Age group	Males		Females	
		n_{oa}/n_t	%	n_{oa}/n_t	%
Left Knee	c.18-25	0/20	0.0	0/3	0.0
	c.25-35	0/31	0.0	0/13	0.0
	c.35-45	4/39	10.3	0/12	0.0
	c.>45	6/47	12.8	2/10	20.0
	Adult	2/13	15.4	1/4	25.0
	Total	12/150	8.0	3/42	7.1
Right Ankle	c.18-25	0/19	0.0	0/3	0.0
	c.25-35	0/28	0.0	0/13	0.0
	c.35-45	0/35	0.0	0/11	0.0
	c.>45	2/37	5.4	0/9	0.0
	Adult	0/14	0.0	0/9	0.0
	Total	2/133	1.5	0/45	0.0
Left Ankle	c.18-25	0/19	0.0	0/3	0.0
	c.25-35	0/29	0.0	0/13	0.0
	c.35-45	0/32	0.0	0/11	0.0
	c.>45	3/39	7.7	0/8	0.0
	Adult	0/16	0.0	0/8	0.0
	Total	3/135	2.2	0/43	0.0
Right Foot	c.18-25	0/19	0.0	0/3	0.0
	c.25-35	0/27	0.0	0/13	0.0
	c.35-45	6/32	18.8	1/11	9.1
	c.>45	12/35	34.3	4/10	40.0
	Adult	1/14	7.1	1/10	10.0
	Total	19/127	15.0	6/47	12.8
Left Foot	c.18-25	0/19	0.0	0/3	0.0
	c.25-35	0/27	0.0	0/13	0.0
	c.35-45	5/32	15.6	0/11	0.0
	c.>45	7/36	19.4	3/9	33.3
	Adult	2/15	13.3	1/9	11.1
	Total	14/129	10.9	4/45	8.9

(g) Pooled cemetery data

n_{oa} number of joints in sample displaying osteoarthritis n_t total number of joints in sample
% percentage of sample displaying osteoarthritis
ψ common odds ratio (a ratio exceeding the value of 1.00 indicates a higher prevalence of osteoarthritis among males, and a ratio of less than 1.00 indicates a higher prevalence of osteoarthritis among females)

		Males		Females		
	Age group	n_{oa}/n_t	%	n_{oa}/n_t	%	ψ
Right Sterno-clavicular	c.18-25	0/94	0.0	0/55	0.0	
	c.25-35	1/113	0.9	0/83	0.0	
	c.35-45	5/122	4.1	3/82	3.7	
	c.>45	38/170	22.4	11/92	12.0	
	Adult	2/27	7.4	0/20	0.0	
	Total	46/526	8.7	14/332	4.2	1.94
Left Sterno-clavicular	c.18-25	0/92	0.0	0/53	0.0	
	c.25-35	0/117	0.0	0/79	0.0	
	c.35-45	5/129	3.9	3/70	4.3	
	c.>45	28/172	16.3	12/90	13.3	
	Adult	2/27	7.4	0/23	0.0	
	Total	35/537	6.5	15/315	4.8	1.18
Right Acromio-clavicular	c.18-25	0/75	0.0	0/45	0.0	
	c.25-35	2/109	1.8	4/75	5.3	
	c.35-45	26/120	21.7	9/67	13.4	
	c.>45	58/163	35.6	17/82	20.7	
	Adult	1/22	4.5	2/14	14.3	
	Total	87/489	17.8	32/283	11.3	1.71
Left Acromio-clavicular	c.18-25	2/79	2.5	0/41	0.0	
	c.25-35	2/106	1.9	3/74	4.1	
	c.35-45	17/118	14.4	6/68	8.8	
	c.>45	49/166	29.5	18/80	22.5	
	Adult	1/17	5.9	2/20	10.0	
	Total	71/486	14.6	29/283	10.2	1.77
Right Shoulder	c.18-25	0/101	0.0	0/56	0.0	
	c.25-35	0/118	0.0	2/82	2.4	
	c.35-45	5/125	4.0	1/75	1.3	
	c.>45	15/182	8.2	7/101	6.9	
	Adult	0/32	0.0	1/24	4.2	
	Total	20/558	3.6	11/338	3.3	1.16

Table 8.2g contd. . . /

Table 8.2g (contd.)

	Age group	Males n_{oa}/n_t	Males %	Females n_{oa}/n_t	Females %	ψ
Left Shoulder	*c.*18-25	1/97	1.0	0/56	0.0	
	*c.*25-35	1/123	0.8	1/90	1.1	
	*c.*35-45	3/135	2.2	1/77	1.3	
	c.>45	15/187	8.0	4/92	4.3	
	Adult	0/30	0.0	0/26	0.0	
	Total	20/572	3.5	6/341	1.8	1.80
Right Elbow	*c.*18-25	0/110	0.0	0/57	0.0	
	*c.*25-35	3/142	2.1	4/95	4.2	
	*c.*35-45	8/153	5.2	4/88	4.5	
	c.>45	14/191	7.3	10/103	9.7	
	Adult	1/51	2.0	1/29	3.4	
	Total	26/647	4.0	19/372	5.1	0.78
Left Elbow	*c.*18-25	0/104	0.0	0/55	0.0	
	*c.*25-35	2/146	1.4	1/98	1.0	
	*c.*35-45	7/151	4.6	3/90	3.3	
	c.>45	7/191	3.7	4/105	3.8	
	Adult	2/39	5.1	2/33	6.1	
	Total	18/631	2.9	10/381	2.6	1.18
Right Wrist	*c.*18-25	0/107	0.0	0/61	0.0	
	*c.*25-35	3/139	2.2	2/93	2.2	
	*c.*35-45	7/145	4.8	3/88	3.4	
	c.>45	32/192	16.7	14/105	13.3	
	Adult	3/57	5.3	2/28	7.1	
	Total	45/640	7.0	21/375	5.6	1.29
Left Wrist	*c.*18-25	0/104	0.0	0/60	0.0	
	*c.*25-35	3/142	2.1	1/101	1.0	
	*c.*35-45	4/158	2.5	3/89	3.4	
	c.>45	30/190	15.8	14/108	13.0	
	Adult	5/51	9.8	4/32	12.5	
	Total	42/645	6.5	22/390	5.6	1.21
Right Hand	*c.*18-25	0/115	0.0	0/61	0.0	
	*c.*25-35	2/145	1.4	2/99	2.0	
	*c.*35-45	11/154	7.1	6/85	7.1	
	c.>45	31/197	15.7	14/110	12.7	
	Adult	3/66	4.5	5/31	16.1	
	Total	47/677	6.9	27/386	7.0	1.15

Table 8.2g contd. . . /

Table 8.2g (contd.)

	Age group	Males n_{oa}/n_t	Males %	Females n_{oa}/n_t	Females %	ψ
Left Hand	*c.*18-25	0/103	0.0	0/59	0.0	
	*c.*25-35	4/138	2.9	2/101	2.0	
	*c.*35-45	9/159	5.7	2/93	2.2	
	c.>45	27/187	14.4	12/107	11.2	
	Adult	1/58	1.7	4/27	14.8	
	Total	41/645	6.4	20/387	5.2	1.54
Right Hip	*c.*18-25	0/113	0.0	0/60	0.0	
	*c.*25-35	2/143	1.4	3/99	3.0	
	*c.*35-45	13/156	8.3	4/86	4.7	
	c.>45	31/198	15.7	17/109	15.6	
	Adult	5/62	8.1	1/38	2.6	
	Total	51/672	7.6	25/392	6.4	1.09
Left Hip	*c.*18-25	0/107	0.0	0/61	0.0	
	*c.*25-35	3/143	2.1	3/100	3.0	
	*c.*35-45	9/164	5.5	5/91	5.5	
	c.>45	31/196	15.8	18/109	16.5	
	Adult	7/63	11.1	3/30	10.0	
	Total	50/673	7.4	29/391	7.4	0.92
Right Knee	*c.*18-25	0/105	0.0	1/56	1.8	
	*c.*25-35	2/143	1.4	2/95	2.1	
	*c.*35-45	9/152	5.9	7/79	8.9	
	c.>45	12/181	6.6	12/101	11.9	
	Adult	4/76	5.3	2/34	5.9	
	Total	27/657	4.1	24/365	6.6	0.55
Left Knee	*c.*18-25	0/100	0.0	1/53	1.9	
	*c.*25-35	0/144	0.0	0/96	0.0	
	*c.*35-45	10/155	6.5	8/80	10.0	
	c.>45	10/191	5.2	12/103	11.7	
	Adult	5/77	6.5	4/35	11.4	
	Total	25/667	3.7	25/367	6.8	0.47
Right Ankle	*c.*18-25	0/104	0.0	0/47	0.0	
	*c.*25-35	1/129	0.8	1/89	1.1	
	*c.*35-45	3/140	2.1	2/74	2.7	
	c.>45	3/166	1.8	2/95	2.1	
	Adult	1/77	1.3	1/40	2.5	
	Total	8/616	1.3	6/345	1.7	0.80

Table 8.2g contd. . . /

Table 8.2g (contd.)

	Age group	Males n_{oa}/n_t	Males %	Females n_{oa}/n_t	Females %	ψ
Left Ankle	*c.* 18-25	0/98	0.0	0/50	0.0	
	c. 25-35	1/134	0.74	0/92	0.0	
	c. 35-45	2/138	1.4	1/75	1.3	
	c. >45	6/171	3.5	1/96	1.0	
	Adult	3/75	4.0	0/33	0.0	
	Total	12/616	1.9	2/346	0.6	2.58
Right Foot	*c.* 18-25	0/101	0.0	0/49	0.0	
	c. 25-35	1/122	0.8	2/87	2.3	
	c. 35-45	10/131	7.6	4/74	5.4	
	c. >45	22/155	14.2	11/97	11.3	
	Adult	6/73	8.2	4/37	10.8	
	Total	39/582	6.7	21/344	6.1	1.22
Left Foot	*c.* 18-25	0/97	0.0	0/51	0.0	
	c. 25-35	1/127	0.8	1/86	1.2	
	c. 35-45	7/135	5.2	3/72	4.2	
	c. >45	13/155	8.4	9/95	9.5	
	Adult	3/67	4.5	4/35	11.4	
	Total	24/581	4.1	17/339	5.0	0.95

Table 8.3a-g Proportional morbidity study for osteoarthritis in the appendicular joints

(a) Wharram Percy

Joint$_r$ rank order of anatomical sites displaying osteoarthritis
f frequency of joints displaying osteoarthritis
% proportion of the total number of osteoarthritic joints in the sample, expressed as a percentage

Males			Females		
Joint$_r$	*f*	%	Joint$_r$	*f*	%
Acromio-clavicular	27	30.0	Acromio-clavicular	11	22.5
Hand	16	17.8	Hand	10	20.4
Hip	14	15.6	Hip	9	18.4
Wrist	13	14.4	Wrist	5	10.2
Foot	6	6.7	Knee	4	8.2
Sterno-clavicular	5	5.6	Sterno-clavicular	3	6.1
Elbow	5	5.6	Elbow	3	6.1
Shoulder	3	3.3	Foot	3	6.1
Ankle	1	1.1	Shoulder	1	2.1
Knee	0	0.0	Ankle	0	0.0

(b) Ipswich Blackfriars

Joint$_r$ rank order of anatomical sites displaying osteoarthritis
f frequency of joints displaying osteoarthritis
% proportion of the total number of osteoarthritic joints in the sample, expressed as a percentage

Males			Females		
Joint$_r$	*f*	%	Joint$_r$	*f*	%
Acromio-clavicular	9	17.7	Knee	5	23.8
Foot	9	17.7	Hand	3	14.3
Hand	7	13.7	Foot	3	14.3
Wrist	6	11.8	Acromio-clavicular	2	9.5
Elbow	5	9.8	Elbow	2	9.5
Hip	5	9.8	Wrist	2	9.5
Shoulder	4	7.9	Hip	2	9.5
Sterno-clavicular	3	5.9	Shoulder	1	4.8
Knee	2	3.9	Ankle	1	4.8
Ankle	1	2.0	Sterno-clavicular	0	0.0

(c) Abingdon

Joint$_r$ rank order of anatomical sites displaying osteoarthritis
f frequency of joints displaying osteoarthritis
% proportion of the total number of osteoarthritic joints in the sample, expressed as a percentage

Males			Females		
Joint$_r$	*f*	%	Joint$_r$	*f*	%
Sterno-clavicular	16	18.4	Knee	12	18.8
Acromio-clavicular	14	16.1	Wrist	10	15.6
Hip	13	14.9	Hip	9	14.1
Wrist	12	13.8	Sterno-clavicular	7	10.9
Elbow	9	10.3	Acromio-clavicular	6	9.4
Hand	8	9.2	Elbow	6	9.4
Shoulder	7	8.1	Shoulder	4	6.3
Knee	3	3.5	Hand	4	6.3
Foot	3	3.5	Foot	4	6.3
Ankle	2	2.3	Ankle	2	3.1

(d) St Nicholas Shambles

Joint$_r$ rank order of anatomical sites displaying osteoarthritis
f frequency of joints displaying osteoarthritis
% proportion of the total number of osteoarthritic joints in the sample, expressed as a percentage

Males			Females		
Joint$_r$	*f*	%	Joint$_r$	*f*	%
Acromio-clavicular	2	22.2	Acromio-clavicular	2	50.0
Hip	2	22.2	Hip	1	25.0
Ankle	2	22.2	Ankle	1	25.0
Elbow	1	11.1	Sterno-clavicular	0	0.0
Wrist	1	11.1	Shoulder	0	0.0
Knee	1	11.1	Elbow	0	0.0
Sterno-clavicular	0	0.0	Wrist	0	0.0
Shoulder	0	0.0	Hand	0	0.0
Hand	0	0.0	Knee	0	0.0
Foot	0	0.0	Foot	0	0.0

(e) Fishergate 4

Joint$_r$ rank order of anatomical sites displaying osteoarthritis
f frequency of joints displaying osteoarthritis
% proportion of the total number of osteoarthritic joints in the sample, expressed as a percentage

Males			Females		
Joint$_r$	*f*	%	Joint$_r$	*f*	%
Hand	3	30.0	Foot	2	33.3
Acromio-clavicular	2	20.0	Acromio-clavicular	1	16.7
Wrist	2	20.0	Elbow	1	16.7
Hip	2	20.0	Hand	1	16.7
Foot	1	10.0	Knee	1	16.7
Sterno-clavicular	0	0.0	Sterno-clavicular	0	0.0
Shoulder	0	0.0	Shoulder	0	0.0
Elbow	0	0.0	Wrist	0	0.0
Knee	0	0.0	Hip	0	0.0
Ankle	0	0.0	Ankle	0	0.0

(f) Fishergate 6

Joint$_r$ rank order of anatomical sites displaying osteoarthritis
f frequency of joints displaying osteoarthritis
% proportion of the total number of osteoarthritic joints in the sample, expressed as a percentage

Males			Females		
Joint$_r$	*f*	%	Joint$_r$	*f*	%
Acromio-clavicular	25	20.2	Hand	5	17.2
Sterno-clavicular	17	13.7	Acromio-clavicular	4	13.8
Foot	17	13.7	Wrist	4	13.8
Wrist	14	11.3	Foot	4	13.8
Hand	14	11.3	Elbow	3	10.3
Hip	13	10.5	Hip	3	10.3
Knee	12	9.7	Knee	3	10.3
Shoulder	5	4.0	Shoulder	2	6.9
Elbow	5	4.0	Sterno-clavicular	1	3.5
Ankle	2	1.6	Ankle	0	0.0

(g) Pooled site data

Joint$_r$ rank order of anatomical sites displaying osteoarthritis
f frequency of joints displaying osteoarthritis
% proportion of the total number of osteoarthritic joints in the sample, expressed as a percentage

Males			Females		
Joint$_r$	*f*	%	Joint$_r$	*f*	%
Acromio-clavicular	79	21.3	Acromio-clavicular	26	15.0
Hip	49	13.2	Knee	25	14.5
Wrist	48	12.9	Hip	25	13.9
Hand	48	12.9	Hand	23	13.3
Sterno-clavicular	41	11.1	Wrist	21	12.1
Foot	36	9.7	Foot	16	9.3
Elbow	25	6.7	Elbow	15	8.7
Shoulder	19	5.1	Sterno-clavicular	11	6.4
Knee	18	4.9	Shoulder	8	4.6
Ankle	8	2.2	Ankle	4	2.3

Table 8.4 Male and female common odds ratios relating the age-specific prevalence of osteoarthritis in the right and left joints, pooled site data

ψ common odds ratio (a ratio exceeding the value of 1.00 indicates a higher prevalence of osteoarthritis among the right joints of the joint pair, and a ratio of less than 1.00 indicates a higher prevalence of osteoarthritis among the left joints of the joint pair)

	ψ	
	Males	Females
Sterno-clavicular	1.45	0.88
Acromio-clavicular	1.34	1.12
Shoulder	1.04	1.63
Elbow	1.59	2.40
Wrist	1.17	1.10
Hand	1.08	1.42
Hip	1.09	0.93
Knee	1.21	1.07
Ankle	0.79	2.57
Foot	1.76	1.30

Table 8.5 Proportion of male and female spines displaying osteoarthritis in the articular processes, within the total cemetery samples and the respective age groups

n_{oa} number of individuals displaying osteoarthritis in the articular processes
n_t total number of individuals with spines represented in the sample
% percentage of sample with spines displaying osteoarthritis in the articular processes

		Males		Females	
	Age group	n_{oa}/n_t	%	n_{oa}/n_t	%
Wharram	c.18-25	1/28	3.6	2/24	8.33
	c.25-35	7/27	25.9	6/23	26.1
	c.35-45	18/30	60.0	18/24	75.0
	c.>45	51/68	75.0	31/41	75.6
	Adult	11/22	50.0	2/11	18.2
	Total	88/175	50.3	59/123	48.0
Ipswich	c.18-25	1/23	4.4	3/11	27.3
	c.25-35	15/35	42.9	10/17	58.8
	c.35-45	21/31	67.7	7/8	87.5
	c.>45	23/27	85.2	13/16	81.3
	Adult	5/12	41.7	2/8	25.0
	Total	65/128	50.8	35/60	58.3
Abingdon	c.18-25	11/21	52.4	11/20	55.0
	c.25-35	26/37	70.3	22/34	64.7
	c.35-45	40/48	83.3	30/33	90.9
	c.>45	65/67	97.0	39/40	97.5
	Adult	1/2	50.0	4/6	66.7
	Total	143/175	81.7	106/133	79.7
St Nicholas	c.18-25	6/15	40.0	1/8	12.5
	c.25-35	9/14	64.3	8/21	38.1
	c.35-45	13/14	92.9	15/16	93.8
	c.>45	4/4	100.0	4/4	100.0
	Adult	7/10	70.0	5/6	83.3
	Total	39/57	68.4	33/55	60.0
Fishergate 4	c.18-25	13/17	76.5	5/6	83.3
	c.25-35	12/12	100.0	6/6	100.0
	c.35-45	8/8	100.0	10/10	100.0
	c.>45	3/3	100.0	3/3	100.0
	Adult	0/0	0.0	2/2	100.0
	Total	36/40	90.0	26/27	96.3

Table 8.5 contd. . . /

Table 8.5 (contd.)

	Age group	Males n_{oa}/n_t	Males %	Females n_{oa}/n_t	Females %
Fishergate 6	*c.* 18-25	17/20	85.0	3/3	100.0
	c. 25-35	31/32	96.9	11/13	84.6
	c. 35-45	41/42	97.6	13/13	100.0
	c. >45	46/47	97.9	10/11	90.9
	Adult	6/6	100.0	1/1	100.0
	Total	141/147	95.9	38/41	92.7
Pooled Site Data	*c.* 18-25	49/124	39.5	25/72	34.7
	c. 25-35	100/157	63.7	63/114	55.3
	c. 35-45	141/173	81.5	93/104	89.4
	c. >45	192/216	88.9	100/115	87.0
	Adult	30/52	57.7	16/34	47.1
	Total	512/722	70.9	297/439	67.7

Table 8.6a-g Prevalence of osteoarthritis in the articular processes of the cervical, thoracic, lumbar and first sacral segments

(a) Wharram Percy

n_{oa} number of individuals displaying osteoarthritis in the articular processes
n_t total number of individuals with the relevant vertebral type represented
% percentage of sample displaying osteoarthritis in the articular processes

		Males		Females	
	Age group	n_{oa}/n_t	%	n_{oa}/n_t	%
Cervical Vertebrae	*c*.18-25	1/25	4.0	1/21	4.8
	c.25-35	4/23	17.4	3/20	15.0
	c.35-45	11/27	40.7	11/24	45.8
	c.>45	38/64	59.4	23/36	63.9
	Adult	5/13	38.5	0/8	0.0
	Total	59/152	38.8	38/109	34.9
Thoracic Vertebrae	*c*.18-25	1/27	3.7	2/23	8.7
	c.25-35	5/25	20.0	4/22	18.2
	c.35-45	14/30	46.7	9/23	39.1
	c.>45	34/62	54.8	20/37	54.1
	Adult	10/19	52.6	2/10	20.0
	Total	64/163	39.3	37/115	32.2
Lumbar Vertebrae	*c*.18-25	1/25	4.0	1/20	5.0
	c.25-35	1/24	4.2	1/21	4.8
	c.35-45	6/27	22.2	9/20	45.0
	c.>45	15/54	27.8	19/36	52.8
	Adult	5/22	22.7	1/10	10.0
	Total	28/152	18.4	31/107	29.0

(b) Ipswich Blackfriars

n_{oa} number of individuals displaying osteoarthritis in the articular processes
n_t total number of individuals with the relevant vertebral type represented
% percentage of sample displaying osteoarthritis in the articular processes

		Males		Females	
	Age group	n_{oa}/n_t	%	n_{oa}/n_t	%
Cervical Vertebrae	*c.* 18-25	0/19	0.0	0/8	0.0
	c. 25-35	8/32	25.0	5/16	31.3
	c. 35-45	17/25	68.0	4/7	57.1
	c. >45	18/25	72.0	6/14	42.9
	Adult	4/8	50.0	1/7	14.3
	Total	47/109	43.1	16/52	30.8
Thoracic Vertebrae	*c.* 18-25	1/23	4.4	3/11	27.3
	c. 25-35	9/32	28.1	8/16	50.0
	c. 35-45	13/31	41.9	6/7	85.7
	c. >45	17/27	63.0	11/14	78.6
	Adult	3/12	25.0	1/8	12.5
	Total	43/125	34.4	29/56	51.8
Lumbar Vertebrae	*c.* 18-25	0/22	0.0	0/11	0.0
	c. 25-35	5/33	15.2	3/14	21.4
	c. 35-45	11/28	39.3	6/8	75.0
	c. >45	15/27	55.6	7/14	50.0
	Adult	2/11	18.2	2/8	25.0
	Total	33/121	27.3	18/55	32.7

(c) Abingdon

n_{oa} number of individuals displaying osteoarthritis in the articular processes
n_t total number of individuals with the relevant vertebral type represented
% percentage of sample displaying osteoarthritis in the articular processes

		Males		Females	
	Age group	n_{oa}/n_t	%	n_{oa}/n_t	%
Cervical Vertebrae	*c.* 18-25	8/19	42.1	8/20	40.0
	c. 25-35	15/31	48.4	11/27	40.7
	c. 35-45	23/34	67.7	16/20	80.0
	c. >45	45/57	79.0	27/34	79.4
	Adult	0/1	0.0	3/4	75.0
	Total	91/142	64.1	65/105	61.9
Thoracic Vertebrae	*c.* 18-25	10/20	50.0	8/20	40.0
	c. 25-35	23/35	65.7	20/29	69.0
	c. 35-45	33/42	78.6	27/31	87.1
	c. >45	60/63	95.3	36/39	92.3
	Adult	1/2	50.0	4/5	80.0
	Total	127/162	78.4	95/124	76.6
Lumbar Vertebrae	*c.* 18-25	9/18	50.0	3/18	16.7
	c. 25-35	17/36	47.2	15/31	48.4
	c. 35-45	31/43	72.1	21/32	65.6
	c. >45	52/60	86.7	33/39	84.6
	Adult	1/2	50.0	3/6	50.0
	Total	110/159	69.2	75/126	59.1
First Sacral Vertebra	*c.* 18-25	3/17	17.7	1/16	6.3
	c. 25-35	9/33	27.3	7/25	28.0
	c. 35-45	17/32	53.1	12/23	52.2
	c. >45	26/49	53.1	21/31	67.7
	Adult	0/1	0.0	1/4	25.0
	Total	55/132	41.7	42/99	42.4

(d) St Nicholas Shambles

n_{oa} number of individuals displaying osteoarthritis in the articular processes
n_t total number of individuals with the relevant vertebral type represented
% percentage of sample displaying osteoarthritis in the articular processes

		Males		Females	
	Age group	n_{oa}/n_t	%	n_{oa}/n_t	%
Cervical Vertebrae	*c.* 18-25	0/10	0.0	0/6	0.0
	c. 25-35	1/7	14.3	1/14	7.1
	c. 35-45	7/13	53.9	9/14	64.3
	c. >45	3/4	75.0	4/4	100.0
	Adult	2/4	50.0	1/2	50.0
	Total	13/38	34.2	15/40	37.5
Thoracic Vertebrae	*c.* 18-25	4/14	28.6	0/7	0.0
	c. 25-35	5/8	62.5	7/17	41.2
	c. 35-45	12/13	92.3	12/15	80.0
	c. >45	2/4	50.0	4/4	100.0
	Adult	6/7	85.7	3/4	75.0
	Total	29/46	63.0	26/47	55.3
Lumbar Vertebrae	*c.* 18-25	4/11	36.4	1/7	14.3
	c. 25-35	6/11	54.5	3/17	17.7
	c. 35-45	6/8	75.0	9/9	100.0
	c. >45	3/4	75.0	4/4	100.0
	Adult	5/7	71.4	2/4	50.0
	Total	24/41	58.5	19/41	46.3
First Sacral Vertebra	*c.* 18-25	2/11	18.2	0/4	0.0
	c. 25-35	1/8	12.5	1/14	7.1
	c. 35-45	2/8	25.0	2/8	25.0
	c. >45	0/4	0.0	2/4	50.0
	Adult	1/6	16.7	1/4	25.0
	Total	6/37	16.2	6/34	17.7

(e) Fishergate 4

n_{oa} number of individuals displaying osteoarthritis in the articular processes
n_t total number of individuals with the relevant vertebral type represented
% percentage of sample displaying osteoarthritis in the articular processes

		Males		Females	
	Age group	n_{oa}/n_t	%	n_{oa}/n_t	%
Cervical Vertebrae	c. 18-25	5/13	38.5	2/5	40.0
	c. 25-35	6/11	54.6	2/6	33.3
	c. 35-45	3/6	50.0	7/7	100.0
	c. >45	1/2	50.0	3/3	100.0
	Adult	0/0	0.0	0/0	0.0
	Total	15/32	46.9	14/21	66.7
Thoracic Vertebrae	c. 18-25	10/14	71.4	5/5	100.0
	c. 25-35	12/12	100.0	6/6	100.0
	c. 35-45	8/8	100.0	9/9	100.0
	c. >45	3/3	100.0	3/3	100.0
	Adult	0/0	0.0	2/2	100.0
	Total	33/37	89.2	25/25	100.0
Lumbar Vertebrae	c. 18-25	3/14	21.4	0/4	0.0
	c. 25-35	5/11	45.5	4/4	100.0
	c. 35-45	8/8	100.0	8/10	80.0
	c. >45	2/3	66.7	2/2	100.0
	Adult	0/0	0.0	1/2	50.0
	Total	18/36	50.0	15/22	68.2
First Sacral Vertebra	c. 18-25	1/13	7.7	0/3	0.0
	c. 25-35	0/9	0.0	0/4	0.0
	c. 35-45	4/8	50.0	4/9	44.4
	c. >45	0/1	0.0	0/2	0.0
	Adult	0/0	0.0	1/2	50.0
	Total	5/31	16.1	5/20	25.0

(f) Fishergate 6

n_{oa} number of individuals displaying osteoarthritis in the articular processes
n_t total number of individuals with the relevant vertebral type represented
% percentage of sample displaying osteoarthritis in the articular processes

		Males		Females	
	Age group	n_{oa}/n_t	%	n_{oa}/n_t	%
Cervical Vertebrae	c. 18-25	3/17	17.7	0/3	0.0
	c. 25-35	10/24	41.7	6/10	60.0
	c. 35-45	30/35	85.7	10/12	83.3
	c. >45	38/44	86.4	7/9	77.8
	Adult	2/3	66.7	1/1	100.0
	Total	83/123	67.5	24/35	68.6
Thoracic Vertebrae	c. 18-25	15/19	79.0	3/3	100.0
	c. 25-35	29/30	96.7	11/12	91.7
	c. 35-45	35/37	94.6	13/13	100.0
	c. >45	43/43	100.0	9/9	100.0
	Adult	3/3	100.0	1/1	100.0
	Total	125/132	94.7	37/38	97.4
Lumbar Vertebrae	c. 18-25	8/20	40.0	1/3	33.3
	c. 25-35	18/32	56.3	8/13	61.5
	c. 35-45	35/37	94.6	10/12	83.3
	c. >45	41/44	93.2	9/9	100.0
	Adult	3/3	100.0	1/1	100.0
	Total	105/136	77.2	29/38	76.3
First Sacral Vertebra	c. 18-25	3/19	15.8	0/3	0.0
	c. 25-35	3/28	10.7	1/12	8.3
	c. 35-45	9/34	26.5	2/9	22.2
	c. >45	16/40	40.0	5/9	55.6
	Adult	0/1	0.0	0/1	0.0
	Total	31/122	25.4	8/34	23.5

(g) Pooled site data

n_{oa} number of individuals displaying osteoarthritis in the articular processes
n_t total number of individuals with the relevant vertebral type represented
% percentage of sample displaying osteoarthritis in the articular processes

		Males		Females	
	Age group	n_{oa}/n_t	%	n_{oa}/n_t	%
Cervical Vertebrae	c.18-25	17/103	16.5	11/63	17.5
	c.25-35	44/128	34.4	28/93	30.1
	c.35-45	91/140	65.0	57/84	67.9
	c.>45	143/196	73.0	70/100	70.0
	Adult	13/29	44.8	6/22	27.3
	Total	308/596	51.7	172/362	47.5
Thoracic Vertebrae	c.18-25	41/117	35.0	21/69	30.4
	c.25-35	83/142	58.5	56/102	54.9
	c.35-45	115/161	71.4	76/98	77.6
	c.>45	159/202	78.7	83/106	78.3
	Adult	23/43	53.5	13/30	43.3
	Total	421/665	63.3	249/405	61.5
Lumbar Vertebrae	c.18-25	25/110	22.7	6/63	9.5
	c.25-35	52/147	35.4	34/100	34.0
	c.35-45	97/151	64.2	63/91	69.2
	c.>45	128/192	66.7	74/104	71.2
	Adult	16/45	35.6	10/31	32.3
	Total	318/645	49.3	187/389	48.1
First Sacral Vertebra	c.18-25	9/60	15.0	1/26	3.8
	c.25-35	13/78	16.7	9/55	16.4
	c.35-45	32/82	39.0	20/49	40.8
	c.>45	42/94	44.7	28/46	60.9
	Adult	1/8	12.5	3/11	27.3
	Total	97/322	30.1	61/187	32.6

Table 8.7 Proportion of male and female spines displaying osteophytosis within the total cemetery samples and the respective age groups

n_{op} number of individuals displaying osteophytosis n_t total number of individuals with spines represented in the sample % percentage of sample with spines displaying osteophytosis

		Males		Females	
	Age group	n_{op}/n_t	%	n_{op}/n_t	%
Wharram	*c.*18-25	3/28	10.7	4/24	16.7
	*c.*25-35	20/27	74.1	14/23	60.9
	*c.*35-45	29/30	96.7	21/24	87.5
	c.>45	60/68	88.2	38/41	92.7
	Adult	18/22	81.8	10/11	90.9
	Total	130/175	74.3	87/123	70.7
Ipswich	*c.*18-25	7/23	30.4	3/11	27.3
	*c.*25-35	25/35	71.4	15/17	88.2
	*c.*35-45	27/31	87.1	6/8	75.0
	c.>45	20/27	74.1	14/16	87.5
	Adult	7/12	58.3	6/8	75.0
	Total	86/128	67.2	44/60	73.3
Abingdon	*c.*18-25	11/21	52.4	10/20	50.0
	*c.*25-35	28/37	75.7	24/34	70.6
	*c.*35-45	46/48	95.8	29/33	87.9
	c.>45	67/67	100.0	40/40	100.0
	Adult	2/2	100.0	4/6	66.7
	Total	154/175	88.0	107/133	80.5
Fishergate 4	*c.*18-25	2/17	11.8	3/6	50.0
	*c.*25-35	12/12	100.0	6/6	100.0
	*c.*35-45	8/8	100.0	10/10	100.0
	c.>45	3/3	100.0	2/3	66.7
	Adult	0/0	0.0	2/2	100.0
	Total	25/40	62.5	23/27	85.2
Fishergate 6	*c.*18-25	8/20	40.0	2/3	66.7
	*c.*25-35	27/32	84.4	10/13	76.9
	*c.*35-45	40/42	95.2	13/13	100.0
	c.>45	46/47	97.9	10/11	90.9
	Adult	5/6	83.3	1/1	100.0
	Total	126/147	85.7	36/41	87.8
Pooled Site Data	*c.*18-25	31/109	28.4	22/64	34.4
	*c.*25-35	112/143	78.3	69/93	74.2
	*c.*35-45	150/159	94.3	79/88	89.8
	c.>45	196/212	92.5	104/111	93.7
	Adult	32/42	76.2	23/28	82.1
	Total	521/665	78.4	297/384	77.3

Table 8.8a-f Prevalence of osteophytosis in the cervical, thoracic, lumbar and first sacral segments

(a) Wharram Percy

n_{op} number of individuals displaying osteophytosis n_t total number of individuals with the relevant vertebral type represented % percentage of sample displaying osteophytosis

		Males		Females	
	Age group	n_{op}/n_t	%	n_{op}/n_t	%
Cervical Vertebrae	c.18-25	0/25	0.0	1/21	4.8
	c.25-35	7/23	30.4	5/20	25.0
	c.35-45	19/27	70.4	16/24	66.7
	c.>45	43/64	67.2	29/36	80.6
	Adult	8/14	57.1	3/8	37.5
	Total	77/153	50.3	54/109	49.5
Thoracic Vertebrae	c.18-25	3/27	11.1	2/23	8.7
	c.25-35	15/25	60.0	12/22	54.6
	c.35-45	25/30	83.3	19/23	82.6
	c.>45	48/62	77.4	34/37	91.9
	Adult	15/19	79.0	7/10	70.0
	Total	106/163	65.0	74/115	64.3
Lumbar Vertebrae	c.18-25	1/25	4.0	2/20	10.0
	c.25-35	12/24	50.0	11/21	52.4
	c.35-45	24/27	88.8	15/20	75.0
	c.>45	38/54	70.4	33/36	91.7
	Adult	11/21	52.4	7/10	70.0
	Total	86/151	57.0	68/107	63.6
First Sacral Vertebra	c.18-25	1/22	4.6	0/19	0.0
	c.25-35	0/17	0.0	2/18	11.1
	c.35-45	8/25	32.0	6/19	31.6
	c.>45	13/48	27.1	17/36	47.2
	Adult	0/19	0.0	2/10	20.0
	Total	22/131	16.8	27/102	26.5

(b) Ipswich Blackfriars

n_{op} number of individuals displaying osteophytosis n_t total number of individuals with the relevant vertebral type represented % percentage of sample displaying osteophytosis

	Age group	Males n_{op}/n_t	Males %	Females n_{op}/n_t	Females %
Cervical Vertebrae	*c.* 18-25	0/19	0.0	0/8	0.0
	c. 25-35	14/32	43.8	7/16	43.8
	c. 35-45	17/25	68.0	6/7	85.7
	c. >45	17/25	68.0	9/14	64.3
	Adult	3/8	37.5	3/7	42.9
	Total	51/109	46.8	25/52	48.1
Thoracic Vertebrae	*c.* 18-25	7/23	30.4	3/11	27.3
	c. 25-35	23/32	71.9	12/17	70.6
	c. 35-45	22/31	71.0	6/7	85.7
	c. >45	17/27	63.0	11/14	78.6
	Adult	5/12	41.7	6/8	75.0
	Total	74/125	59.2	38/57	66.7
Lumbar Vertebrae	*c.* 18-25	2/22	9.1	1/11	9.1
	c. 25-35	19/33	57.6	13/14	92.9
	c. 35-45	20/28	71.4	5/8	62.5
	c. >45	17/27	63.0	12/14	85.7
	Adult	7/11	63.6	4/8	50.0
	Total	65/121	53.7	35/55	63.6
First Sacral Vertebra	*c.* 18-25	0/21	0.0	1/10	10.0
	c. 25-35	7/32	21.9	9/15	60.0
	c. 35-45	10/28	35.7	3/8	37.5
	c. >45	7/23	30.4	9/13	69.2
	Adult	1/10	10.0	2/7	28.6
	Total	25/114	22.0	24/53	45.3

(c) Abingdon

n_{op} number of individuals displaying osteophytosis n_t total number of individuals with the relevant vertebral type represented % percentage of sample displaying osteophytosis

		Males		Females	
	Age group	n_{op}/n_t	%	n_{op}/n_t	%
Cervical Vertebrae	*c.* 18-25	6/18	33.3	4/20	20.0
	c. 25-35	15/30	50.0	14/28	50.0
	c. 35-45	25/33	75.8	17/20	85.0
	c. >45	49/56	87.5	30/34	88.2
	Adult	1/1	100.0	2/4	50.0
	Total	96/138	69.6	67/106	63.2
Thoracic Vertebrae	*c.* 18-25	9/19	47.4	8/20	40.0
	c. 25-35	25/34	73.5	19/30	63.3
	c. 35-45	38/42	90.5	22/31	71.0
	c. >45	60/63	95.2	37/38	97.4
	Adult	2/2	100.0	4/5	80.0
	Total	134/160	83.8	90/124	72.6
Lumbar Vertebrae	*c.* 18-25	3/17	17.7	7/18	38.8
	c. 25-35	19/36	52.8	19/32	59.4
	c. 35-45	39/43	90.7	28/32	87.5
	c. >45	60/61	98.4	38/39	97.4
	Adult	2/2	100.0	4/6	66.7
	Total	123/159	77.4	96/127	75.6
First Sacral Vertebra	*c.* 18-25	2/17	11.8	1/16	6.3
	c. 25-35	12/33	36.4	10/26	38.5
	c. 35-45	22/33	66.7	18/23	78.3
	c. >45	38/51	74.5	25/31	80.7
	Adult	0/1	0.0	2/4	50.0
	Total	74/135	54.8	56/100	56.0

(d) Fishergate 4

n_{op} number of individuals displaying osteophytosis n_t total number of individuals with the relevant vertebral type represented % percentage of sample displaying osteophytosis

	Age group	Males		Females	
		n_{op}/n_t	%	n_{op}/n_t	%
Cervical Vertebrae	*c.* 18-25	0/13	0.0	0/5	0.0
	c. 25-35	7/11	63.6	3/5	60.0
	c. 35-45	4/6	66.7	7/7	100.0
	c. >45	1/2	50.0	2/3	66.7
	Adult	0/0	0.0	0/0	0.0
	Total	12/32	37.5	12/20	60.0
Thoracic Vertebrae	*c.* 18-25	0/14	0.0	2/5	40.0
	c. 25-35	11/12	91.7	6/6	100.0
	c. 35-45	7/8	87.5	9/9	100.0
	c. >45	3/3	100.0	2/3	66.7
	Adult	0/0	0.0	1/2	50.0
	Total	21/37	56.8	20/25	80.0
Lumbar Vertebrae	*c.* 18-25	2/14	14.3	1/3	33.3
	c. 25-35	7/11	63.6	3/4	75.0
	c. 35-45	7/8	87.5	10/10	100.0
	c. >45	2/2	100.0	2/2	100.0
	Adult	0/0	0.0	2/2	100.0
	Total	18/35	51.4	18/21	85.7
First Sacral Vertebra	*c.* 18-25	0/12	0.0	0/2	0.0
	c. 25-35	0/7	0.0	1/4	25.0
	c. 35-45	6/8	75.0	6/8	75.0
	c. >45	1/1	100.0	0/1	0.0
	Adult	0/0	0.0	1/1	100.0
	Total	7/28	25.0	8/16	50.0

(e) Fishergate 6

n_{op} number of individuals displaying osteophytosis n_t total number of individuals with the relevant vertebral type represented % percentage of sample displaying osteophytosis

	Age group	Males n_{op}/n_t	Males %	Females n_{op}/n_t	Females %
Cervical Vertebrae	*c.*18-25	4/16	25.0	2/3	66.7
	*c.*25-35	14/24	58.3	4/10	40.0
	*c.*35-45	28/34	82.4	9/12	75.0
	c.>45	39/43	90.7	8/9	88.9
	Adult	2/3	66.7	1/1	100.0
	Total	87/120	80.8	24/35	68.6
Thoracic Vertebrae	*c.*18-25	3/19	15.8	1/3	33.3
	*c.*25-35	21/28	75.0	10/13	76.9
	*c.*35-45	32/35	91.4	11/12	91.7
	c.>45	42/42	100.0	9/9	100.0
	Adult	2/3	66.7	1/1	100.0
	Total	100/127	78.7	32/38	84.2
Lumbar Vertebrae	*c.*18-25	3/20	15.0	1/3	33.3
	*c.*25-35	15/31	48.4	6/12	50.0
	*c.*35-45	34/37	91.9	12/12	100.0
	c.>45	42/42	100.0	7/8	87.5
	Adult	3/3	100.0	1/1	100.0
	Total	97/133	72.9	27/36	75.0
First Sacral Vertebra	*c.*18-25	0/19	0.0	0/3	0.0
	*c.*25-35	3/27	11.1	1/10	10.0
	*c.*35-45	27/36	75.0	4/8	50.0
	c.>45	31/40	77.5	8/8	100.0
	Adult	1/1	100.0	0/1	0.0
	Total	62/123	50.4	13/30	43.3

(f) Pooled site data

n_{op} number of individuals displaying osteophytosis n_t total number of individuals with the relevant vertebral type represented % percentage of sample displaying osteophytosis

	Age group	Males		Females	
		n_{op}/n_t	%	n_{op}/n_t	%
Cervical Vertebrae	*c.* 18-25	10/91	11.0	7/57	12.3
	c. 25-35	57/120	47.5	33/79	41.8
	c. 35-45	93/125	74.4	55/70	78.6
	c. >45	149/190	78.4	78/96	81.3
	Adult	14/26	53.8	9/20	45.0
	Total	323/552	58.5	182/322	56.5
Thoracic Vertebrae	*c.* 18-25	22/102	21.6	16/62	25.8
	c. 25-35	95/131	72.5	59/88	67.0
	c. 35-45	124/146	84.9	67/82	81.7
	c. >45	170/197	86.3	93/101	92.1
	Adult	24/36	66.7	19/26	73.1
	Total	435/612	71.1	254/359	70.8
Lumbar Vertebrae	*c.* 18-25	11/98	11.2	12/55	21.8
	c. 25-35	72/135	53.3	52/83	62.7
	c. 35-45	124/143	86.7	70/82	85.4
	c. >45	159/186	85.5	92/99	92.9
	Adult	23/37	62.2	18/27	66.7
	Total	389/599	64.9	244/346	70.5
First Sacral Vertebra	*c.* 18-25	3/91	3.3	2/50	4.0
	c. 25-35	22/116	19.0	23/73	31.5
	c. 35-45	73/130	56.2	37/66	56.1
	c. >45	90/163	55.2	59/89	66.3
	Adult	2/31	6.5	7/23	30.4
	Total	190/531	35.8	128/301	42.5

Table 8.9 Proportion of male and female spines displaying Schmorl's nodes within the total cemetery samples and the respective age groups

n_{sn} number of individuals displaying Schmorl's nodes n_t total number of individuals with spines in the sample
% percentage of sample with spines displaying Schmorl's nodes χ^2 Chi-square statistic p probability

	Age group	Males		Females			
		n_{sn}/n_t	%	n_{sn}/n_t	%	χ^2	p
Wharram	c.18-25	7/28	25.0	4/24	16.7	.538	.463
	c.25-35	7/27	25.9	7/23	30.4	.125	.723
	c.35-45	16/30	53.3	7/24	29.2	3.185	.074
	c.>45	32/68	47.1	19/41	46.3	.005	.942
	Adult	7/22	31.8	5/11	45.5		
	Total	69/175	39.4	42/123	34.1	.862	.353
Ipswich	c.18-25	8/23	34.8	3/11	27.3	.192	.661
	c.25-35	17/35	48.6	4/17	23.5	2.980	.084
	c.35-45	13/31	41.9	2/8	25.0	.771	.380
	c.>45	11/27	40.7	3/16	18.8	2.213	.137
	Adult	4/12	33.3	1/8	12.5		
	Total	53/128	41.4	13/60	21.7	6.987	.008
Abingdon	c.18-25	9/21	42.9	10/20	50.0	.210	.647
	c.25-35	25/37	67.6	15/34	44.1	3.961	.047
	c.35-45	27/48	56.3	15/33	45.5	.913	.339
	c.>45	45/67	67.2	30/40	75.0	.734	.392
	Adult	2/2	100.0	2/6	66.7		
	Total	108/175	61.7	72/133	54.1	1.787	.181

Table 8.9 contd. . . /

Table 8.9 (contd.)

	Age group	Males n_{sn}/n_t	Males %	Females n_{sn}/n_t	Females %	χ^2	p
St Nicholas	*c.*18-25	1/15	6.7	0/8	0.0	.558	.455
	*c.*25-35	1/14	7.1	1/21	4.8	.088	.766
	*c.*35-45	1/14	7.1	0/16	0.0	1.182	.277
	c.>45	0/4	0.0	0/4	0.0	-	-
	Adult	1/10	10.0	0/6	0.0		
	Total	4/57	7.0	1/55	1.8	1.774	.183
Fishergate 4	*c.*18-25	10/17	58.8	3/6	50.0	.140	.708
	*c.*25-35	9/12	75.0	4/6	66.7	.138	.710
	*c.*35-45	7/8	87.5	7/10	70.0	.787	.375
	c.>45	3/3	100.0	2/3	66.7	1.200	.273
	Adult	0/0	0.0	1/2	50.0		
	Total	29/40	72.5	17/27	63.0	.681	.409
Fishergate 6	*c.*18-25	11/20	55.0	1/3	33.3	.491	.484
	*c.*25-35	21/32	65.6	5/13	38.5	2.796	.094
	*c.*35-45	28/42	66.7	10/13	76.9	.489	.484
	c.>45	44/47	93.6	10/11	90.9	.102	.750
	Adult	3/6	50.0	1/1	100.0		
	Total	107/147	72.8	27/41	65.9	.753	.385
Pooled Site Data	*c.*18-25	46/124	37.1	21/72	29.2	1.273	.259
	*c.*25-35	80/157	51.0	36/114	31.6	10.128	.001
	*c.*35-45	92/173	53.2	41/104	39.4	4.924	.026
	c.>45	135/216	62.5	64/115	55.7	1.468	.226
	Adult	17/52	32.7	10/34	29.4		
	Total	370/722	51.3	172/439	39.2	15.970	.000

Table 8.10a-g Prevalence of Schmorl's nodes in the cervical, thoracic, lumbar and first sacral segments

(a) Wharram Percy

n_{sn} number of individuals displaying Schmorl's nodes n_t total number of individuals with the relevant vertebral type represented % percentage of sample displaying Schmorl's nodes

		Males		Females	
	Age group	n_{sn}/n_t	%	n_{sn}/n_t	%
Cervical Vertebrae	c.18-25	0/25	0.0	0/21	0.0
	c.25-35	0/23	0.0	0/20	0.0
	c.35-45	0/27	0.0	0/24	0.0
	c.>45	2/64	3.1	1/36	2.8
	Adult	0/13	0.0	0/8	0.0
	Total	2/152	1.3	1/109	0.9
Thoracic Vertebrae	c.18-25	7/27	25.9	3/23	13.0
	c.25-35	7/25	28.0	6/22	27.3
	c.35-45	15/30	50.0	7/23	30.4
	c.>45	27/62	43.5	14/37	37.8
	Adult	7/19	36.8	5/10	50.0
	Total	63/163	38.7	35/115	30.4
Lumbar Vertebrae	c.18-25	2/25	8.0	2/20	10.0
	c.25-35	4/24	16.7	4/21	19.0
	c.35-45	4/27	14.8	1/20	5.0
	c.>45	15/54	27.8	8/36	22.2
	Adult	3/22	13.6	1/10	10.0
	Total	28/152	18.4	16/107	15.0

(b) Ipswich Blackfriars

n_{sn} number of individuals displaying Schmorl's nodes n_t total number of individuals with the relevant vertebral type represented % percentage of sample displaying Schmorl's nodes

	Age group	Males		Females	
		n_{sn}/n_t	%	n_{sn}/n_t	%
Cervical Vertebrae	c. 18-25	0/19	0.0	0/8	0.0
	c. 25-35	0/32	0.0	0/16	0.0
	c. 35-45	0/25	0.0	0/7	0.0
	c. >45	0/25	0.0	0/14	0.0
	Adult	0/8	0.0	0/7	0.0
	Total	0/109	0.0	0/52	0.0
Thoracic Vertebrae	c. 18-25	8/23	34.8	2/11	18.2
	c. 25-35	16/32	50.0	2/17	11.8
	c. 35-45	12/30	40.0	2/7	28.6
	c. >45	11/27	40.7	3/14	21.4
	Adult	4/12	33.3	1/8	12.5
	Total	51/124	41.1	10/57	17.5
Lumbar Vertebra	c. 18-25	3/22	13.6	2/11	18.2
	c. 25-35	11/33	33.3	2/14	14.3
	c. 35-45	5/28	17.9	0/8	0.0
	c. >45	3/26	11.5	1/14	7.1
	Adult	2/11	18.2	0/8	0.0
	Total	24/120	20.0	5/55	9.1

(c) Abingdon

n_{sn} number of individuals displaying Schmorl's nodes n_t total number of individuals with the relevant vertebral type represented % percentage of sample displaying Schmorl's nodes

	Age group	Males		Females	
		n_{sn}/n_t	%	n_{sn}/n_t	%
Cervical Vertebrae	*c*.18-25	2/19	10.5	1/20	5.0
	c.25-35	5/30	16.7	4/28	14.3
	c.35-45	8/33	24.2	2/20	10.0
	c.>45	21/56	37.5	13/33	39.4
	Adult	0/1	0.0	0/4	0.0
	Total	36/139	25.9	20/105	19.0
Thoracic Vertebrae	*c*.18-25	8/20	40.0	9/20	45.0
	c.25-35	24/35	68.6	10/30	33.3
	c.35-45	27/42	64.3	13/31	41.9
	c.>45	32/63	50.8	23/39	59.0
	Adult	2/2	100.0	1/5	20.0
	Total	93/162	57.4	56/125	44.8
Lumbar Vertebrae	*c*.18-25	3/18	16.7	8/18	44.4
	c.25-35	19/37	51.4	11/32	34.4
	c.35-45	17/42	40.5	11/32	34.4
	c.>45	29/60	48.3	20/39	51.3
	Adult	2/2	100.0	2/6	33.3
	Total	70/159	44.0	52/127	40.9
First Sacral Vertebra	*c*.18-25	0/16	0.0	1/16	6.3
	c.25-35	2/32	6.3	2/26	7.7
	c.35-45	4/32	12.5	1/22	4.5
	c.>45	10/48	20.8	8/32	25.0
	Adult	0/1	0.0	0/4	0.0
	Total	16/129	12.4	12/100	12.0

(d) St Nicholas Shambles

n_{sn} number of individuals displaying Schmorl's nodes n_t total number of individuals with the relevant vertebral type represented % percentage of sample displaying Schmorl's nodes

		Males		Females	
	Age group	n_{sn}/n_t	%	n_{sn}/n_t	%
Cervical Vertebrae	*c.* 18-25	0/10	0.0	0/6	0.0
	c. 25-35	0/7	0.0	0/15	0.0
	c. 35-45	0/13	0.0	0/14	0.0
	c. >45	0/4	0.0	0/4	0.0
	Adult	0/4	0.0	0/2	0.0
	Total	0/38	0.0	0/41	0.0
Thoracic Vertebrae	*c.* 18-25	1/14	7.1	0/7	0.0
	c. 25-35	0/8	0.0	0/17	0.0
	c. 35-45	1/13	7.7	0/15	0.0
	c. >45	0/4	0.0	0/4	0.0
	Adult	0/7	0.0	0/4	0.0
	Total	2/46	4.3	0/47	0.0
Lumbar Vertebrae	*c.* 18-25	0/11	0.0	0/7	0.0
	c. 25-35	1/11	9.1	1/17	5.9
	c. 35-45	0/8	0.0	0/9	0.0
	c. >45	0/4	0.0	0/4	0.0
	Adult	1/7	14.3	0/4	0.0
	Total	2/41	4.9	1/41	2.4
First Sacral Vertebra	*c.* 18-25	0/11	0.0	0/4	0.0
	c. 25-35	0/8	0.0	0/14	0.0
	c. 35-45	0/8	0.0	0/8	0.0
	c. >45	0/4	0.0	0/4	0.0
	Adult	0/6	0.0	0/4	0.0
	Total	0/37	0.0	0/34	0.0

(e) Fishergate 4

n_{sn} number of individuals displaying Schmorl's nodes n_t total number of individuals with the relevant vertebral type represented % percentage of sample displaying Schmorl's nodes

	Age group	Males		Females	
		n_{sn}/n_t	%	n_{sn}/n_t	%
Cervical Vertebrae	c.18-25	0/13	0.0	0/5	0.0
	c.25-35	0/11	0.0	2/5	40.0
	c.35-45	3/6	50.0	3/7	42.9
	c.>45	1/2	50.0	1/3	33.3
	Adult	0/0	0.0	0/0	0.00
	Total	4/32	12.5	6/20	30.0
Thoracic Vertebrae	c.18-25	10/14	71.4	2/5	40.0
	c.25-35	9/12	75.0	3/6	50.0
	c.35-45	7/8	87.5	4/9	44.4
	c.>45	3/3	100.0	2/3	66.7
	Adult	0/0	0.0	1/2	50.0
	Total	29/37	78.4	12/25	48.0
Lumbar Vertebrae	c.18-25	5/14	35.7	2/3	66.7
	c.25-35	6/11	54.5	2/4	50.0
	c.35-45	2/8	25.0	7/10	70.0
	c.>45	1/2	50.0	2/2	100.0
	Adult	0/0	0.0	1/2	50.0
	Total	14/35	40.0	14/21	66.7
First Sacral Vertebra	c.18-25	0/13	0.0	0/3	0.0
	c.25-35	0/9	0.0	0/4	0.0
	c.35-45	2/8	25.0	2/8	25.0
	c.>45	0/1	0.0	0/1	0.0
	Adult	0/0	0.0	0/0	0.0
	Total	2/31	6.5	2/16	12.5

(f) Fishergate 6

n_{sn} number of individuals displaying Schmorl's nodes n_t total number of individuals with the relevant vertebral type represented % percentage of sample displaying Schmorl's nodes

	Age group	Males		Females	
		n_{sn}/n_t	%	n_{sn}/n_t	%
Cervical Vertebrae	*c.* 18-25	0/16	0.0	0/3	0.0
	c. 25-35	0/24	0.0	0/10	0.0
	c. 35-45	13/34	38.2	8/12	66.7
	c. >45	31/43	72.1	8/9	88.9
	Adult	1/3	33.3	1/1	100.0
	Total	45/120	37.5	17/35	48.6
Thoracic Vertebrae	*c.* 18-25	11/19	57.9	1/3	33.3
	c. 25-35	21/29	72.4	4/13	30.8
	c. 35-45	18/34	52.9	7/11	63.6
	c. >45	36/42	85.7	5/9	55.6
	Adult	1/3	33.3	1/1	100.0
	Total	87/127	68.5	18/37	48.6
Lumbar Vertebrae	*c.* 18-25	10/20	50.0	1/3	33.3
	c. 25-35	10/32	31.3	4/12	33.3
	c. 35-45	21/37	56.8	2/12	16.7
	c. >45	25/42	59.5	2/8	25.0
	Adult	1/3	33.3	1/1	100.0
	Total	67/134	50.0	10/36	27.8
First Sacral Vertebra	*c.* 18-25	1/18	5.6	0/3	0.0
	c. 25-35	1/28	3.6	0/12	0.0
	c. 35-45	7/36	19.4	0/9	0.0
	c. >45	6/40	15.0	3/7	42.9
	Adult	0/2	0.0	0/1	0.0
	Total	15/124	12.1	3/32	9.4

(g) Pooled site data

n_{sn} number of individuals displaying Schmorl's nodes n_t total number of individuals with the relevant vertebral type represented % percentage of sample displaying Schmorl's nodes

	Age group	Males		Females	
		n_{sn}/n_t	%	n_{sn}/n_t	%
Cervical Vertebrae	*c.* 18-25	2/102	2.0	1/63	1.6
	c. 25-35	5/127	3.9	6/94	6.4
	c. 35-45	24/138	17.4	13/84	15.5
	c. >45	5/194	28.4	23/99	23.2
	Adult	1/29	3.4	1/22	4.5
	Total	87/590	14.7	44/362	12.2
Thoracic Vertebrae	*c.* 18-25	45/117	38.5	17/69	24.6
	c. 25-35	77/141	54.6	25/105	23.8
	c. 35-45	80/157	51.0	33/96	34.4
	c. >45	109/201	54.2	47/106	44.3
	Adult	14/43	32.6	9/30	30.0
	Total	325/659	49.3	131/406	32.3
Lumbar Vertebrae	*c.* 18-25	23/110	20.9	15/62	24.2
	c. 25-35	51/148	34.5	24/100	24.0
	c. 35-45	49/150	32.7	21/91	23.1
	c. >45	73/188	38.8	33/103	32.0
	Adult	9/45	20.0	5/31	16.1
	Total	205/641	32.0	98/387	25.3
First Sacral Vertebra	*c.* 18-25	1/58	1.7	1/26	3.8
	c. 25-35	3/77	3.9	2/56	3.6
	c. 35-45	13/84	15.5	3/47	6.4
	c. >45	16/93	17.2	11/44	25.0
	Adult	0/9	0.0	0/9	0.0
	Total	33/321	10.3	17/182	9.3

9. Dental Pathology

9.1 Introduction

The purpose of this chapter was to investigate the prevalence of caries, abscesses and ante-mortem tooth loss among males and females from the medieval cemeteries, in order to construct a comparative picture of dental health between the sexes. Dental health may also provide evidence for inferring other aspects of lifestyle, such as dietary practices and oral hygiene (Lukacs 1989; Powell 1985; Roberts and Manchester 1995:44). Of the variety of dental health indicators observable in skeletal remains (Hillson 1986:283-318; 1996:254-287; Larsen 1997:65-82; Lukacs 1989; Mays 1998:146-161; Powell 1985; Roberts and Manchester 1995:44-64), caries, abscesses and ante-mortem tooth loss were selected for examination in this study because they are among the most commonly observed conditions, and were routinely recorded in all the cemetery samples. However, as Roberts and Manchester (1995:44) emphasise, 'the dental diseases do not develop in isolation from one another; there is a complex relationship between them'.

Dental caries, or dental decay, is a destructive disease affecting the calcified tissues of the teeth. The aetiology of caries is multifactorial, and the main predisposing and resisting factors are summarised below. However, the disease is essentially initiated by organic acids produced by plaque-dwelling bacteria, through their metabolism of carbohydrate substrates. The acids may depress the pH of the plaque adherent on tooth surfaces to levels which dissolve enamel, cement and dentine, leading to cavitation; as shown on plate 9.1 (Hillson 1986:287-292; 1996:269-276; Larsen 1997:65; Lukacs 1989:265; Legler and Menaker 1980:212-216; Mays 1998:146-149; Roberts and Manchester 1995:45-46; Silverstone *et al.* 1981:4-17). The disease is usually progressive, although a developing lesion may undergo periods of arrest. Once reaching the enamel-dentine junction, enamel caries tend to progress laterally and pulpally. Lateral procession of the lesion may undermine the enamel resulting in collapse of the tooth crown. Invasion of the pulp permits bacterial infection, causing inflammation and pain. Caries initiated on cement or root dentine tend to occur in older individuals following exposure through gingival recession. The pattern of destruction is characterised by broad, shallow lesions extending around the cemento-enamel junction,

Plate 9.1 Cavity (1), ante-mortem tooth loss (2), and attrition (3)

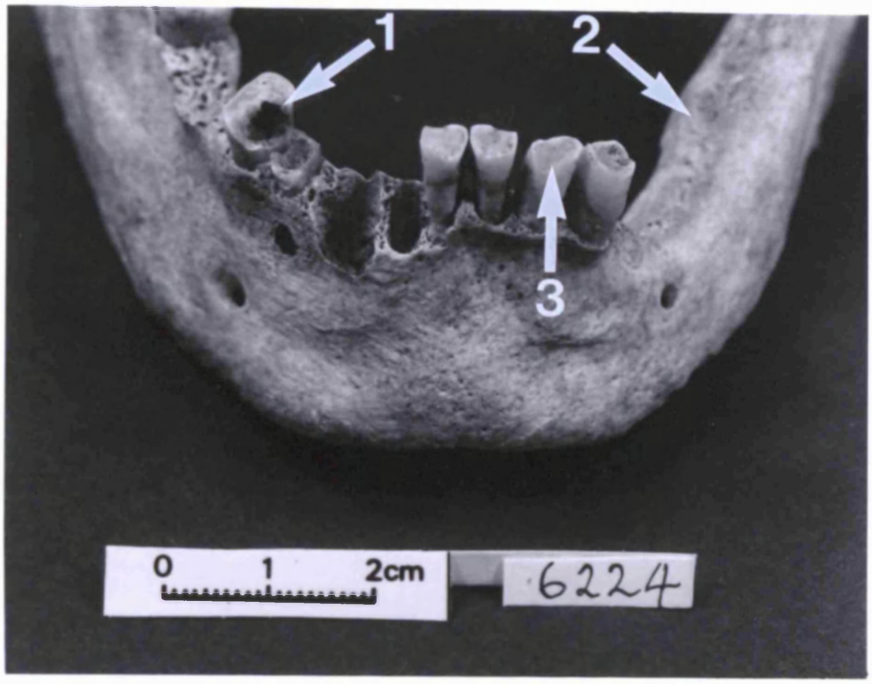
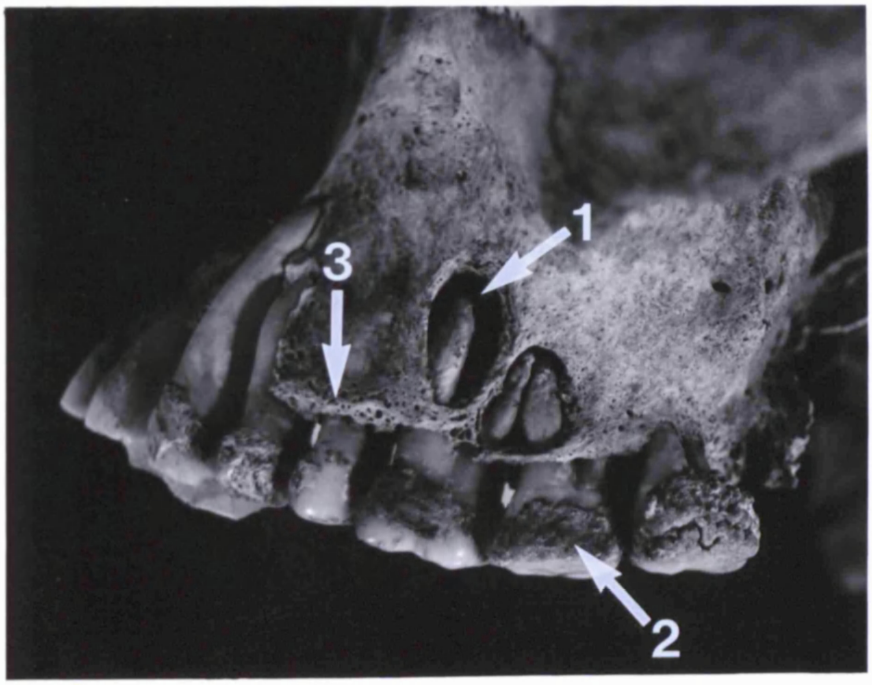


Plate 9.2 Abscess sinus (1), calculus (2), and alveolar bone resorption due to periodontal disease (3)



and advancement is usually slow with many arrested phases (Hillson 1986:289; 1996:274-275; Legler and Menaker 1980:219; Silverstone *et al.* 1981:6).

Diet is considered to be the most influential determinant in caries epidemiology, not only its chemical composition but also its texture and the daily pattern of consumption (Powell 1985). Carbohydrates of low molecular weight, i.e. sugars, are the most cariogenic foodstuff as they diffuse through plaque rapidly and are readily metabolised by bacteria. Frequent ingestion of sugar affords a particularly cariogenic effect by maintaining critically low pH levels. Of all sugars, sucrose has been identified as the most cariogenic (Hillson 1986:293; 1996:278; Legler and Menaker 1981; Silverstone *et al.* 1981:11-12) and studies of modern and archaeological populations have demonstrated a close correlation between the uptake of sucrose into the diet and a rapid rise in caries prevalence (Helöe and Haugejorden 1981; Mays 1998:151; Moore and Corbett 1973; Roberts and Manchester 1995:48). Small quantities of cane sugar, a prime source of sucrose, were imported into Britain from the twelfth century. Cane and loaf sugar were expensive items throughout the thirteenth and most of the fourteenth centuries (Hammond 1995:10-11; Stroud and Kemp 1993:257), but Moore and Corbett (1973) state that 'by the end of the Middle Ages the price of sugar had fallen to a level which could be afforded, at least as an occasional luxury, by a substantial proportion of the population'. Hammond (1995:10) also states that sugar was 'used more and more as the Middle Ages progressed'.

Other dietary sugars, including glucose and fructose, are also capable of causing rapid pH depression. Honey was the most commonly utilised sweetening agent during the medieval period (Hammond 1995:39; Mays unpublished:31). Hammond (1995:10) affirms that it 'was used extensively in cooking for sweetening'. Larsen (1997:73) describes honey as a 'highly cariogenic food', and Powell (1985:320) suggests that it 'may actually promote more caries than refined white sugar because of its high vitamin content that stimulates bacterial reproduction'. However, James (pers. comm.) also points out that honey contains a natural inhibitor which may slow down bacterial fermentation in the mouth; although James notes that this might be destroyed by cooking or dissolving into hot drinks. Sweetened wine, ale, cider and mead were popular, particularly among the more affluent (Hammond 1995:58, 72, 113-114; Reeves 1995:154). Dried fruits, high in sugar, were imported in rising quantities from the thirteenth century, although these were only affordable to the wealthier peasants and urban classes (Dyer 1989:197; Hammond 1995:60,65; Harvey 1993:57; Moore and Corbett 1973; Stroud and Kemp 1993:257). Fresh fruits and vegetables were seasonally available and accessible to all, as testified by latrine deposits (Greig 1981) in addition to documentary sources (Dyer 1989:157, 197; 1994:113-131; Hammond 1995:26-102; Moore and Corbett 1973; Stroud and Kemp 1993:257); although Powell (1985:314) states that 'even those containing sugars (e.g., apples and carrots) are minimally cariogenic because the more vigorous mastication that they require (when consumed raw) stimulates the flow of saliva, a major natural oral cleanser'.

Starch formed the staple component of the medieval diet in all sectors of society, mainly through the consumption of bread, and pottage among the poorer classes (Dyer 1989:157,197; Greig 1981; Hammond 1995:26-102; Moore and Corbett 1973; Reeves 1995:148). High molecular weight carbohydrates have a lower cariogenicity than simple sugars because they are too large to diffuse through plaque and cannot be metabolised directly by bacteria. However, if allowed to stagnate in the oral environment, starches are broken down by salivary enzymes, enabling bacterial utilisation and resultant acid production (Hillson 1996:278; Mays 1998:151; Powell 1985). The impact of complex carbohydrate consumption on caries prevalence has been demonstrated by the apparent rise in caries rates which has accompanied the shift to agriculture among numerous groups across the world (Hillson 1996:283). There is scant skeletal evidence that oral hygiene was practised in the Middle Ages. In the monastic phase of the Fishergate cemetery, three males displayed polished, abraded buccal tooth surfaces, and one male exhibited wear of cementum in a pattern that was consistent with the use of a toothpick (Watson 1993:247). However, regular removal of plaque and food debris was not customary, as testified by the widespread deposits of calculus on teeth from medieval skeletal remains (see plate 9.2).

Proteins and fats are not cariogenic because they are not metabolised by cariogenous bacteria. They may even confer a cariostatic effect through the release of alkaline waste products following enzymatic breakdown in the buccal cavity, which serve to neutralize pH levels and inhibit bacterial activity. Thus populations subsisting on a diet of protein and fat exhibit negligible caries (Hillson 1996:279; Legler and Menaker 1980:215; Mays 1998:149; Powell 1985). The wealthiest elements of medieval peasant and urban society enjoyed the greatest quantity and variety of meat, game, fish and dairy products, subject to seasonal variation. Consumption of these products tended to diminish with decreasing wealth (Harvey 1993:34-71; Hammond 1995:26-102; Moore and Corbett 1973). The poorest of peasants ate little animal protein during the period prior to the Black Death, but Dyer (1989:158-159, 199-202; 1994:77-99) has identified a shift towards greater meat consumption among all classes during the more prosperous years of the later Middle Ages (see section 5.3).

The intake of fluoride, from fluoridated water or foods grown on fluoridated soils, may significantly moderate caries experience. Incorporation of fluoride into the developing dentition reduces tissue solubility, and continued consumption may enhance remineralization and inhibit bacterial activity. Hillson (1996:279) stresses that environmental flourine levels are an important consideration in any study of caries epidemiology, but acknowledges that they are unfortunately difficult to establish for archaeological samples.

Dietary texture can influence caries experience substantially. Soft, sticky foods are cariogenic because without deliberate removal, they cling to tooth surfaces and become impacted in crevices allowing time for fermentation. Conversely, abrasive foods may impede the caries process by scouring the teeth of plaque and food debris, stimulating saliva production, and removing the pits and fissures which serve as foci for decay (Mays 1998:152). It has been suggested that the heavy tooth wear which results from eating a coarse diet (plate 9.1) may also reduce caries frequency by obliterating early lesions, thereby preventing their progression (Powell 1985); although Hillson (1996:284) disputes this idea owing to the slow rate of attrition relative to the rapid progression of caries. A variety of bread textures were available in the Middle Ages, but the medieval poor ate the coarsest, black bread, while the most refined products were only affordable to the rich (Hammond 1995:26-102; Moore and Corbett 1973). However, there was a general transition toward the use of finer, white flours in the later Middle Ages (Dyer 1989:198; 1994:77-99; Goose 1962; Hammond 1995:92).

Host susceptibility to caries may be influenced by various endogenous factors (Powell 1985). These include salivary composition and flow rate, and immunity to cariogenic bacteria. Tooth morphology affects intraoral patterns of occurrence. Teeth with more complex morphology experience greater carious involvement due to the pits and fissures which trap food particles and provide a sheltered environment for bacterial activity. Thus molars display the highest prevalence, followed by premolars. The anterior teeth are least affected (Hillson 1996:280). However, hypoplastic defects, which occur most frequently on the anterior dentition, may provide lines of weakness to caries attack, although the influence of enamel hypoplasia on caries epidemiology has not yet been established (Hillson 1996:283-284). Entrapment of food between teeth causes approximal surfaces to be more caries prone than lingual and buccal surfaces which are more readily cleansed by natural mechanisms.

Once the carious process has advanced to allow bacterial invasion of the pulp chamber, the inflammatory reaction produces an accumulation of pus, termed an abscess, comprising exudate, dead cells and bacteria. Severe attrition and crown fracture can also predispose to abscess development by exposing the pulp, thereby permitting bacterial infiltration. Pulpal necrosis usually follows abscess formation. The infection can then spread down the root canal to form an abscess at the apex of the tooth. Bone is resorbed to accommodate the abscess. A sinus, or fistula, usually develops, commonly emerging on the buccal surface of the jaw, through which the pus is discharged (see also section 6.5.1; Hillson 1986:316-318; Hillson 1996:284-287; Lukacs 1989; Mays 1998:148-149; Powell 1985; Roberts and Manchester 1995:50-52). A sinus enables the skeletal identification of an abscess, illustrated on plate 9.2. Prior to the development of a sinus, an abscess can usually only be detected radiographically. It has therefore been suggested that the true abscess prevalence is probably underestimated in skeletal remains (Lukacs 1989; Roberts and Manchester 1995:50), although a study by Swärdstedt (1966 in Hillson 1986:317; 1996:287) reported that most periapical radiolucencies are accompanied by sinuses. The process of abscess development usually culminates in the exfoliation of the affected tooth, after which the lesion heals. However, in the pre-antibiotic era, abscessing posed the threat of serious, potentially fatal complications, through the spread of bacterial infection to the surrounding bone, soft tissues, and to more distant sites via the bloodstream and lymphatic system (see section 6.5.1; Mays 1998:148-149; Silverstone *et al.* 1981:5).

While untreated caries and abscesses are significant causes of ante-mortem tooth loss, other major causes include periodontal disease, super-eruption, trauma and deliberate extraction (Bennike 1985:165; Brothwell 1981:154; Lukacs 1989; Mays

1998:155). Periodontal disease is a chronic condition affecting the tissues that surround the teeth. It commences with gingivitis, an inflammation of the gums that is usually incited by infection from plaque bacteria or irritation by calculus deposits. Poor oral hygiene is therefore an important predisposing agent. Hormonal and dietary factors can also influence its development. The inflammation may then advance, causing destruction of the periodontal ligaments and resorption of the alveolar bone, so that the tooth roots become exposed and teeth are eventually lost due to a lack of support (see plate 9.2) (Hillson 1986:305-316; 1996:260-269; Larsen 1997:77-82; Roberts and Manchester 1995:55-57). Tooth loss through super-eruption occurs in response to extreme attrition. Teeth continue to erupt passively throughout life in an attempt to compensate for wear and maintain occlusion. Severe attrition may induce eruption to the extent that the teeth are only weakly supported by the root tips, ultimately leading to tooth loss (Hillson 1996:138, 263-264; Lilley *et al.* 1994:502; Mays 1998:155; Roberts and Manchester 1995:53, 56; Stroud and Kemp 1993:245; Whittaker 1993:60-63). Ante-mortem tooth loss is recognised archaeologically by the alveolar remodelling which takes place after exfoliation, depicted on plate 9.1. However, it is often not possible to reconstruct the specific pathological processes which precipitated the loss (Hillson 1996:287). Owing to the various potential causes of tooth loss in archaeological populations, it is generally advised that carious teeth and those lost ante-mortem are analysed separately in epidemiological studies (Mays 1998:155). This departs from the standard techniques applied in clinical studies, which usually combine carious and missing teeth in a single index of tooth decay because caries is the primary cause of tooth loss in western populations that consume a diet high in sugar and refined carbohydrates (Helöe and Haugejorden 1981; Hillson 1986:293-295; 1996:279-280; Mays 1998:155; Burt 1981:23-25).

9.2 Method

All material had been examined macroscopically, and X-radiography was used to assist in the diagnosis of dental pathology within the Jewbury collection. A similar format had been used to record dentition in all the cemeteries. Each tooth was scored as being either present, lost ante-mortem, lost post-mortem or not present due to possible uneruption, impaction or congenital absence. The presence or absence of alveolar bone had been recorded for each tooth position, and the state of jaw preservation noted. Teeth affected by caries were indicated. Diagnosis was based on visual assessment, without the use of a dental probe, and positive classifications relied on the presence of cavitation, not superficial lesions. Cavity size and surface location had been recorded for all but the material from St Nicholas Shambles, but this data was not utilised for the purposes of analysis because it was considered to be of insufficient relevance to an investigation of sex related pathology. Lesion size reflects the stage of carious progression at the time of death, and patterns in caries initiation site largely relate to gross aspects of dietary texture and chemical composition (Hillson 1996:282-283; Silverstone *et al.* 1981:6, 25-26; Whittaker 1993:53). Positive identification of abscesses depended on the existence of a sinus.

The adult male and female prevalence of caries, abscesses and ante-mortem tooth loss was quantified for each cemetery sample, using both the standard 'individual count' and 'tooth count' methods (tables 9.1-9.6) (Lukacs 1989; Mays 1988:147-148; Roberts and Manchester 1995:47, 63). The individual count method is broadly analogous to the 'crude prevalence' statistic, described in section 6.5.2. Hence caries prevalence was defined as the proportion of dentate individuals displaying caries. The prevalence of abscesses was expressed as the number of individuals affected out of the total number of individuals with an appropriate portion of maxilla or mandible represented, and ante-mortem tooth loss prevalence was determined as a proportion of individuals with alveolar bone present. Chi-square tests were applied to each cemetery sample and the pooled site data, in order to establish whether there was any statistical association between sex and the prevalence of caries, abscesses or ante-mortem tooth loss respectively (tables 9.1, 9.3 and 9.5). Like the crude prevalence statistic, the limitation of this approach lies in the premise that in typically fragmented archaeological remains, all absent material lacks pathological lesions (Lukacs 1989; Mays 1988:147-148; Roberts and Manchester 1995:47). This invariably leads to an underestimate of the true prevalence, and results may be biased by sample preservation. This can be particularly problematical when comparing data derived from different cemeteries.

The tooth count method largely circumvents this problem. It is akin to the 'corrected prevalence' statistic described in section 6.5.2. Using the tooth count method, caries prevalence was defined as the number of carious teeth out of the total number of teeth available for examination. The prevalence of ante-mortem tooth loss was expressed as a proportion of tooth sockets available for examination. Similarly, abscess prevalence was determined as a proportion of extant tooth positions. This approach eliminates the question over the reliability of negative evidence by excluding all missing material from the calculation. The drawback with the procedure is that standard tests of statistical significance cannot be applied to the data because teeth/tooth positions in an individual skeleton cannot be regarded as independent observations for statistical analysis. Mays (1988:148) therefore advocates the simultaneous application of both the individual and tooth count methods. The former enables statistical testing and the latter can be used to determine whether a consistent pattern emerges. However, as Hillson (1986:294; 1996:280) notes, the tooth count method does not eradicate the problem of sample preservation bias because all tooth classes are aggregated, despite their differing susceptibility to disease and post-mortem loss. For example, samples with poor anterior tooth preservation could generate an inflated caries prevalence, owing to the greater caries experience of molar teeth. The problem can be avoided by applying the tooth count method to each of the tooth types separately. This approach was attempted in this study, but aborted due to the sparse data sets created by splitting the samples by tooth type and sex.

The age-specific prevalence of caries, abscesses and ante-mortem tooth loss was computed for males and females in each of the four adult age categories, using the individual count method (tables 9.7-9.9). This was necessary because the prevalence of dental pathology tends to rise with age, as a result of increased exposure time and the progressive nature of dental disease. Differences in the age structure of skeletal samples may therefore impair the comparability of data (Lukacs 1989; Mays 1988:148; Roberts and Manchester 1995:63; Waldron 1994:61-63). Common odds ratios were also computed for each cemetery sample using the Mantel-Haenszel estimate described in section 8.2.1 (table 9.10). This procedure controlled the confounding factor of age to enable the comparison of male and female prevalence in a single summary statistic.

The prevalence of caries among the sexed subadults from Abingdon and Fishergate was calculated in relation to the permanent, deciduous and entire dentition respectively, using both the individual count and tooth count methods (table 9.11 and 9.12). Chi-square tests were applied to determine whether there was any statistical association between sex and caries prevalence. The prevalence of abscesses and ante-mortem tooth loss was not determined owing to the extremely low frequency of subadults affected.

9.3 Results and Discussion

The results of the individual count method for quantifying caries prevalence, presented in table 9.1, suggested the existence of a slight sex bias toward a higher caries experience among females. The percentage of females displaying caries exceeded the percentage of males in five of the seven cemetery samples: Ipswich, Abingdon, Fishergate 4, Fishergate 6 and Jewbury. An approximately equal percentage of males and females were affected from Wharram Percy, and only St Nicholas Shambles displayed a higher caries prevalence among males. The female bias in the majority of cemeteries probably contributed to the overall bias toward a higher female prevalence in the pooled site data, in which 65.2% of females were affected compared with 61.4% of males. However, despite the fairly consistent trend across the cemeteries, only the sample from the early phase at Fishergate displayed a statistically significant association between sex and caries prevalence (χ^2=12.685 p<0.001), according to the results of the chi-square tests. The disparities between the male and female mortality profiles in this sample probably contributed to the greater female caries prevalence; the large component of young males reducing the typical male age at death, and thus caries prevalence, by comparison to the females.

The results of the tooth count analysis, presented in table 9.2, again showed a consistent female propensity toward a higher caries experience. The pattern of results conformed with the findings from the individual count method. A greater percentage of female teeth were affected in the same five cemeteries. A male bias was observed in the collection from St Nicholas Shambles, and a similar percentage of male and female teeth were affected in the Wharram Percy collection. Within the pooled cemetery sample, 10.3% of all female teeth were affected compared with 9.5% of male teeth.

It was suspected that this inclination might actually be more pronounced than the results from the entire cemetery samples suggested, because males displayed a higher average age at death than females in all but the Fishergate samples (see chapter 5), and caries prevalence tends to increase with age. This suspicion was confirmed by the age-specific prevalence figures and common odds ratios, presented in tables 9.7 and 9.10. A higher percentage of females were affected in the majority of age groups. The sex difference was most exaggerated among those aged *c.*18-25 years. In this cohort, the percentage of females affected exceeded the percentage of males in every single cemetery and the pooled site data, in which 68.3% of females displayed caries compared with only 41.5% of all males. The common odds ratios also revealed a higher caries prevalence among females in five of the seven collections: Ipswich, Wharram Percy, Fishergate 4, Fishergate 6 and Jewbury. Abingdon generated a common odds ratio of unity, although St Nicholas Shambles persisted in displaying a higher caries prevalence among males.

The prevalence of caries among the subadults from Abingdon and Fishergate was considerably lower than virtually all the adult samples, as demonstrated by the results in tables 9.11 and 9.12. This is the reverse of the situation today, where caries is often described as a 'disease of childhood' (Burt 1981:26-27). The difference can be ascribed to dietary factors. Today, children consume a diet high in sucrose, which is particularly detrimental because newly erupted enamel is more susceptible to caries attack. Following eruption, teeth take up minerals which confers a resistance to caries, a process known as enamel maturation (Legler and Menaker 1980:222). Unlike the adult data, the subadult data did not yield a consistent sex bias in caries prevalence. With respect to the entire, often mixed dentition, a higher percentage of males (42.3%) than females (22.2%) were affected by caries in the Abingdon assemblage, and approximately 30% of males and females were affected from Fishergate. However, in frequency terms, only fifteen subadults from Abingdon and a total of eleven subadults from Fishergate displayed caries, so the expression of prevalence in percentage terms could be considered inappropriate. It is possible that the age structure of these small samples also influenced the results. Neither cemetery displayed a statistically significant relationship between sex and caries prevalence in the entire dentition, according the chi-square tests. The tooth count method also failed to reveal a consistent sex difference. As with the individual count method, a higher percentage of male teeth (6.0%) than female teeth (4.0%) were affected from Abingdon; whereas a higher percentage of female teeth (5.9%) than male teeth (2.6%) were affected from Fishergate. When the permanent and deciduous dentition were analysed separately, a similarly varied set of results were obtained, although this breakdown did reveal that the slightly higher prevalence of caries observed in the entire dentition of Abingdon males could be attributed to a cluster of carious permanent teeth in a small number of individuals. Aside from this, the deciduous dentition generally showed a higher caries prevalence than the permanent teeth, using both the individual count and tooth count methods, which is consistent with their longer exposure time among many of the subadults in the cohort.

As with the analysis of caries, the results of the individual count method for quantifying abscesses in adults, presented in table 9.3, revealed a consistent tendency towards a higher abscess prevalence in females. A greater percentage of females were affected in six of the seven cemeteries. Only Wharram Percy deviated from this trend, which contained a higher percentage of affected males. When the data from all cemeteries were pooled, 38.4% of males and 37.8% of females displayed abscesses. The fractionally higher percentage of males affected overall can at least partly be accredited to the influence of the Wharram Percy sample on the total population, as it was the largest of all the assemblages and contained the highest frequency of individuals with abscesses. None of the samples yielded a statistical relationship between sex and abscess prevalence, although the chi-square value approached significance in the Abingdon (χ^2=2.922 p=.087) and Fishergate 4 (χ^2=3.515 p=.061) collections. The results of the tooth count method were less consistent, as demonstrated in table 9.4. Four of the cemeteries continued to display a higher female prevalence: Abingdon, Fishergate 4, Fishergate 6 and Jewbury; whereas three displayed a higher male prevalence: Wharram Percy, Ipswich and St Nicholas Shambles. A total of 3.8% of tooth positions in males and 3.1% of tooth positions in females were abscessed when the data from all cemeteries were pooled. However, like the results for caries, the age-structure of the samples had probably biased the abscess results, as indicated by the age-specific prevalence figures and the common odds ratios presented in tables 9.8 and 9.10. There was a tendency for females to display a higher prevalence of abscesses among the age-specific prevalence figures. Even the Wharram Percy assemblage displayed a higher female abscess prevalence among those in the age group *c.*18-25. According to the common odds ratios, all seven cemeteries and the pooled site data displayed a higher abscess prevalence among females.

The results obtained from the individual and tooth count analysis of ante-mortem tooth loss did not show a consistent bias toward either sex, as indicated in tables 9.5 and 9.6. According to both methods, three cemeteries displayed a higher female prevalence: Ipswich, Fishergate 4 and Jewbury; and three displayed a higher male prevalence: Wharram Percy, Abingdon, St Nicholas Shambles. Both methods produced an almost identical prevalence of ante-mortem tooth loss among males and females from Fishergate 6. The prevalence of tooth loss was greater among males in the pooled cemetery sample: 64.1% of males and 60.6% females displayed ante-mortem losses; and 15.3% of male teeth and 14.3% of female teeth were lost ante-mortem. However, the chi-square tests revealed that none of the observed differences between the male and female samples were statistically significant. The age-specific prevalence figures, presented in table 9.9, did not reveal any obvious sex differences either; although when the data from all cemeteries were pooled, the greatest disparities between the sexes were evident in the youngest (*c.* 18-25 years) and eldest (>*c.*45 years) age groups, in which a slightly higher percentage of females were affected. The common odds ratio for the pooled site data also indicated that females displayed a higher prevalence of ante-mortem tooth loss. Furthermore the results in table 9.10 revealed a common odds ratio in favour of females within five of the seven cemeteries: Ipswich, Wharram Percy, Abingdon, Fishergate 6 and Jewbury. Only St Nicholas Shambles and Fishergate 4 displayed a common odds ratio that was skewed towards a higher prevalence of ante-mortem tooth loss in males.

Overall, these results suggested that the dental health status of adult females was inferior to that of adult males. The sex differences were often subtle, but the trend was fairly consistent. Caries and abscesses exhibited the strongest sex bias, although there was some evidence that females also experienced a slightly higher prevalence of ante-mortem tooth loss. These results are consistent with the findings of several other studies of archaeological material (Larsen 1983; 1997:81-82; Hillson 1986:297). Bennike (1985:163,170) has examined a series of Swedish samples dating from the neolithic to the Middle Ages, and found a higher prevalence of caries and ante-mortem tooth loss among females in all periods, and the sex differences were statistically significant ($p<0.01$) in the medieval group. Larsen (1997:72) also states that 'Comparisons of a wide range of archaeological populations from different times and settings reveal a common pattern of greater caries prevalence in females than in males'. Larsen attributes the sex differences to cultural factors, primarily different dietary practices between the sexes. He suggests that females tended to consume a greater proportion of plant carbohydrates whereas males ate more meat. Larsen provides ethnographic evidence to support this interpretation, with reference to societies in which males are primarily responsible for procuring meat and females are largely responsible for obtaining and processing plant foods. He maintains that these roles directly contributed to distinctions in dietary habits. However, this line of interpretation would seem most appropriate for hunter-gatherer populations, and not really relevant to the economy of medieval England where consumption was primarily within the household.

Nevertheless, it is possible that dietary differences existed between the sexes, perhaps via the sexual division of labour, although this can really only be a matter for speculation. Women were largely responsible for food preparation and cooking (Bennett 1987:116; Hanawalt 1977; 1986:8; Henisch 1976:61; Shahar 1983:240), and this might have encouraged frequent snacking, which tends to be deleterious to dental health, especially the frequent ingestion of readily fermentable carbohydrates (James pers. comm.; Larsen 1997:74). Sexual divisions in labour might have provided differential access to foods of varying cariogenicity. For example, women usually managed the beehives that were the chief source of honey (Hammond 1995:48); they were the main gatherers of wild produce, and commonly worked as hucksters selling bread in the town streets (Goldberg 1992:82-157; Hammond 1995:39, 48; Hanawalt 1986:10). Hammond (1995:48) asserts that the hucksters 'seem to have made their profit as a result of being allowed, by law, to receive thirteen batches for every twelve bought: a 'baker's dozen'. By contrast, butchery was largely the preserve of men (Goldberg 1992:108-109, 190; Graham 1997:126-136) and men were more often involved in the hunting and poaching of animals (Reeves 1995:198-200; Hammond 1995:18).

Alternatively, developmental or physiological factors might explain the higher prevalence of dental pathology among females. Clinical studies have demonstrated that girls experience a higher caries rate than boys of the same age, which is normally attributed to the earlier age of dental eruption in girls (Hillson 1996:280; Legler and Menaker 1980:217). This sex difference was not identified among the subadults from Abingdon and Fishergate, but perhaps this was due to the small sample sizes combined with the generally low subadult caries prevalence. However, it seems unlikely that sex differences in eruption timings could impinge on caries experience into adulthood, although it might explain the particularly pronounced bias toward a higher female caries prevalence among those in the youngest adult age group, *c.* 18-25 years.

Pregnancy is associated with increased gingivitis (Hillson 1986:312; James pers.comm.; Larsen 1997:75), and this may have had important repercussions on dental health status, especially during a period when repeated pregnancies were probably common and general health was comparatively poor (Bennike 1985:173-174). The hormonal changes associated with pregnancy may produce an exaggerated inflammatory reaction to an existing irritant, such as calculus deposits. As the precursor to periodontal disease, chronic gingivitis could ultimately contribute to a higher prevalence of tooth loss among females. The discomfort caused by the condition might also discourage attempts at oral hygiene and the consumption of foods which scour the teeth naturally, and instead encourage a preference for soft foods (Bennike 1985:173; James pers. comm.). This factor might therefore secondarily promote the development of caries and abscesses in females (James pers. comm.). It might also have contributed to the elevated caries experience among younger females, and the slightly greater percentage of young females displaying ante-mortem tooth loss. The marginally higher percentage of females affected by ante-mortem tooth loss among those aged over *c.*45 years might be attributable to post-menopausal bone loss (Watson 1994:504; Jilka 1998). Several studies have identified a greater severity of alveolar recession among older females (Bennike 1985:155-156; Watson 1994:504).

Finally, it was clear that differences existed between the cemeteries in the prevalence of dental pathology. The proportion of individuals exhibiting caries ranged from approximately 21% to 74% across the samples; abscess prevalence ranged from between 6% and 59%; and the proportion of individuals displaying ante-mortem tooth loss spanned from about 20% to 77%. According to the tooth count method, between 2.2% and 14.2% of teeth displayed caries, between 0.1% and 7.3% of tooth positions were abscessed, and the proportion of tooth positions displaying ante-mortem tooth loss ranged from 2.1% to 26.5% across the cemeteries. Furthermore, it was apparent that the cemetery hierarchy of prevalence was remarkably consistent for all three indicators of dental pathology, using both the individual count and tooth count methods of quantification, and for both sexes. An initial interpretation might be that the differences were attributable to inter-observer variation in recording. However, this explanation seemed insufficient because the recognition of caries, abscesses and especially ante-mortem tooth loss is fairly unambiguous, particularly with respect to their presence/absence in individuals. Preservation differences could be a factor, although the results of the 'tooth count' analyses tended to support those obtained using the 'individual count' method, which would tend to play down this possibility. It may be of relevance that the site hierarchy of prevalence for all three dental health indicators bears a general correspondence with the cemeteries' dates of use, detailed in chapter 2 and bracketed below. As tables 9.13 and 9.14 illustrate, the approximate rank order of cemeteries, in increasing order of dental pathology prevalence, were as follows: St Nicholas Shambles (11^{th}-12^{th} centuries), Fishergate 4 (mid 11^{th}-end of 12^{th} century), Jewbury (mid 12^{th} century-1230), Fishergate 6 (1195-1538), Wharram Percy (11^{th}-16^{th} centuries), Ipswich (1263-1538), Abingdon (*c.*1300-1540). This temporal rise in dental pathology may be a reflection of the historically identified transition in the English diet during the Middle Ages toward the use of refined white flours and increased sugar consumption (Dyer 1989:198; 1994:77-99; Goose 1962; Hammond 1995:10,92; Moore and Corbett 1973). The pattern is supported by a similar study conducted by James (pers. comm.), which has identified a clear rise in caries prevalence and ante-mortem tooth loss within three medieval cemeteries dating to the 10^{th}-12^{th} centuries, *c.*1300-1540, and the 15^{th}-16^{th} centuries respectively. Further research into other cemeteries might establish this potential link between deteriorating oral health and the progression of the Middle Ages, and so perhaps confirm whether the dietary changes which took place during the period had an increasingly detrimental impact upon oral health.

Table 9.1 Proportion of individuals displaying caries within the adult male and female cemetery samples (individual count method)

n_c number of individuals displaying caries n_t total number of dentate individuals in sample
% percentage of dentate individuals displaying caries χ^2 chi-square statistic p probability

	Males		Females			
	n_c/n_t	%	n_c/n_t	%	χ^2	p
Wharram	110/162	67.9	72/107	67.3	.011	.916
Ipswich	75/115	65.2	37/51	72.6	.865	.352
Abingdon	87/121	71.9	67/90	74.4	.169	.681
St Nicholas	16/32	50.0	19/45	42.2	.456	.499
Fishergate 4	7/34	20.6	15/22	68.2	12.685	.000
Fishergate 6	64/99	64.6	25/34	73.5	.902	.342
Jewbury	72/139	51.8	67/114	58.8	1.230	.267
Pooled site data	431/702	61.4	302/463	65.2	1.755	.185

Table 9.2 Proportion of male and female teeth displaying caries (tooth count method)

n_c number of carious teeth n_t total number of teeth in sample
% percentage of carious teeth in sample

	Males		Females	
	n_c/n_t	%	n_c/n_t	%
Wharram	279/2635	10.6	190/1854	10.2
Ipswich	202/2035	9.9	98/851	11.5
Abingdon	280/2157	13.0	245/1723	14.2
St Nicholas	30/674	4.5	35/971	3.6
Fish 4	19/847	2.2	41/446	9.2
Fish 6	218/1868	11.7	84/610	13.8
Jewbury	182/2576	7.1	178/1967	9.0
Pooled site data	1210/12792	9.5	871/8422	10.3

Table 9.3 Proportion of individuals displaying abscesses within the adult male and female cemetery samples (individual count method)

n_a number of individuals displaying abscesses n_t total number of individuals with an appropriate portion of maxilla or mandible in sample % percentage of individuals displaying abscesses
χ^2 chi-square statistic p probability

	Males		Females			
	n_a/n_t	%	n_a/n_t	%	χ^2	p
Wharram	95/162	58.6	56/104	53.9	.594	.441
Ipswich	62/116	53.5	27/49	55.1	.038	.846
Abingdon	36/134	26.9	37/99	37.4	2.922	.087
St Nicholas	2/33	6.1	3/45	6.7	.012	.914
Fishergate 4	5/34	14.7	8/22	36.4	3.515	.061
Fishergate 6	42/100	42.0	18/35	51.4	.933	.334
Jewbury	33/138	23.9	29/117	24.8	.026	.871
Pooled site data	275/717	38.4	178/471	37.8	.038	.845

Table 9.4 Proportion of tooth positions displaying abscesses among males and females (tooth count method)

n_a number of tooth positions displaying abscesses n_t total number of extant tooth positions in sample
% percentage of tooth positions displaying abscesses

	Males		Females	
	n_a/n_t	%	n_a/n_t	%
Wharram	310/4243	7.3	153/2799	5.5
Ipswich	164/2980	5.5	67/1315	5.1
Abingdon	64/3586	1.8	58/2753	2.1
St Nicholas	2/868	0.2	3/1215	0.1
Fishergate 4	17/1010	1.7	16/617	2.6
Fishergate 6	116/2753	4.2	43/909	4.7
Jewbury	58/3760	1.5	51/3069	1.7
Pooled site data	731/19200	3.8	391/12677	3.1

Table 9.5 Proportion of individuals displaying ante-mortem tooth loss within the adult male and female cemetery samples (individual count method)

n_{am} number of individuals displaying ante-mortem tooth loss n_t total number of individuals with alveolar bone in sample % percentage of individuals displaying ante-mortem tooth loss
χ^2 chi-square statistic p probability

	Males		Females			
	n_{am}/n_t	%	n_{am}/n_t	%	χ^2	p
Wharram	104/157	66.2	60/102	58.8	1.465	.226
Ipswich	82/116	70.7	35/49	71.4	.009	.924
Abingdon	103/134	76.9	71/99	71.7	.798	.372
St Nicholas	17/33	51.5	21/45	46.7	.179	.672
Fishergate 4	7/34	20.6	6/22	27.3	.335	.563
Fishergate 6	63/100	63.0	22/35	62.9	.000	.988
Jewbury	80/138	58.0	69/117	59.0	.026	.871
Pooled site data	456/712	64.1	284/469	60.6	1.472	.225

Table 9.6 Proportion of male and female teeth lost ante-mortem (tooth count method)

n_{am} number of teeth lost ante-mortem n_t total number of extant tooth positions in sample
% percentage of teeth lost ante-mortem

	Males		Females	
	n_{am}/n_t	%	n_{am}/n_t	%
Wharram	703/4243	16.6	405/2799	14.5
Ipswich	490/2980	16.4	238/1315	18.1
Abingdon	949/3586	26.5	620/2753	22.5
St Nicholas	52/868	6.0	66/1215	5.4
Fishergate 4	21/1010	2.1	30/617	4.9
Fishergate 6	308/2753	11.2	102/909	11.2
Jewbury	409/3760	10.9	354/3069	11.5
Pooled site data	2932/19200	15.3	1815/12677	14.3

Table 9.7 Age-specific prevalence of caries among the adult male and female cemetery samples

n_c number of individuals in age group displaying caries n_t total number of dentate individuals in age group
% percentage of dentate individuals in age group displaying caries

		c. 18-25		*c.* 25-35		*c.* 35-45		*c.* >45	
		n_c/n_t	%	n_c/n_t	%	n_c/n_t	%	n_c/n_t	%
Wharram	Males	12/28	42.9	19/30	63.3	26/35	74.3	50/64	78.1
	Females	17/24	70.8	13/22	59.1	17/23	73.9	23/31	74.2
Ipswich	Males	15/26	57.7	24/34	70.6	17/28	60.7	19/24	79.2
	Females	11/11	100.0	12/17	70.6	7/8	87.5	9/13	69.2
Abingdon	Males	14/19	73.7	25/30	83.3	21/29	72.4	25/40	62.5
	Females	15/19	79.0	25/29	86.2	10/17	58.8	14/21	66.7
St Nicholas	Males	1/5	20.0	6/8	75.0	6/12	50.0	2/6	33.3
	Females	2/7	28.6	10/18	55.6	4/15	26.7	3/4	75.0
Fishergate 4	Males	1/15	6.7	4/11	36.4	1/5	20.0	1/3	33.3
	Females	2/4	50.0	4/6	66.7	6/9	66.7	3/3	100.0
Fishergate 6	Males	2/9	22.2	14/20	70.0	24/30	80.0	23/39	59.0
	Females	2/3	66.7	9/9	100.0	9/11	81.8	5/9	55.6
Jewbury	Males	9/28	32.1	17/30	56.7	24/39	61.5	20/39	51.3
	Females	22/36	61.1	12/23	52.2	20/31	64.5	12/23	52.2
Pooled site data	Males	54/130	41.5	109/163	66.9	119/178	66.9	140/215	65.1
	Females	71/104	68.3	85/124	68.6	73/114	64.0	69/104	66.3

Table 9.8 Age-specific prevalence of abscesses among the adult male and female cemetery samples

n_a number of individuals displaying abscesses in age group n_t total number of individuals with an appropriate portion of maxilla or mandible in age group % percentage of individuals in age group displaying abscesses

		c.18-25		*c*.25-35		*c*.35-45		*c*.>45	
		n_a/n_t	%	n_a/n_t	%	n_a/n_t	%	n_a/n_t	%
Wharram	Males	3/28	10.7	12/30	40.0	21/35	60.0	55/64	85.9
	Females	8/24	33.3	7/22	31.8	13/23	56.5	26/31	83.9
Ipswich	Males	10/26	38.5	10/34	29.4	18/28	64.3	21/24	87.5
	Females	3/11	27.3	6/17	35.3	7/8	87.5	10/13	76.9
Abingdon	Males	2/19	10.5	12/30	40.0	10/29	34.5	12/40	30.0
	Females	4/19	21.1	12/29	41.4	12/17	70.6	8/21	38.1
St Nicholas	Males	0/5	0.0	0/8	00.0	2/12	16.7	0/6	00.0
	Females	0/7	0.0	0/18	00.0	2/15	13.3	1/4	25.0
Fishergate 4	Males	1/15	6.7	1/11	9.1	1/5	20.0	2/3	66.7
	Females	0/4	0.0	3/6	50.0	5/9	55.6	0/3	0.0
Fishergate 6	Males	1/9	11.1	7/20	35.0	9/30	30.0	24/39	61.5
	Females	0/3	0.0	5/9	55.6	9/11	81.8	4/9	44.4
Jewbury	Males	4/28	14.3	4/30	13.3	12/39	30.8	11/39	28.8
	Females	6/36	16.7	3/23	13.0	12/31	38.7	7/23	30.4
Pooled site data	Males	21/130	16.2	46/163	28.2	73/178	41.0	125/215	58.1
	Females	21/104	20.2	36/124	29.0	60/114	52.6	56/104	53.9

Table 9.9 Age-specific prevalence of ante-mortem tooth loss among the adult male and female cemetery samples

n_{am} number of individuals displaying ante-mortem tooth loss in age group n_t total number of individuals with alveolar bone in age group
% percentage of individuals in age group displaying ante-mortem tooth loss

		*c.*18-25		*c.*25-35		*c.*35-45		*c.*>45	
		n_{am}/n_t	%	n_{am}/n_t	%	n_{am}/n_t	%	n_{am}/n_t	%
Wharram	Males	2/28	7.1	11/30	36.7	24/35	68.6	64/64	100.0
	Females	4/24	16.7	8/22	36.4	14/23	60.9	31/31	100.0
Ipswich	Males	8/26	30.8	22/34	64.7	22/28	78.6	24/24	100.0
	Females	5/11	45.5	11/17	64.7	6/8	75.0	13/13	100.0
Abingdon	Males	3/19	15.8	22/30	73.3	27/29	93.1	40/40	100.0
	Females	6/19	31.6	17/29	58.6	17/17	100.0	21/21	100.0
St Nicholas	Males	2/5	40.0	6/8	75.0	5/12	41.7	3/6	50.0
	Females	2/7	28.6	7/18	38.9	7/15	46.7	4/4	100.0
Fishergate 4	Males	0/15	00.0	2/11	18.2	3/5	60.0	2/3	66.7
	Females	0/4	00.0	0/6	00.0	4/9	44.4	2/3	66.7
Fishergate 6	Males	1/9	11.1	12/20	60.0	18/30	60.0	31/39	79.5
	Females	1/3	33.3	5/9	55.6	8/11	72.7	8/9	88.9
Jewbury	Males	4/28	14.3	10/30	33.3	30/39	76.9	33/39	84.6
	Females	5/36	13.9	14/23	60.9	25/31	80.7	23/23	100.0
Pooled site data	Males	20/130	15.4	85/163	52.2	129/178	72.5	197/215	91.6
	Females	23/104	22.1	62/124	50.0	81/114	71.1	102/104	98.1

Table 9.10 Common odds ratios relating the age-specific prevalence of dental pathology in males and females

ψ common odds ratio (a ratio exceeding the value of 1.00 indicates a higher prevalence of dental pathology among males, and a ratio of less than 1.00 indicates a higher prevalence of dental pathology among females)

	ψ		
	Caries	Abscesses	Ante-mortem tooth loss
Ipswich	0.59	0.99	0.85
Wharram	0.84	0.92	0.98
Abingdon	1.00	0.56	0.99
St Nicholas	1.39	0.72	1.19
Fishergate 4	0.15	0.53	2.34
Fishergate 6	0.54	0.51	0.66
Jewbury	0.74	0.83	0.49
Pooled site data	0.78	0.87	0.87

Table 9.11 Proportion of individuals displaying caries within the subadult male and female samples (individual count method)

n_c number of individuals displaying caries n_t total number of dentate individuals in sample
% percentage of dentate individuals displaying caries χ^2 chi-square statistic p probability

		Males		Females			
		n_c/n_t	%	n_c/n_t	%	χ^2	p
Permanent dentition	Abingdon	10/23	43.5	2/15	13.3	3.818	.051
	Fishergate	3/20	15.0	2/12	16.7	.016	.900
Deciduous dentition	Abingdon	1/16	6.3	2/9	22.2	1.392	.238
	Fishergate	3/10	30.0	3/13	23.1	.140	.708
Entire dentition (i.e.mouths)	Abingdon	11/26	42.3	4/18	22.2	1.910	.167
	Fishergate	6/20	30.0	5/17	29.4	.002	.969

Table 9.12 Proportion of subadult male and female teeth displaying caries (tooth count method)

n_c number of carious teeth n_t total number of teeth in sample % percentage of carious teeth in sample

		Males		Females	
		n_c/n_t	%	n_c/n_t	%
Permanent dentition	Abingdon	21/315	6.7	4/255	1.6
	Fishergate	3/266	1.1	5/118	4.2
Deciduous dentition	Abingdon	5/120	4.2	9/74	12.2
	Fishergate	6/83	7.2	8/102	7.8
Entire dentition (i.e.mouths)	Abingdon	26/435	6.0	13/329	4.0
	Fishergate	9/349	2.6	13/220	5.9

Table 9.13 Site rankings for the proportion of males and females displaying dental pathology, sites ordered in descending prevalence

% Percentage of individuals affected in sample

Caries				Abscesses				Am Loss			
Males	%	Females	%	Males	%	Females	%	Males	%	Females	%
Abingdon	71.9	Abingdon	74.4	Wharram	58.6	Ipswich	55.1	Abingdon	76.9	Abingdon	71.7
Wharram	67.9	Fishergate 6	73.5	Ipswich	53.5	Wharram	53.9	Ipswich	70.7	Ipswich	71.4
Ipswich	65.2	Ipswich	72.6	Fishergate 6	42.0	Fishergate 6	51.4	Wharram	66.2	Fishergate 6	62.9
Fishergate 6	64.6	Fishergate 4	68.2	Abingdon	26.9	Abingdon	37.4	Fishergate 6	63.0	Wharram	58.8
Jewbury	51.8	Wharram	67.3	Jewbury	23.9	Fishergate 4	36.4	Jewbury	58.0	Jewbury	59.0
St Nicholas	50.0	Jewbury	58.8	Fishergate 4	14.7	Jewbury	24.8	St Nicholas	51.5	St Nicholas	46.7
Fishergate 4	20.6	St Nicholas	42.2	St Nicholas	6.1	St Nicholas	6.7	Fishergate 4	20.6	Fishergate 4	27.3

Table 9.14 Site rankings for the proportion of male and female teeth/tooth positions displaying dental pathology, sites ordered in descending prevalence

% Percentage of teeth/tooth positions affected in sample

Caries				Abscesses				Am Loss			
Males	%	Females	%	Males	%	Females	%	Males	%	Females	%
Abingdon	13.0	Abingdon	14.2	Wharram	7.3	Wharram	5.5	Abingdon	26.5	Abingdon	22.5
Fishergate 6	11.7	Fishergate 6	13.8	Ipswich	5.5	Ipswich	5.1	Wharram	16.6	Ipswich	18.1
Wharram	10.6	Ipswich	11.5	Fishergate 6	4.2	Fishergate 6	4.7	Ipswich	16.4	Wharram	14.5
Ipswich	9.9	Wharram	10.2	Abingdon	1.8	Fishergate 4	2.6	Fishergate 6	11.2	Jewbury	11.5
Jewbury	7.1	Fishergate 4	9.2	Fishergate 4	1.7	Abingdon	2.1	Jewbury	10.9	Fishergate 6	11.2
St Nicholas	4.5	Jewbury	9.0	Jewbury	1.5	Jewbury	1.7	St Nicholas	6.0	St Nicholas	5.4
Fishergate 4	2.2	St Nicholas	3.6	St Nicholas	0.2	St Nicholas	0.1	Fishergate 4	2.1	Fishergate 4	4.9

10. Conclusions

The aim of this project has been to determine whether there is evidence to suggest that males and females in medieval England experienced differences in health and mortality which could be objectively demonstrated from their skeletal remains. This has been investigated through the comparative analysis of palaeodemographic and palaeopathological data derived from seven large and well-documented cemeteries. The results were interpreted with the assistance of medical, historical and archaeological evidence. A method for sexing subadults was also developed using tooth measurements. This enabled subadult remains to be included in the project, so that the sexual comparison could be pushed back to include individuals in the pre-adult phase of life.

Intuitively, it might be expected that differences would exist between the sexes, either due to biological factors or gender differences in social roles. The results upheld this expectation, revealing sex differences in mortality, general health status, activity-related pathology, and dental disease. However, the sex differences were frequently of a low magnitude, with age and site differences largely transcending disparities between the sexes. Although there are limitations to the inferences which can be drawn from skeletal evidence, in many respects the collective picture which emerged from the results tended to diminish the commonly assumed importance of sex and gender in terms of their impact on health and mortality. Furthermore, some of the sex differences contradicted expectation, questioning some of the implicit assumptions about male and female social status and the determinism of male and female biology.

The study focused on a selective range of demographic and pathological indicators. The results obtained from each aspect of analysis have been discussed in detail in the preceding chapters, so this chapter only aims to draw together the main findings and provide a composite interpretation of the evidence. It also discusses the strengths and limitations of the method, and suggests areas for further research. The conclusions drawn from the investigation into the subadult sexing methodology have been stated comprehensively in chapter 3, so will not be discussed further here.

The analysis of the demographic structure of the medieval cemeteries began with an investigation into their sex composition, and an examination of the possible causes for the consistent over-representation of male skeletons, not only in the monastic assemblages which would be expected due to the large component of brethren burials, but also the secular cemeteries. This is a characteristic common to many archaeological series derived from various periods and locations, and contrasts with the female bias that tends to prevail in many living adult populations (Bennike 1985:31-36; Brothwell 1972; Hanawalt 1993:58; Larsen 1997:335; Mays 1995a; Russell 1948:148; Stinson 1985:126; Waldron 1994:23; Weiss 1972). The analysis provided statistical confirmation that the sexual disparity was unlikely to have occurred through pure chance, but unfortunately, it did not identify the probable origins of the bias. Nevertheless, it drew the various strands of interpretation together and highlighted aspects of interpretation which could benefit from further investigation.

A crude evaluation of potential bias in skeletal sexing methodology did not support the widely quoted hypothesis that there may be a systematic methodological sexing bias toward male classification (Roberts and Manchester 1995:23,25; St Hoyme and Iscan 1989; Weiss 1972). This theory contends that preconceptions about female build, and the increase in skeletal robusticity which tends to occur through habitual strenuous activity or age, may result in robust female skeletons being mis-classified as male. This has profound implications for all sex comparative studies as they depend on the accurate sexing of the base population sample. The chief source of sexing bias is thought to derive from sexing indicators which are graded as being 'larger' or 'smaller' in nature, rather than those which rely on the existence of discontinuous traits. In this study, it was anticipated that the skeletons that had been sexed less securely, conventionally designated as being of 'probable' sex, would be most susceptible to potential weaknesses in sexing methodology. These skeletons tend to be less complete, lacking the most reliable diagnostic traits, or display ambiguous sex characteristics. However, contrary to expectation, the analysis indicated that a greater proportion of these skeletons had actually been classified as female. When removed from the cemetery samples, the male bias became slightly more exaggerated. One explanation might be that biological anthropologists are over-compensating for the proposed source of sexing bias, inclining to classify individuals with ambiguous or inadequate sex characteristics as female. Alternatively, the results could support the findings of a study conducted by Meindl and co-workers (1985), which indicated that males are more prone to mis-diagnosis owing to a greater variability in pelvic morphology, whereas females are rarely mis-sexed. Meindl and colleagues concluded that the proportion of males in many skeletal assemblages could even be underestimates of the true sex ratios. The results of this study therefore emphasise the need for further evaluation of the accuracy and reliability of skeletal sexing methodology, particularly if it is to be used as an explanation for biased sex ratios in skeletal assemblages. The crude assessment employed in this study was limited by the use of existing cemetery data, and the composite sex assignations of many individuals which had been attributed using a collective range of sex indicators. Perhaps future research should concentrate on testing skeletal sex indicators independently in order to identify whether certain traits are inherently responsible for producing a consistent error in the classification of either sex.

An assessment of skeletal completeness did not support the hypothesis that the under-representation of females could have arisen because they are more prone to decay (Bennike 1985:34; Walker *et al.* 1988), which has been forwarded on the premise that female skeletons are more gracile or older female bones more porous. Although preservation differences were detected among the cemetery samples examined, no consistent bias was identified toward either sex or any particular age group. Further research into this area would probably benefit from the use of samples with documented age and sex, so as to avoid any inherent biases associated with inaccurate age or sex diagnoses.

Site sampling cannot be excluded as a possible source of sex bias in skeletal retrieval, but it is difficult to reconcile how the bias should fall so regularly in favour of males. The suggestion that female burials were preferentially cleared to make way for new interments (Hanawalt 1986:102) seems improbable in a period when named grave markers were not generally used (Wakely pers. comm.). Similarly, there was no evidence to support the proposal that male skeletons were interred with greater care, which might have enhanced their chances of preservation (Bennike 1985:35-36).

Several authors have suggested that population movements could have contributed to distorted sex ratios in skeletal samples, instigated by a range of agents including the gender-specific demand for labour (Grauer 1991; Mays 1997; 1998:72; Thrupp 1965-6). This approach was applied to provide seemingly adequate interpretations for the demographic composition of all the samples included in this project, and fragments of historical evidence were even used to support these interpretations. However, the migration theory is flawed by the fact that skeletal assemblages usually consist of cumulative aggregates of unidentifiable burials that were deposited over a protracted period, so its application can largely only remain circumstantial. Furthermore, migration patterns are notoriously difficult to trace historically (Fox 1973:78; Goldberg 1992:280).

It is conceivable that an excess of females lie within the subadult component of cemetery assemblages, which would serve to counterbalance the deficit among adults. The subadult sex assignments that were attributed using the tooth measurement technique did not provide immediate support for this hypothesis, as a slightly higher frequency were classified as male in both the Abingdon and Fishergate samples. However, as the samples were small and the method did not extend to young children with undeveloped permanent teeth, it would be inappropriate to draw any general conclusions on the basis of these results. This emphasises the need for advancement in subadult sexing methodology, which could confirm whether there is any foundation to this proposition.

Meanwhile, a review of documentary sources did not provide any convincing evidence to support the hypothesis that females were at a greater risk of mortality during the subadult years. The process of childbearing may have posed a specific mortality threat to females, especially as the legal age for marriage was just twelve years for girls, which could be taken to imply an early age for first pregnancy. However, documentary evidence suggests that the majority delayed marriage until later. The average age probably varied with time and locality, but some historians have placed it in the late teens to early twenties (Bennett 1989:72-73; Hanawalt 1986:96; Razi 1980:50-64,135-137) while others argue that it was more common for women to remain single into their mid-twenties, following a period of active employment and financial independence (Goldberg 1986; 1992:225-232; 1997:1-15; Smith 1979 in Campbell 1990:104-105 and Goldberg 1996:232). It is possible that the average age at first pregnancy was lower than that at first marriage as documentary sources indicate that birth outside wedlock was not an uncommon occurrence (Goldberg 1992:232; Hanawalt 1986:195-196; Razi 1980:64-65; Shahar 1983:113-120). However, the age at death profiles may undermine the importance of this potential source of premature female mortality, as they indicated a generally low level of mortality among the teenage cohort.

Infants and children comprised the majority of subadult remains, and female infanticide has been proposed as a factor which may have contributed to low skeletal sex ratios (Coleman 1976; Mays 1993; 1995; Russell 1948). However, the review of skeletal and historical studies indicated that while infanticide occurred during the medieval period, there is no evidence to suggest that it was a common practice, or that females were more often the victims. Nevertheless, the potential secrecy surrounding the act could have obscured its prevalence (DeMaitre 1976; Hanawalt 1986:102; 1977; Helmholtz 1975; Herlihy 1978; Johansson 1984; Kellum 1974; Kroll and Bachrach 1986; Langer 1974a; 1974b; Mays 1993, 1995; Scrimshaw 1984; Shahar 1990:118-120; 1992:132-139).

Alternatively, a higher female mortality rate among subadults may have arisen if female children were less valued, and received inferior treatment as a result. This situation exists in some modern societies which practice a gender system that favours male offspring, where boys tend to be fed a more nutritionally adequate diet and are more likely to receive medical attention when unwell (Johansson 1986; Stinson 1985). Bennett (1987:68) has suggested that sons may have been more highly valued than daughters during the Middle Ages because they were the preferred heirs through whom the family name and lands would pass. However, anecdotal evidence and coroner's records indicate that while parents sometimes displayed favouritism towards certain children, it was not necessarily their sons (Hanawalt 1986:184-184; Shahar 1992:82-83). Several didactic authors did recommend a later weaning age for boys, and emphasised that good nourishment was more important for male children, but there is no evidence to indicate whether or not this advice was actually heeded in the parental home (DeMaitre 1976:474; Shahar 1992:81). The investigation into skeletal stress indicators provided a valuable insight into this line of interpretation, demonstrating how skeletal evidence can complement historical evidence and assist in counteracting its limitations. The collective analysis of stature, enamel hypoplasia and cribra orbitalia did not yield any convincing evidence to suggest that female children experienced an inferior level of general health, which would tend to repudiate the idea that female children received inferior treatment in terms of diet and care. This further diminished the possibility that subadult females experienced an elevated mortality rate due to an underprivileged social status, leaving the enigma of the 'missing' adult females unresolved.

The second aim of the demographic analysis was to compare male and female age at death within the adult samples. It is widely asserted that females experienced an earlier age at death. This is usually attributed to the hazards of pregnancy and childbirth, although the possibility of an impaired health status as a consequence of a lower social status has also been proposed (Brothwell 1972; Dawes and Magilton 1980:63-66; Manchester 1983:8-9; Wells 1975). The comparison of male and female mortality profiles for the cemeteries included in this study did produce results which were somewhat consistent with the view that females experienced an earlier age at death, but not overwhelmingly so. A pattern was observed in the data which was most perceptible when divided into just two age groups, above and below *c.*35 years. A slightly greater percentage of females were allotted to the younger group in five of the seven of cemeteries, but no statistical association ($p>0.05$) between sex and age at death was identified for any of the samples, suggesting that the observed sex difference in age at death could have arisen by pure chance. Given the fairly consistent pattern observed, a statistical association might have been expected when the data from all cemeteries were pooled. However, while the 5% probability level was approached, even this procedure did not reveal an unequivocal statistical association between sex and age at death, despite the substantial size of the aged and sexed sample, which comprised *c.*1,500 individuals. In percentage terms, 48.1% of all females were allotted to the younger age category compared with 43.3% of males, and 56.7% of all males were allotted to the older category compared with 51.9% of females. When each of the cemetery samples were divided into four age intervals, the results were fairly erratic. This could be taken as further evidence to diminish the perceived association between sex and age at death, although it may have been a product of the reduced sample sizes having split the data into four cohorts. The pooled data did suggest that most of the discrepancy observed between male and female mortality derived from a peak in female deaths among those aged *c.*25-35 years. In contrast to the female mortality profile, the males displayed a fairly gradual increase in the proportion allotted to each successive age interval.

These results led to the conclusion that the disparity in male and female age at death was probably of a fairly low magnitude, even among large-scale samples. The lack of a marked sex difference could suggest that too much emphasis has traditionally been placed on the idea that females generally experienced a younger age at death, and it perhaps diminishes the commonly assumed importance of childbearing on female mortality or the potential health effects resulting from a subordinate social status. The results tend to imply that other factors probably played an overriding role in determining survival for both sexes, the most likely contender being the ubiquitous threat of infectious disease (Manchester 1983:17-20; Rawcliffe 1995:3; Roberts and Manchester 1995:124-125). Another interpretation might be that certain factors preferentially curtailed the lifespan of males, which virtually counterbalanced those acting to the detriment of females. Fatal trauma or a lower resistance to environmental stress are possible examples.

Nevertheless, a discrepancy in age at death was noted between the sexes. Since former methods for determining parity status in skeletal remains have now been invalidated (Cox and Scott 1992; Molleson and Cox 1993:135-136), it would be difficult to infer whether childbearing was the most important agent in determining the slight female proclivity toward a lower age at death. However, the rise in female mortality among those aged *c.*25-35 in the pooled sample may lend support to this interpretation. If an inferior health status were the more likely cause, it might be reasonable to expect that this would exert a fairly steady erosion on female survival. An age at death study alone cannot negate the possibility that females experienced an inferior health status consequent to an inferior social status; and as Manchester (1983:9) has noted, impaired health can exacerbate the risks associated with childbearing and vice versa, so the two factors are not necessarily exclusive. However, the analysis of stress indicators did help to elucidate this question, as a poorer general health status was not identified among females, suggesting that the purported subordination of females did not extend to prejudice their basic level of health, during childhood or adulthood. By implication, this would tend to weaken the hypothesis that females experienced an earlier age at death as a result of a lower social status, leaving childbearing as the more important influence on premature female mortality. Although it should be stressed that skeletal age does not necessarily correspond with chronological age, if childbearing was the prime factor contributing to the rise in mortality within the *c.*25-35 year age cohort, it could also lend support to the argument forwarded by some historians that females often delayed marriage and family responsibilities into their mid-twenties (Goldberg 1986; 1992:225-232; 1997:1-15; Smith 1979 in Campbell 1990:104-105 and Goldberg 1996:232).

Contrary to expectation, the composite analysis of skeletal stress indicators appeared to suggest that it was males who were more likely to experience an inferior level of general health, during childhood and as adults. This was primarily interpreted as evidence to support the hypothesis that males have a greater biological susceptibility to environmental stress, which would in turn support the interpretation that this factor could have preferentially curtailed the lifespan of males. Taken independently, none of the stress indicators unequivocally demonstrated that a sex difference in health status existed between the sexes, owing to ambiguities in aetiology, limitations in methodology, and the subtlety of many of the observed differences. However, when considered concurrently, a consistent pattern emerged. This justifies Goodman and co-workers (Goodman *et al.* 1984; Goodman *et al.* 1988; Huss-Ashmore *et al.* 1982; Martin *et al.* 1985) recommendation that multiple traits should be employed to characterise health status.

The stature analysis indicated that medieval men and women were closer in height than men and women are today, but that much of the disparity originated in a greater difference between male heights. Medieval males were relatively short by comparison to modern males, whereas medieval and modern females were closer in height. This was interpreted as evidence to indicate that males were more likely to experience growth retardation, leading to a reduced terminal stature. Since nutrition is a major determinant on the attainment of optimal stature, this might imply that an inferior or inadequate diet was actually afforded to boys rather than girls, contrary to the advice of didactic authors. However, the hypothesis that males have a greater sensitivity to environmental stress provides a more feasible interpretation. If both sexes were equally exposed to the same environmental constraints, including similar nutritional inadequacies, these could have had a more detrimental impact on male growth. The results did not support the idea that females could have received an inferior diet.

Nevertheless, the stature analysis was limited by assumptions and shortcomings in the methodology. The integrity of comparing stature values derived from dried bones with those of living persons is questionable, and the possibility that there may be an inherent methodological bias toward the over or underestimation of stature in one sex cannot be excluded. This demonstrates the need for an evaluation of potential sex biases in skeletal stature estimation (Waldron 1998). Perhaps future studies could minimise these problems by comparing actual bone lengths, rather than calculated stature values.

The soundness of comparing the medieval stature values with modern figures is also debatable, partly because the improvements in diet, healthcare and living conditions that have been largely responsible for recent height increases could have worked to the preferential benefit of one sex, and also because the extensive population movements which have taken place over the centuries could render the medieval and modern data incomparable on a genetic basis.

Nevertheless, the analysis of enamel hypoplasia did reveal that a greater proportion of males were affected, and that males displayed a higher frequency of defects than females. As acute infection is thought to be an important aetiological factor, this pattern is consistent with the view that males have a lower resistance to environmental stress, in this instance infectious disease. Similarly, it would lend support to the idea that females have a superior immune reactivity.

The results of the investigation into anaemia were less consistent, although they did not actually contradict those obtained from the analysis of stature and enamel hypoplasia. Neither sex displayed a consistently higher prevalence of cribra orbitalia, suggesting that neither males or females were more susceptible to the aetiological factors which invoke anaemia. Severe or chronic blood loss is an established cause, such as that arising through parasitic infestation or diarrhoea. Traditionally, anaemia has also been viewed as a condition caused by a diet deficient in iron, and following this the results would suggest that neither sex was more likely to have been deprived of iron rich foods. However, this view is becoming superseded by the belief that anaemia develops as a result of an immune response to underlying disease, particularly infection. The lack of a sex difference in cribra orbitalia prevalence departs from the greater male prevalence of enamel hypoplasia, which has also been linked with infection. This inconsistency may imply differences in the specific infective processes that invoke the two conditions. Perhaps cribra orbitalia reflects the effects of chronic disease whereas enamel hypoplasia represents acute infection. Alternatively, enamel hypoplasia might be a more sensitive indicator of gender-related stress. Along a similar line of interpretation, another possibility could be that after formation during childhood, subtle sex differences in cribra orbitalia are more prone to obliteration through remodelling during continued skeletal development. Since enamel is not remodelled after formation, hypoplastic defects might be retained for longer, until obliterated by attrition, thus preserving discrete sex differences into adulthood.

The analysis of non-specific infectious lesions produced results which were more concordant with the findings for stature and enamel hypoplasia. Although neither sex displayed a generally higher prevalence of periostitis according to the crude prevalence statistics, the corrected prevalence figures for the lower limb bones revealed a fairly pronounced and consistent sex bias toward a higher male prevalence. Again, this is consistent with the hypothesis that males have a greater biological susceptibility to environmental stress, in this case non-specific infection, and that females have a more effective immune response. However, other aetiological factors have been proposed for periostitis, which could undermine this interpretation (Larsen 1997:83; Mensforth *et al.* 1978; Roberts and Manchester 1995:129-130). Repeated minor trauma has been implicated, so the results could indicate that males were more often involved in hazardous activities which placed them at greater risk of developing periostitis; an interpretation which is supported by the higher prevalence of trauma among males. The prevalence of osteomyelitis was generally low for both sexes, but the proportion of males affected exceeded the proportion of females, which could be indicative of a greater male biological susceptibility to infection. Alternatively, this could represent another example of males facing increased exposure to stress, not simply a lower resistance to infection, perhaps through their increased risk of trauma. Open fractures present a direct route for bacterial invasion, and it was noted that all cases of osteomyelitic infection associated with fractures were male. Future investigation into a wider range of infectious disease indicators, such as specific infections, might provide firmer evidence to indicate the greater male biological susceptibility to infectious disease. A large skeletal sample would be a prerequisite, owing to the potentially small magnitude of the sex difference.

An alternative line of interpretation was considered for the results obtained from the collective analysis of skeletal stress indicators. Paradoxically, the pattern of stress identified among males could actually reflect a more robust health status, which enabled survival despite the burden of stress imposed (Grauer 1991; Manchester 1983:36); whereas the relative lack of evidence for stress among females could imply an inferior health status, whereby death ensued before a visible skeletal reaction took place (Roberts and Manchester 1995:164). However, these inferences were rejected, largely because a review of the literature indicated that there is a general tendency for population samples derived from circumstances conducive to increased stress, such as poor nutrition and population aggregation, to display a comparatively high prevalence of skeletal stress indicators (Goodman *et al.* 1994; 1988; 1991; 1992; Huss-Ashmore *et al.* 1982; Larsen 1997:61; Martin *et al.* 1985; Sweeney 1967; 1971; Enwonwu 1973).

The age-specific prevalence figures for the general health indicators revealed some further patterns in the data, and these were far more pronounced than those identified between the sexes. The prevalence of cribra orbitalia and enamel hypoplasia clearly displayed an inverse relationship with increasing age. Subadults displayed a considerably higher prevalence than adults, and younger adults tended to display a higher prevalence than older adults. This could suggest that individuals experiencing increased stress were inclined to an earlier age at death, for several reasons. Such individuals could be representative of those who experienced a greater exposure to stress. They may represent those with an inherently greater susceptibility to stress, which could imply that the pattern is reflecting the Darwinian idea of 'selective advantage'. Alternatively, following the 'biological damage' hypothesis proposed by Goodman and Armelagos (1988 in Mays 1998:161), the individuals could represent those who had sustained damage through stress early in life, and this impaired their ability to rally from subsequent episodes of stress leading to a premature death. However, a more straightforward interpretation for the decrease in cribra orbitalia and enamel hypoplasia prevalence with advancing age is simply that the lesions are gradually obliterated through bone remodelling and dental attrition. The age-specific analysis of stature lends support to the latter interpretation, since bone length does not alter once growth has ceased and no relationship was identified between stature and age at death. However, there is a possibility that the traits are not comparable due to the different aetiological factors which contribute most to their development. The stature results could suggest that age at death was not influenced by an inadequate diet, whereas the pattern identified for cribra orbitalia and enamel hypoplasia could suggest that infectious disease did curtail age at death.

Periostitis displayed the converse relationship with age. The prevalence was lower among subadults than adults, and the prevalence of tibial periostitis among adults increased with advancing age. Again, this pattern is open to several interpretations. Perhaps inactive lesions are not readily remodelled and therefore accumulate with age.

The lesions may be manifestations of enduring but non-serious infections resulting in an increase in prevalence with age, or the individuals affected could represent those with a robust immunity who survived into older age despite chronic infection. Alternatively, as venous insufficiency has been implicated in the aetiology of periostitis, the rise in prevalence among adults could be reflecting the expected rise in this age-related condition. The distribution of lesions also differed between the adults and subadults. The tibia and fibula were most commonly affected in adults, but the majority of subadult lesions were present elsewhere on the skeleton, which could imply that different aetiological factors were primarily responsible. Perhaps subadults were at a lower risk of repeated minor trauma, which is concordant with lack of fractures among subadults, or perhaps this form of trauma is less likely to incite a periosteal reaction in subadult bones. The lack of periostitis in the lower limbs may be associated with the rarity of circulatory disorders in subadults. Alternatively, tibial periostitis may simply be under-recorded in subadults because it resembles the normal process of subperiosteal bone deposition during growth.

It is apparent that much of the ambiguity over the interpretation of these age-specific prevalence patterns derives from the ambiguity in the aetiology of stress indicators. It may never be possible to isolate the specific causative factors due to the synergistic relationship between stressors, although future advances may resolve some of the uncertainty. The differences observed between adults and subadults may also suggest that it is not necessarily appropriate to draw inferences about childhood stress retrospectively, using retained indicators of childhood stress among adults. Lesions in subadults could represent a different aetiology, or those surviving to maturity may not be representative of those dying in childhood in terms of stress resistance or exposure. This reiterates the need for a routine method of subadult sexing for comparing male and female childhood stress. Regardless of the interpretive problems, the existence of age patterns in stress indicator prevalence emphasises the need to take age into account when conducting any comparative study, otherwise differences in the age structure of the samples being compared could strongly bias results. In this study, the age-specific prevalence figures conferred support for the above inferences on male and female health status.

The investigation into skeletal trauma confirmed that males displayed a higher overall prevalence of fractures, indicating that males were more often engaged in hazardous activities. Cranio-facial and blade injuries predominantly occurred in male skeletons, and projectile wounds and nasal fractures were exclusive to males, suggesting that males were more likely to be involved in violent interactions, including armed combat. When violent injuries were excluded from the analysis, the male prevalence continued to surpass that of females, and although the cause of fractures must remain speculative, this suggested that males were also at an elevated risk of accidental injury. Nevertheless, females displayed a considerable prevalence of fractures, and the sex difference in prevalence diminished when violent injuries were omitted from the analysis. This implied that females were also at a substantial risk of accidental injury, and that they too undertook hazardous activities, lending support to the historical view that women comprised an integral part of the labour force (Goldberg 1986; 1990; 1992; 1997; Hadley 1999; Hanawalt 1977; 1986; Lees 1994; Shahar 1983). The results are concordant with medieval coroner's records which indicate that women undertook physically demanding work, but men generally carried out the most dangerous tasks (Hanawalt 1977). This is also consistent with the finding that males tended to display a higher prevalence of multiple fractures, indicating that they were either more prone to repeated injury, or were more likely to experience serious traumatic episodes which caused the simultaneous fracture of more than one bone.

Further evidence to imply the existence of sex differences in activity patterns was identified from the anatomical distribution of male and female fractures. Females displayed a higher prevalence of fractures to the ulna. This might have been interpreted as evidence for female-directed assault, but this was difficult to assess due to difficulties in determining which of the fractured ulnae displayed typical 'parry' fractures. However, the scarcity of cranio-facial and weapon injuries among females pointed away from an interpretation of violence. Instead, accidental falls may be a more appropriate explanation, especially as females also displayed a comparatively high prevalence of fractures to the radius and clavicle, both of which are commonly sustained when falling onto an outstretched hand. Males displayed a higher prevalence of fractures to the tibia and fibula. These often result from falls caused by tripping or twisting the ankle when the foot is caught, particularly when walking on rough terrain, suggesting that males were more often engaged in activities which placed them at risk from this type of accident.

Both sexes displayed a rise in fractures with increasing age. Broken bones were virtually absent among the sexed subadult material, although this need not necessarily indicate that subadults escaped fractures, as greenstick fractures can heal without trace. However, if the lack of fractures does directly reflect the subadult experience, it could either attest to the greater resilience of immature bone to fracture, or imply that subadults were at a lower risk of fracture. The latter interpretation would suggest that subadults were shielded against many of the rigours of adult life, at least in terms of workload, which would repudiate the contention of Ariès (1986:125) and supporters (Schultz 1991; Shorter 1977:169; Stone 1979:57, 65, 82-83), that childhood was not recognised as a distinct developmental phase in medieval society. It would also uphold the view that children were not generally subjects of physical abuse (Kroll and Bachrach 1986), which is consistent with the lack of evidence for infanticide.

The adult prevalence increased with advancing age, which, at least in part, probably reflects the cumulative nature of the skeletal fracture record. Fractures occurring in adulthood often leave a permanent lesion, and a longer lifespan extends the opportunity to encounter traumatic events. This reiterates the need to consider the age-specific prevalence of trauma when conducting comparative studies, as differences in the age structure of the samples could bias results.

Neither sex displayed a pronounced rise in any particular age category indicative of a cohort at an increased risk of injury within the respective cemeteries, although slight sex differences were noted when the data from all sites were pooled. Males displayed a fairly steady rise of about 8% in the proportion affected with each consecutive age group, suggesting that the risk of fracture was fairly constant through all cohorts. Females displayed a more exponential-type rise in prevalence. The prevalence was similar to that of males within the youngest age group, *c.*18-25 years, with around 8% of individuals affected, but only rose by 3.6% in the following group, aged *c.*25-35. There was a 6.8% increase in female fracture prevalence in the group aged *c.*35-45, and a rise of 10.3% among those aged above *c.*45 years, which served to close much of the gap in male and female prevalence.

The similarity in prevalence between males and females aged *c.*18-25 was surprising, as it might have been assumed that young males were among the most physically active. Instead, the results suggested that young females were at an equivalent risk of injury, implying that they experienced a similarly arduous lifestyle, which might lend further support to the argument that females remained single into their mid-twenties, during which time they participated actively in the workforce. The disparity between males and females aged *c*.25-35 may add strength to this interpretation, especially as it coincides with the rise in female deaths within this cohort. Perhaps the smaller increment in fractures among females could suggest that childbearing took women away from the types of labour in which they were more likely to encounter physical injury. The rise in fracture prevalence among older women may indicate that this was only a temporary status. However, further research on other large samples would be necessary to determine whether this is a pattern common to other series, and hence whether there is evidence to corroborate these interpretations.

Osteoporosis might have been another factor contributing to the rise in trauma among females aged over *c*.45 years, although there was little evidence to support this in terms of the typical pattern of bone involvement which tends to be associated with osteoporosis (Mays 1998:176-178; Roberts and Manchester 1995:74). A fractionally higher percentage of females displayed vertebral compression fractures among the eldest age category (>*c*.45 years), but the number of individuals affected was generally small in all samples. Males tended to display a higher prevalence of rib fractures in all age groups, which could be taken as evidence to diminish the importance of osteoporosis on female fracture prevalence, although if males were at a relatively greater risk of rib fracture from accidental or violent causes, this could have served to obscure any potential sex difference in pathological rib fractures. However, fractures to the wrist and femoral neck were also scarce, and the fact that the overall prevalence of fractures among the eldest females did not actually surpass that of males perhaps suggests that the importance of osteoporosis on fracture prevalence should not be overplayed. This appears to contrast with the situation today, where fractures resulting from osteoporosis are a major cause of mortality and disability, particularly among post-menopausal females (Mays 1997:140-142). Perhaps the comparatively short medieval lifespan truncated the possibility of experiencing this serious repercussion of the disease. Alternatively, osteoporosis may have been less prevalent among medieval females, either as a direct result of the shorter lifespan or because of certain lifestyle factors (Mays 1998:141-142). The lack of a consistent sex or age difference in skeletal preservation could support this, following the common assumption that skeletons with osteoporosis are more prone to decay (Bennike 1985:34; Walker *et al.* 1988). This clearly represents an area which could benefit from further research, relevant to both clinical and archaeological studies. In particular, the comparative study of medieval and modern osteoporosis prevalence might help to elucidate the relative importance of the various aetiological factors which contribute to its development (Mays 1997:140-142; Roberts and Wakely 1992).

The results obtained from the investigation into joint disease provided further evidence to infer the existence of sex differences in activity patterns, which generally accorded with the interpretations drawn from the analysis of trauma. Males displayed a higher prevalence of osteoarthritis, although the sex difference was not as consistent or pronounced as that identified for trauma. The aetiology of osteoarthritis is multifactorial, but the findings could suggest that males were more likely to have been habitually involved in physically arduous activities (Larsen 1997:194), although the lack of an extreme or consistent sex difference emphasises that females also endured an arduous lifestyle.

The age-specific prevalence figures supported this interpretation. Males generally displayed a higher prevalence of osteoarthritis in the three youngest categories, spanning the interval *c.*18-45 years, whereas the female prevalence largely surpassed that of males among those aged above *c.*45 years. This implied an earlier age of onset in males, with an increase in female prevalence in later middle age. Roberts and Manchester (1995:109) contend that for occupationally induced changes to become manifest, the activity must be undertaken from a young age, and that an elevated prevalence of osteoarthritis among young individuals may be indicative of an occupationally induced cause; so the male pattern of osteoarthritis prevalence could indicate that males were habitually involved in arduous physical activities from a young age. The higher female prevalence among older individuals concords with the findings of clinical studies (Larsen 1997:163; Spector *et al.* 1994; Rogers and Waldron 1995:32; Waldron 1997), which has led to the hypothesis that there may be a hormonal component in the development of the disease.

The analysis of the distribution of joints affected by osteoarthritis revealed that males experienced a higher prevalence of osteoarthritis in the acromio-clavicular and sterno-clavicular joints, whereas the knee joints were more commonly involved in females. As the acromio-clavicular and sterno-clavicular joints are both involved in arm-swinging movements, and the acromio-clavicular joint is involved in weight-bearing, the greater male involvement suggested that males bore a greater physical workload with the upper limbs. This interpretation was corroborated by the analysis of Schmorl's nodes of the vertebral column, which revealed a distinctly greater prevalence among males. Traumatic stress is the most important aetiological factor in Schmorl's node development, particularly that associated with weight-bearing, such as the strain of heavy lifting. Furthermore, Schmorl's nodes commonly develop in young individuals, as the vertebrae are able to grow and adapt to the shape of the herniated disc, so the results could again imply that males engaged in weight-bearing activities from a relatively young age, which is consistent with the generally younger age of osteoarthritis onset among males.

There are several possible interpretations for the relatively high female prevalence of osteoarthritis in the knee. Obesity is the predominant aetiological factor in modern populations (Spector *et al.* 1994), so the results could indicate that obesity was more common among females, although presumably the prevalence of obesity was comparatively low among medieval populations. Perhaps weight gained during repeated pregnancies could have imposed a similar stress on this weight-bearing joint. However, mechanical stress is another important predisposing factor, and clinical research has identified an association between osteoarthritis of the knee and prolonged or repeated knee bending, through kneeling, squatting or climbing stairs; risk factors which may be augmented by mechanical loading through heavy lifting (Cooper *et al.* 1994). The results of this study could therefore suggest that females were more often involved in tasks which involved these actions. A further explanation for the higher female prevalence of osteoarthritis in the knee could stem from anatomical differences between the sexes. The lower limbs in males are positioned more vertically than those of females, which tend to be inwardly angled as a result of a wider pelvis (Brothwell 1981:32), so perhaps this invokes differences in the mechanical stress imposed on the knee joint.

The investigation into osteoarthritis of the articular facets and spinal osteophytosis did not reveal any consistent sex differences in prevalence. In general, males and females were similarly affected. Since sex differences in activity-related stress appeared to have manifested in the appendicular skeleton, the results could support the view of Knüsel, Göggel and Lucy (1997) that joint disease in the vertebral column does not provide an effective indicator of activity-related stress, owing to the overriding mechanical stresses imposed on the spine through weight-bearing, postural support and locomotion. However, there were inadequacies in the methodology applied in the present study which could have limited the results obtained. Vertebral pathology was examined with respect to the entire spine and broad segments of it. It is possible that this was not sensitive enough to distinguish the functional determinants from the potential joint changes arising through activity-related stress, so the results may have been inconclusive. Perhaps future comparisons between the sexes should concentrate on detailed examination of the respective vertebrae and avoid generalised comparisons between large segments of the spine.

A further pattern identified in the data was a predilection for the appendicular joints on the right side of the skeleton to display a higher prevalence of osteoarthritis than those on the left. The bias was common to both sexes, and probably reflects the predominance of right-handedness among the general population. If so, this would tend to confirm that osteoarthritis can be used as a marker for inferring generalised activity-related stress in the skeleton. The existence of the bias in the lower limb joints could also indicate that the behavioural bias is not restricted to the upper limbs.

In contrast to the general tendency for males to sustain a poorer general health status and a greater prevalence of activity-related pathology, the comparative analysis of caries, abscesses and ante-mortem tooth loss revealed that the dental health of adult females was inferior to that of males. The sex differences were often subtle, and most of the samples did not yield a statistical relationship between sex and dental pathology prevalence, but the bias was consistent. Of the three indicators examined, the sex difference was most pronounced for caries, especially among those in the youngest adult cohort, aged *c.*18-25 years. This female bias did not pervade the sexed subadult samples, within which no consistent sex differences were identified, although this was at least partly due to the low frequency affected. The subadult prevalence was less than the adult prevalence, which is the converse of the situation today, and probably testifies to the impact of sucrose in the modern diet.

The poorer dental health status among females is open to several interpretations. The possibility of dietary differences between the sexes can be considered. Perhaps sex divisions in labour provided different access to certain food groups, with females gaining greater access to cariogenic carbohydrates (Bennett 1987:116; Goldberg 1992:82-157; Graham 1997:126-136; Hammond 1995:39,48; Hanawalt 1977; 1986:8,10; Henisch 1976:61; Reeves 1995:198-200; Shahar 1983:240). In particular, if women were primarily responsible for food preparation and cooking, this might have encouraged frequent snacking, which can promote the development of caries and subsequent abscess formation through the maintenance of low pH levels. Alternatively, developmental or physiological factors might be responsible. Dental eruption occurs slightly earlier in girls, thereby extending exposure time to the agents which invoke pathology (Hillson 1996:280; Legler and Menaker 1980:217). It seems unlikely that this could have impinged on dental health throughout adulthood, but it might explain the distinct sex difference in caries prevalence among those in the youngest group, aged *c.*18-25 years. The sexed subadult sample was too small to confirm whether this interpretation was feasible, but future studies of sexed subadult material might elucidate this. Pregnancy might also have contributed to the poorer dental health of younger females (Bennike 1985:173-174; Hillson 1986:312; James pers. comm.; Larsen 1997:75). Hormone changes during pregnancy may have a detrimental effect on dental health, by invoking the development of gingivitis and periodontal disease which can lead to tooth loss. The discomfort caused may also discourage attempts at oral hygiene, and encourage a preference of soft foods in favour of those which scour the teeth naturally, secondarily contributing to caries and abscess development. Repeated pregnancies would probably have enhanced these risk factors.

Further to the comparisons between male and female mortality and pathology, the study revealed considerable differences between the various cemeteries. These tended to be more pronounced than those detected between the sexes, suggesting that factors other than sex had a greater influence on mortality and pathology, although inter-observer variation in recording techniques undoubtedly contributed to the site differences observed, despite the efforts made to rationalise the data into a comparable format.

However, this is unlikely to constitute the entire explanation because both samples from Fishergate, and those from Ipswich and Wharram Percy, were examined by a single observer.

The demographic analysis exposed substantial site differences in age at death, which were more conspicuous than the small disparities detected between the sexes, corroborating the interpretation that sex was not a particularly strong determinant on age at death. Other factors were probably more important, such as a common living environment. There was some evidence to support the widespread belief that a rural environment was more beneficial to health and survival (Waldron 1989). The rural cemetery of Wharram Percy displayed a distinctive mortality profile, skewed toward the older age groups with approximately 40% of adults aged above *c.*45 years upon death. This contrasted with the mortality profile for St Nicholas Shambles, which was skewed toward the younger age categories with only about 10% of adults attaining *c.*45 years or more at death. The shorter adult lifespan for the London cemetery may attest to the deleterious conditions which are often incumbent upon urban communities. Population aggregation encourages the spread of infectious disease, in addition to the poor hygiene and sanitation which tends to arise through dense occupation. The pattern may also be suggestive of an immigrant population, in which young migrants succumbed to foreign pathogens upon entering the urban environment. These interpretations were somewhat supported by the analysis of the skeletal stress indicators which are associated with infectious disease: enamel hypoplasia, cribra orbitalia and tibial periostitis. The cemeteries of Wharram Percy and St Nicholas Shambles were polarised in the cemetery hierarchy of prevalence, Wharram Percy displaying a generally low prevalence of these indicators and St Nicholas Shambles displaying a high prevalence. Their contrasting prevalence rankings would also provide further evidence to support the view that stress indicator prevalence provides a direct analogy to health status, rather than the paradoxical argument that a raised stress indicator prevalence is indicative of a more robust health status, thereby corroborating the above interpretations on sex and health status.

However, the results obtained for the other cemeteries did suggest that the notion of an urban/rural divide in health and mortality may be too simplistic. The age at death profiles for the urban cemeteries were not all uniform, and neither did they display a consistently high prevalence of stress indicators associated with infectious disease. This included the samples for York, yet contemporary references indicate that the densely populated city would have been burdened with a high pathogen load, much like London. Ordinances dating to the thirteenth and fourteenth centuries refer to the persistent contamination of York's chief water supply, the River Ouse, and the putrid condition of the streets (Grauer 1993). The latter problem is illustrated in a rebuke made by Edward III following a visit to York in 1332, when he complained of 'the abominable smell abounding in the said city more than in any other city of the realm from dung and manure, and other filth and dirt wherewith the streets and lanes are filled and obstructed' (Hall 1996:80). Conversely, similarities might have been expected between Wharram Percy and Abingdon, as the Abingdon cemetery was thought to contain a strong rural component. Like Wharram Percy, the mortality profile for Abingdon was skewed toward the older age groups, yet the prevalence of stress indicators was comparatively high.

These anomalies suggest more complex causes for the site differences observed. It is important to reiterate that the cemetery collections represent chronological aggregates of unidentifiable burials; and that a multitude of factors probably influenced the health status of a local population at any given time. In addition, several factors probably served to blur the distinction between urban and rural communities. The widespread process of migration meant that many adults living in urban centres could have spent their formative years in the countryside; and the expansion and contraction of marketing meant that many settlements gained and lost their urban status throughout the medieval period (Beresford 1973; Fox 1973; Unwin 1990). Furthermore, although it is likely that rural settlements were less prone to the hygiene problems associated with larger centres of human aggregation, they may nevertheless have been exposed to alternative sources of pathogens, one possibility being via greater animal-to-human contact (Roberts and Manchester 1995:11-12). Contact with animals not only occurred through livestock farming but also within peasant living quarters. Livestock and humans were accommodated under the same roof within medieval long-houses, examples of which have been excavated at Wharram Percy (Adkins and Adkins 1982:170; Beresford and Hurst 1990:39-41; Platt 1978:107). Many parasites have animal host stages in their life-cycle, so these conditions might favour the spread of some parasites, or encourage the transmission of infectious diseases such as tuberculosis (Manchester 1983:49). These factors suggest that a wider range of cemeteries require comparative analysis before the urban/rural divide in health and mortality can be demonstrated unequivocally. A comparable method of recording would be a prerequisite, in order to attenuate this source of ambiguity in interpretation.

The stature analysis revealed that three of the assemblages displayed distinctive height characteristics. Males and females from Jewbury and Wharram Percy displayed particularly low mean statures. One possible explanation for both cemeteries could be a lack of gene dispersion through intermarriage within a relatively closed community. Alternatively, perhaps the Jewbury stature values are reflective of a distinct immigrant ancestry; or the Wharram Percy values testify to Dyer's (1989:197) proposal that the diet of medieval rural communities was inferior and less varied than that which was accessible to town-dwellers. By contrast, males from Ipswich displayed a distinctively tall stature, and the mean female stature also exceeded all the other cemeteries. This might be associated with the relatively high socio-economic status of the interments, although the material from the monastic phase at Fishergate did not display an equally tall stature, despite the ostensible similarities in the status of the interments. Neither did these cemeteries display similarities in age at death or stress indicator prevalence, which may suggest that socio-economic status was not a particularly powerful determinant on health status. Another explanation for the site differences in stature could be that they are a manifestation of regional height variations, which have also been detected in modern British samples (Barker *et al.* 1990; Knight 1984), although further research would be required to determine whether this is a consistent pattern among other archaeological series, and the potential causes for any regional disparities.

Substantial site differences were identified in the prevalence of trauma and joint disease. The crude prevalence figures initially suggested that there may have been an urban/rural divide in trauma prevalence. Males and females from Abingdon unequivocally displayed the highest fracture prevalence of all the cemeteries, followed by the assemblage from Wharram Percy; whereas St Nicholas Shambles displayed a markedly low fracture prevalence. This could have been taken as evidence to suggest a more arduous rural lifestyle. However, closer examination of the data revealed inconsistencies in this pattern. Firstly, the crude prevalence figures for the urban cemeteries of Ipswich and Fishergate approached that of the rural assemblage from Wharram Percy; and secondly, the corrected prevalence statistics yielded different site rankings altogether, in which Wharram Percy displayed the lowest fracture prevalence and St Nicholas Shambles displayed one of the highest, suggesting that the crude prevalence figures were biased by site differences in skeletal preservation. The site differences in joint disease prevalence did not conform to any discernible pattern in terms of known cemetery characteristics. Again, this suggests that many indeterminable factors may have contributed toward the apparent differences between cemeteries, and that it may not be possible to attribute the differences to single, broad causes.

The inability to provide a satisfactory interpretation for many of the inter-site differences identified in this study has highlighted the immense lack of knowledge which exists about the composition of skeletal assemblages. If basic characteristics are known about a cemetery, it is tempting attribute skeletal findings to those characteristics. However, the opportunity to compare cemeteries with a range of fundamental characteristics in this study has demonstrated that such a practice may often be inappropriate. While it was concluded that factors other than sex probably exerted a greater influence on mortality and pathology, it may not be feasible to specify exactly what those factors could have been.

One possible exception identified in this study emerged from the inter-site comparisons of dental disease. The cemetery prevalence rankings were consistent for all three indicators of dental health, and both sexes. The hierarchy corresponded to the dates of cemetery use, and so the apparent deterioration in dental health with time was interpreted as reflecting the historically documented shift in the English diet during the Middle Ages towards increased sugar consumption and the use of refined white flours (Hammond 1995:10; Moore and Corbett 1973). James (pers. comm.) has identified a similar pattern within a series of three cemeteries derived from different phases of the medieval period. However, a wider range of cemeteries would of course be required to confirm these interpretations. Unlike many aspects of skeletal pathology, the relatively discrete presentation of dental pathology may enhance the comparability of data recorded by different observers.

Among the limitations of the methodology that were encountered in this study, the lack of uniformity in recording protocol employed across the various cemeteries was the most problematical. Fortunately, the problem had less severe implications when comparing male and female data within the respective cemetery collections. However, it undoubtedly hampered attempts to compare data between cemeteries, including the identification of consistent sex differences in pathology across the cemeteries, and when comparing male and female pooled cemetery data. Much effort was invested in enhancing the comparability of data, but it is difficult to determine how successful this process was. The difficulties encountered in this study demonstrate the need for universally accepted standards for data collection. There have been repeated calls for this matter to be addressed within the profession, and although various recommendations have been published, there is no consensus on adoption (Brothwell 1981:xii; Buikstra and Ubelaker 1994; Larsen 1997:340; Roberts and Manchester 1995:8,199). The development of standards is unlikely to eradicate the problem of intra-observer variation in scoring, and inter-observer differences in the implementation of recording protocol, especially for the more ambiguous skeletal traits. It is also important that any potential protocol should not stifle the development of innovative recording techniques. However, the application of a common, basic recording framework would be a substantial improvement. It is impractical to re-examine material for every research project, especially for broad-based topics such as this, and when large samples are required, which is becoming increasingly common with the shift from a descriptive to an epidemiological approach to skeletal studies (Larsen 1997:3; Waldron 1994:1-9; Roberts and Manchester 1995:3-4,196). Furthermore, with the growing movement towards reburial and repatriation (Larsen 1997:341-342; Roberts and Manchester 1995:199), this option is increasingly unavailable. The Jewbury cemetery is a case in point, demonstrating how fundamental data needs to be recorded for posterity. The Abingdon collection has also now been reinterred.

The database which was designed to store and analyse the data proved to be a highly effective tool for managing the problem of variation in recording protocol. Using the data management facilities provided by SPSS in conjunction with the coding system devised, data could be entered according to any recording protocol, then transformed as necessary in order to provide optimal correlation with other recording systems. It also held the capability for expansion, to accommodate further cemeteries and pathological indicators. This aspect of the methodology is therefore recommended for future comparative and epidemiological analyses of skeletal data.

The epidemiological approach that was required for this study undoubtedly provided a satisfactory method for comparing the male and female data in an objective and rigorous manner, and is also advocated for use in future studies. Large sample sizes are a prerequisite for this approach, emphasising the value and need for large, well preserved cemetery collections. It is important to emphasise that a seemingly large sample can rapidly become reduced after splitting the data into groups for comparison, such as by age or sex. This can present an enigma, whereby the more groups are cut down with the aim of refining their characteristics for comparison, the less representative of the groups that they were meant to represent they become, owing to the reduction in sample size. This problem is exacerbated by the problem of 'sparse data', inherent to archaeology, whereby the incomplete preservation of material from archaeological deposits means that a complete set of data can rarely be obtained for a given individual. The sample used in this study proved to be of sufficient size to satisfy the objectives, yet even within this ostensibly large group, the effects of these processes were demonstrated repeatedly. The total number of individuals retrieved from the medieval cemeteries exceeded 2,500. This figure fell to below 2,000 when all unsexed material was excluded. When the data were split according to cemetery, sex, and age group, and when material lacking the relevant skeletal components for each analysis were excluded, the number of individuals left for comparison often fell into single figures. This illustrates how the process of dividing a sample for analysis coupled with the problem of sparse data could potentially conspire to exclude such a substantial portion of a skeletal sample that a comparative epidemiological analysis is simply untenable, or will produce results that are inconclusive.

Nevertheless, the use of the 'corrected' prevalence statistic provided an effective means of dealing with the problem of sparse data (Waldron 1994:53-54, and see section 6.5.2). Excluding all individuals lacking the relevant skeletal components to an analysis goes some way toward adjusting for preservation differences between samples. The procedure often served to refine or enhance the 'crude' prevalence figures, although in certain instances the corrected prevalence figures actually overturned the findings obtained using the crude prevalence statistic. This was most apparent when comparing data from different cemeteries, owing to site differences in preservation, which brings into question the widespread practice of comparing 'crude' prevalence figures between cemeteries. The utility of the corrected prevalence statistic emphasises the importance of documenting an inventory of skeletal elements for each individual, and this should certainly be included as part of any universal standards devised for data collection. Just a simple tick-sheet denoting the chief elements represented would help to optimise the value of pathological data recorded. This was repeatedly illustrated by the Jewbury assemblage, as the sudden pressure for reburial prevented the documentation of inventories, which meant that the considerable record of pathology which had already been achieved could not be used to its full potential (Lilley *et al.* 1994:424-425).

The application of inferential statistical techniques also proved to be extremely beneficial (Cohen and Holliday 1982:6-7). One potential hazard in confining an analysis to descriptive statistics, such as the computation of simple prevalence figures, is the unconscious temptation to 'find' patterns in the data which may not really be there; or to over-interpret an apparent difference or relationship between variables which could simply have occurred as a result of chance sampling errors. The use of statistical significance testing tempered these potential pitfalls, by effectively providing a baseline from which to draw comparisons. The application of inferential statistics is therefore recommended for future comparative studies. However, it also became apparent from the range of cemeteries included in this study that this recommendation may not necessarily be universally applicable, particularly with regard to small samples. Often sex differences in prevalence were only of a small magnitude, and many the respective cemetery samples were too small to allow these discrepancies to be confirmed statistically. This heightens the risk of committing what is termed statistically as a 'type 2 error', where the power of a test is insufficient to reject the null hypothesis (that there is no difference in prevalence between the groups being compared), when in fact the null hypothesis was false and should have been rejected (Cohen and Holliday 1982:120-124). This was a fairly common occurrence throughout the project, whereby a consistent sex bias in prevalence was noted across the respective cemeteries, but the difference or association only attained statistical significance when the data from all cemeteries were pooled into larger samples. Had the cemeteries only been examined singularly, many of the small sex differences in prevalence would not have been identified. Lazenby (1990) has also discussed this problem with reference to archaeological data. The ideal way of alleviating the problem would be to increase the sample size, again reiterating the value of large, well preserved cemeteries. However, as Lazenby acknowledges, this is not always practicable for archaeological populations. An alternative method of enhancing the power of a statistical test is to relax the level of acceptance for statistical significance; for example, by accepting a probability of less than 0.1 as significant rather than the conventional level of 0.05. This would inevitably increase the possibility of committing a 'type 1 error', i.e. rejecting the null hypothesis when in fact it is true, but as Lazenby (1990:470) suggests, this procedure may be worth considering when attempting to detect small effects within small samples.

For all the limitations surrounding the use of skeletal evidence, this study has nevertheless shown its value and potential as a tool for exploring sex and gender in past human populations. It indicates that there is ample scope for further research into a wider range of cemeteries and pathological indicators, which could yield a more comprehensive reconstruction. Ideally, subadults should be encompassed in this process as they may hold vital clues to the emergence of gender roles within society, and as such, research into possible methods of subadult sexing should be encouraged (Evison 1996; Mays 1998:38-42; Saunders 1992). The results of the comparative epidemiological analyses suggest that the approach could be successfully applied to other archaeological periods, including prehistory, especially if the integration with other forms of archaeological evidence is developed further. Large cemetery collections should be seized upon, right from the excavation stage, especially those that are representative of social groups for which there is currently a deficit, such as rural communities.

Palaeopathologists have sometimes voiced concern that human remains are an undervalued resource, and that the area of study is a marginalised aspect of archaeology, typically included at the back of site reports or relegated to microfiche. To illustrate this point, Larsen has quoted Noël Hume's woeful advice that 'burials on historical sites are much more trouble than they are worth . . . Unless the circumstances are very special, I would advise quickly covering them over and forgetting you ever saw them' (Noël Hume 1975:158,160 in Larsen 1997:1). Bush and Zvelebil (1991:5 in Larsen 1997:1-2) have also lamented, 'Unaware of the potential of human skeletal remains, many archaeologists view them as, at best, an irrelevance, and when encountered *in situ* as objects whose excavation is time-consuming and which somehow does not constitute "real" archaeology'. Similarly, Brothwell (1981:xi) has remarked 'Bones are still commonly a problem to archaeologists, even though the human skeleton offers a no less fruitful subject of inquiry than ceramics, metals, architecture or any other field of historical or prehistorical study'. The results of this study illustrate Brothwell's point. Fortunately there is evidence that the situation is changing. In recent years, a dramatic rise in osteoarchaeological publications has been reported (Larsen 1997:2), reflecting the subject's higher profile and a growing recognition that human remains hold important, direct evidence for interpreting the 'lifeways of past peoples' at both the individual and the population level (Larsen 1997:1). This includes the exploration of sex and gender (Grauer 1991; Grauer and Stuart-Macadam 1998; Roberts and Manchester 1995:1991).

The study of sex and gender in the past is itself a relatively new discipline. However, most research has so far depended on documentary, ethnographic, artefactual and iconographic evidence (Bennett 1987; Goldberg 1986; 1990; 1992; 1997; Hanawalt 1977; 1986; Walde and Willows 1991; Shahar 1983). Drawn from other cultures, geographical locations and different eras, ethnographic sources are not necessarily applicable to archaeological settings. Historical evidence is limited by its tendency to be anecdotal in nature, and by the fact that records were documented by the educated, and are therefore inclined to portray the male, upper class perspective. The application and interpretation of all these sources can also be heavily biased by the perspectives and motives of those who use them. The interpretation of skeletal evidence is by no means free from the latter source of bias, but the mortal remains of past human populations offers primary, empirical data which is directly representative of a wide spectrum of society, even if this cannot be defined on an individual basis. Skeletal evidence therefore holds advantages over other forms of evidence, and so can complement and compensate for some of their biases and shortfalls in order to provide a more rounded picture. Furthermore, it is available on a vast scale, and is still largely untapped.

A review of the literature indicates that Calvin Wells, a pioneer of palaeopathology, was the first with the foresight to recognise that human remains represent a rich resource from which aspects of sex and gender may be inferred. Writing in 1975, Wells derived the concept from his observation that females displayed an earlier mean age at death than males in a number of cemetery collections. Wells discussed a wide range of biological and social factors which could have been responsible, and illustrated how various pathological indicators might be used to elucidate the most likely cause. He endorsed the idea that childbearing was probably a contributory factor, but concluded that a more important explanation could originate in the presumed inferior social status of women, which directly resulted in premature mortality through inadequate nutrition coupled with overwork from domestic duties. Wells derived this theory from the premise that 'almost all the early historic peoples of northern Europe . . . were male-dominated societies: patrilineal, patriarchal, and patrilocal'(p.1246). This assumption led Wells to deduce that from childhood, males must have been held in higher esteem. To Wells, boys were the 'up-and-coming warriors and patriarchs'; whereas girls, Wells expresses mournfully, were the 'future drudges and mothers' (p.1248). In his characteristically colourful style, Wells goes on to surmise that 'the boys, as potential warriors and the favoured sex, were given more generous helpings than their sisters - who probably had to make do with the toughest, poorest cuts of meat and the leftovers of the meal, at least in times of food shortage'. Wells illustrates how this prejudice could have manifest in adulthood. As the presumed defenders, rulers, and providers, it was important that men were 'as fit as possible - not weak from present starvation or previous malnutrition. It is likely, therefore, that in adult life, when they could assert themselves and demand it, the men took the lion's share of the food' (p.1246). 'By the time kitchen duties gave adolescents or young women some command of the cooking pot, it was too late to make up the deficiencies of their early years. Pregnant or not, females remained somewhat undernourished, marasmic, susceptible to iron-deficiency anemia, less resistant to infection than the men, and lacking the reserves of vital energy which might have helped them toward a long life' (p.1248).

Today it is apparent that Wells' hypotheses were based on a series of assumptions and an inherent form of gender stereotyping that stems from the social climate of the time (Morgan 1985). They might even be construed as being sympathetic towards many of the sentiments of the 1970's feminist movement (Greer 1991). Wells should at least be credited for addressing the subject. However, since Wells postulated his ideas twenty-five years ago, there has been a hiatus in palaeopathological research which is specifically targeted at the exploration of sex and gender. This seems to have permitted such inherent assumptions to be carried forward unchallenged to the present day, whether expressed explicitly or implied latently (Grauer 1991; Manchester 1983:9; Mays

1998:42; Molleson 1989; 1993:181). The results of this study at least indicate that a re-evaluation is required. With future empirical investigation, the skeletal remains of males and females may well reveal that many of these assumptions should be overturned.

Appendix 1. Inventory of Excavated English Medieval Cemeteries

* Sites selected for inclusion into this study

Site	Sample size/sex ratio	Notes (contact names withheld; references not included in the bibliography)
Abingdon Vineyard*	590 (223 male, 171 female)	Material and skeletal recording sheets available for use at Leicester University.
Austin Friars, Leicester	26? Predominantly male	Stirland, A. 1981. The Human Bones. In Mellor, J.E. and Pearce, T. *The Austin Friars, Leicester.* CBA Research Report No.35, pp.168-169 and microfiche 1 of 2.
Barton-on-Humber	3000	St Mary's Church, Barton-on-Humber. Palaeopathology Association Newsletter No.10, April 1991. Five year research grant awarded to Bristol University. Large component Saxon.
Bedford		Large medieval site, never properly worked through. Personal communication to Leicester University from County Archaeologist in 1990.
Bermondsey Abbey		Late 11th and 12th centuries. Grimes, W.F. 1968. *The Excavation of Roman and Medieval London* pp.1, 101.
Beverley Dominican Priory	10	Dawes J.D. 1987. The Human Bones. In Armstrong, P. and Tomlinson, D (eds.) *Excavations at the Dominican Priory, Beverley 1960-83.* Hull: Humberside County Council, pp.26-29.
Bodmin, Cornwall	25 skeletons + parts	Material in good condition and available for examination; permission granted via personal communication between Cornwall Archaeological Unit and Leicester University in 1990.
Bordesley Abbey		Rahtz, P.A. and Hurst, S. 1976. Bordesley Abbey, First Report on Excavations 1969-73. *British Archaeological Reports* 23:116-117. Rahtz, P.A.R. *et al.* 1981. Bordesley Abbey, Hereford and Worcester. *West Midlands Archaeology.*

Site	Sample size/sex ratio	Notes (contact names withheld; references not included in the bibliography)
Carlisle Blackfriars	214 (93 male; 52 female)	13^{th}-16^{th} centuries. Good condition. Material at Carlisle Archaeological Unit, available for consultation at Carlisle or Leicester; permission granted via personal communication between Carlisle Archaeological Unit and Leicester University in 1990. Henderson, J. 1990. The Human Skeletal Remains. In McCarthy, M.R. *A Roman Anglian and Medieval site at Blackfriars Street, Carlisle.* Cumberland and Westmorland Antiquaries and Archaeological Society 4:330-355.
Carlisle Cathedral		Collection ranges in date from Anglo-Scandinavian period to Post-medieval, including about 40 pre-Norman skeletons. Material available for examination at Birmingham University; permission granted via personal communication between Carlisle Archaeological Unit and Leicester University in 1990, but material described as being due for reburial 'imminently'.
Castle Hill, Scarborough	>100	Mostly Anglo-Saxon, some medieval. Collection stored at the Natural History Museum.
Chelmsford Blackfriars	138 (68 male; 44 female)	Bayley, J.1975. *Chelmsford Dominican Priory, Human Bone Report.* Ancient Monuments Laboratory Report No. 1890. Unpublished report available from English Heritage.
Chester Blackfriars	34 (predominantly male)	West, B.A. 1990. The Human Bones. In Ward, S.W. (ed.) *Excavations at Chester. The Lesser Mediaeval Religious Houses. Sites Investigated 1964-83.* Grosvenor Museum Archaeological Excavation and Survey Reports No.6., pp.127-137.
Clementhorpe Nunnery, York	22 male; 57 female	Burials excavated from the Clementhorpe nunnery cemetery between 1976-1977 by the York Archaeological Trust. Burials date from the mid 12^{th} - mid 16^{th} centuries. Noted on p.71 of Dawes, J.D. and Magilton, J.R. 1980. *The Cemetery of St Helen-on-the-Walls, Aldwark.* The Archaeology of York Volume 12: The Medieval Cemeteries. York: York Archaeological Trust/Council for British Archaeology.
Clopton, Cambridgeshire		Reference on p.114 of Ward, A. and Anderson, T. 1990. Excavations at Rochester Cathedral. *Archaeologia Cantania* 108:91-145.

Site	Sample size/sex ratio	Notes (contact names withheld; references not included in the bibliography)
Coventry Carthusian Monastery	41 (majority male, at least 2 females and 4 children)	Burials date from 1385-1582. Skeletal material available for examination; permission granted via personal communication between Coventry Museums and Leicester University. Report in preparation (1990).
Fishergate, York*	402 (223 male; 86 female)	Monastic and lay burials. Permission given to examine the material at York Archaeological Trust, and to use the data recording sheets at the Environmental Archaeology Unit, York. Stroud, G. and Kemp, R.L. 1993. *Cemeteries of the Church and Priory of St Andrew, Fishergate.* The Archaeology of York Volume 12: The Medieval Cemeteries. York: York Archaeological Trust/Council for British Archaeology.
Gloucester Blackfriars	140 (predominantly male)	Report and skeletal material available for consultation at the Calvin Wells Laboratory, University of Bradford. Report authors: Wiggins, R., Boylston, A. and Roberts, C.
Guildford Blackfriars	117 (63 male; 10 female)	Henderson, J. 1984. The Human Remains. In Poulton, R. and Woods, H. Excavations on the site of the Dominican Friary at Guildford in 1974 and 1978. *Research Volume of the Surrey Archaeological Society* 9:58-71.
Guildhall, London	70	Excavated by the Museum of London Archaeology Service. Bateman, N.C.W. 1997. The early 11th to mid 12th century graveyard at Guildhall, City of London. In De Boe, G. and Verhaeghe, F. (eds.) *Death and Burial in Medieval Europe.* Papers of the Medieval Europe Brugge 1997 Conference Volume 2. Zellik: I.A.P.
Hartlepool Greyfriars	150 (66 male; 56 female)	Birkett, D.A. 1986. The Human Burials. In Daniels, R. The excavation of the church of the Franciscans, Hartlepool, Cleveland. *Archaeological Journal* 143:291-299.
Hereford Cathedral	>640	Collection currently with specialist in Bristol. Noted in Palaeopathology Association British Section News, No.16 April 1994.

Site	Sample size/sex ratio	Notes (contact names withheld; references not included in the bibliography)
Holy Trinity Priory, Aldgate.		Burials date from 11th-12th centuries. Schofield J. 1985 Excavations at Holy Trinity Priory, Aldgate, 1979. DUA Archive Report. Also, Riviere, S. 1985/86. Excavations at Mitre Street. *Popular Archaeology* 6 (14):37-41.
Hulton Abbey, Staffordshire	94	Burials date to the early 13th century. Part of the assemblage was excavated in the late 19th century, although most have been excavated post 1987. Klemperer, W.D. 1992. The study of burials at Hulton Abbey. *Death and Burial.* Proceedings of the Conference of Medieval Europe 1992, pre-printed papers volume 4:85-89. Wise, P.J. 1985. Hulton Abbey: A century of excavation. *Staffordshire Archaeological Studies* 2.
Hythe, Kent	112 male; 87 female	Material dates from 1100-1600. Noted on p.70 of Dawes, J.D. and Magilton, J.R. 1980. *The Cemetery of St Helen-on-the-Walls, Aldwark.* The Archaeology of York Volume 12: The Medieval Cemeteries. York: York Archaeological Trust/Council for British Archaeology.
Ipswich Blackfriars*	250 (146 male; 64 female)	Material and laboratory data available for consultation. Mays, S.A. *The Medieval Burials from the Blackfriars Friary, School Street, Ipswich, Suffolk.* Unpublished Ancient Monuments Laboratory Report 16/91.
Jarrow St Paul's	>200	Calvin Wells. Unpublished. Listed on Ancient Monuments Laboratory Database.
Jewbury, York*	469 (161 male; 150 female)	Jewish lay cemetery. Skeletal material reburied but permission given to use the skeletal recording sheets stored at York Archaeological Trust. Lilley, J.M., Stroud, G., Brothwell, D.R. and Williamson, M.H. 1994. *The Jewish Burial Ground and Jewbury.* The Archaeology of York Volume 12: The Medieval Cemeteries. York: York Archaeological Trust/Council for British Archaeology.
Magdelen Street, Norwich	>400	Collection currently being examined on behalf of the Norfolk Archaeological Unit. Material will be available for consultation when specialist examination is complete and the report published. Noted in Palaeopathology Association British Section News, No.16 April 1994.

Site	Sample size/sex ratio	Notes (contact names withheld; references not included in the bibliography)
Maldon Priory, Essex	10	Skeletal report available from the Calvin Wells Laboratory, University of Bradford. Authors: King, S. and Roberts, C.
Merton Priory, Surrey	35 (34 male; 1 female)	Waldron, H.A. 1985. DISH at Merton Priory: evidence for a 'new' occupational disease?. *British Medical Journal* 291:1762-1763.
Milton Keynes Village	97	Skeletal report available from the Calvin Wells Laboratory, University of Bradford. Authors: Ensor, S., Boylston, A. and Roberts, C.
North Elmham	167 (82 male; 76 female)	Burials predominantly Saxon in date. Reports at Bradford/Norwich Castle Museum. See also Wells, C. 1980. *East Anglian Archaeology* 9
Norwich Castle		Ayers, B. 1985. Excavations within the north-east bailey of Norwich Castle, 1979. *East Anglian Archaeology* 28:49-57.
Northampton Greyfriars	14	Griffiths, R. 1978. The Human Skeletal Remains. In Williams, J.H. Excavations at Greyfriars, Northampton. *Northampton Archaeology* 13:155-157.
Old Sarum	28	Collection at the Natural History Museum
Oxford Castle		Hassall T.G. (ed.) Excavations at Oxford Castle, 1965-73. *Oxonesia* 41:271-274.
Oxford Dominican Priory	68 (53 males; 10 females)	Harman, M. 1985. The human remains. In Lambrick, G. Further excavations on the second site of the Dominican Priory, Oxford. *Oxonesia* 50:188-190.
Oxford Greyfriars	48 (47 male; 1 female)	Harman, M. 1985. The human remains. In Lambrick, G. Further excavations on the second site of the Dominican Priory, Oxford. *Oxonesia* 50:188-190.
Pontefract Priory	72 male; 15 female	Pre-reformation medieval. Skeletons recovered during excavations on the site of Pontefract Priory by C.V.Bellamy. Noted on p.75 of Dawes, J.D. and Magilton, J.R. 1980. *The Cemetery of St Helen-on-the-Walls, Aldwark*. The Archaeology of York Volume 12: The Medieval Cemeteries. York: York Archaeological Trust/Council for British Archaeology.

Site	Sample size/sex ratio	Notes (contact names withheld; references not included in the bibliography)
Rochester Cathedral	61 (30 male; 19 female)	Lay cemetery, burials dating from the medieval period - 19th century. Ward, A. and Anderson, T. 1990. Excavations at Rochester Cathedral. *Archaeologia Cantania* 108:91-145.
Royal Mint, London	>100	Large plague cemetery. Collection currently with specialist. The material will be available for consultation when specialist examination is complete and report published.
Sandwell Priory, Staffordshire	73	Burials date to the 12th century. Hodder, M.A. 1991. Excavations at Sandwell Priory and Hall 1982-8. *Transactions of the South Staffordshire Archaeological and Historical Society* 31.
Scarborough	43 male; 17 female	Lay burials from Scarborough Castle. Material excavated in 1921-25 and examined 1943-46. Noted on p.75-76 of Dawes, J.D. and Magilton, J.R. 1980. *The Cemetery of St Helen-on-the-Walls, Aldwark.* The Archaeology of York Volume 12: The Medieval Cemeteries. York: York Archaeological Trust/Council for British Archaeology.
Scotch Street, Carlisle	>20	Poorly preserved. Excavated from an urban medieval cemetery. No plans to re-inter. Material available for examination at Birmingham University, or Carlisle Archaeological Unit when transferred for permanent storage; permission granted via personal communication between Carlisle Archaeological Unit and Leicester University in 1990.
Southampton Franciscan Friary	34	Burials date from 1233-1538. Condition variable, some incomplete. Material available for examination; permission granted via personal communication between Southampton Council and Leicester University in 1990.
St Brides, Fleet Street	>25	Burials vary in date from Saxon through post-medieval. Some skeletons housed at the Natural History Museum and available for examination. See also Grimes, W.F. 1968. The Excavation of Roman and Medieval London

Site	Sample size/sex ratio	Notes (contact names withheld; references not included in the bibliography)
St George's, Canterbury	269 (95 male; 97 female)	84 skeletons are of medieval date, 185 post-medieval. Laboratory findings and skeletal report supplied by Canterbury Archaeological Trust.
St Giles, Yorkshire	35	Permission given to examine the skeletons, stored at Bradford University, and to consult the skeletal recording sheets.
St Gregory's Priory, Canterbury	1339	11th-16th centuries. Monastic and parochial cemetery. Good condition. Examination of skeletons not yet complete (1995), but permission nevertheless granted by the Canterbury Archaeological Trust to examine the material and to use the laboratory findings available to date.
St Helen-on-the-Walls, York	338 male; 394 female	Skeletal data was originally stored on a mainframe computer and is no longer accessible. Dawes, J.D. and Magilton, J.R. 1980. *The Cemetery of St Helen-on-the-Walls, Aldwark, York*. The Archaeology of York Volume 12: The Medieval Cemeteries. York: York Archaeological Trust/Council for British Archaeology.
St James' Chichester	351 (predominantly male)	Burials excavated from Christchurch Leper Hospital, Dorset. Burials date from 12th-17th centuries. The interments were predominantly male until the 15th century when women were admitted to the hospital. Permission granted to examine the material and data recording sheets at the Calvin Wells Laboratory, University of Bradford.
St James' Priory, Bristol	20	Burials date to the 12th century. Material poorly preserved. Available for examination; permission granted via personal communication between Bristol Archaeological Unit and Leicester University in 1990.
St Johns, Colchester		Norman/early medieval in date. Crummy, P. 1981. Aspects of Anglo Saxon and Norman Colchester. *CBA Research Report* 39:45 and Fig.37.
St Margaret's Leper Hospital, High Wycombe		Farley, M. and Manchester K. 1989. The cemetery of the leper hospital of St Margaret, High Wycombe, Bucks. *Medieval Archaeology* 33:82-89.
St Marks, Lincoln	248 (32 male; 30 female)	Material in a fragmentary condition. Gilmour, B.J. and Stocker, D.A. 1986. Trust for Lincolnshire Archaeology, The Archaeology of Lincoln 13(1).

Site	Sample size/sex ratio	Notes (contact names withheld; references not included in the bibliography)
St Mary's Priory, Thetford		Wells, C. 1957. The Medieval Burials. In Robertson-Mackay, R. Recent Excavations at the Cluniac Priory of St Mary, Thetford, Norfolk. *Medieval Archaeology* 1:99-103 Appendix A.
St Mary's, Stow		Fairweather, P. 1984. Excavation Report: St Mary's Church, Stow, Lincolnshire. *Bulletin of the International Society for the Study of Church Monuments* 10:218.
St Nicholas Shambles, London*	234 (91 male; 74 female)	Lay cemetery. Burials date to 11th-12th centuries. Skeletal material and data recording sheets available for consultation. White, W.J. 1988. *Skeletal Remains from the Cemetery of St Nicholas Shambles, City of London.* London: Museum of London and the London and Middlesex Archaeological Society.
St Oswalds Priory, Gloucester		Material largely dates to 10th-11th centuries. Heighway, C.M. 1980. Excavations at Gloucester: 5th Interim Report, St Oswalds Priory 1977-8. *Antiquaries Journal* 40:217
St Paul-in-the-Bail, Lincolnshire		Skeletal report to be published as part of Trust for Lincolnshire Archaeology 'Archaeology of Lincoln Series'.
Stonar, Kent	126 (47 male; 27 female)	Urban lay cemetery. Eley, J. and Bayley, J. 1975. *Stonar, Kent, Human Bone Report.* Unpublished Ancient Monuments Laboratory Report No.1903.
Stratford Langthorne Abbey, London	94 (93 male; 1 female)	Stuart-Macadam, P. 1986. Health and Disease in the monks of Stratford Langthorne Abbey'. *Essex Journal* 21:67-71.
Trowbridge Castle		Wessex Archaeology Monograph 1993.
Westminster Abbey		Probably a small sample. Saxon/early medieval. *RCHM London I: Westminster Abbey* 1924: 81.
Wharram Percy*	685 (212 male; 129 female)	Rural, lay cemetery. Permission granted from the Ancient Monuments Laboratory, English Heritage, to use the material and laboratory data.

Site	Sample size/sex ratio	Notes (contact names withheld; references not included in the bibliography)
Winchester	900	Burials mainly Saxon but some of medieval date. Kjølbye-Biddle, B.K. 1975. A Cathedral Cemetery: Problems in Excavation and Interpretation'. *World Archaeology* 7:89-91.
York Minster	98 male: 74 female	The majority of burials are pre-12th century, and the remainder are dated to the 12th-14th centuries. Noted on p.71 of Dawes, J.D. and Magilton, J.R. 1980. *The Cemetery of St Helen-on-the-Walls, Aldwark.* The Archaeology of York Volume 12: The Medieval Cemeteries. York: York Archaeological Trust/Council for British Archaeology.

Appendix 2. Form for Recording Tooth Measurements

Cemetery: Sex:

Skeleton Number: Age:

Tooth Measurements/Dentition:

CH												
RL												
MD												
BL												
Tooth No.	16	15	14	13	12	11	21	22	23	24	25	26
	46	45	44	43	42	41	31	32	33	34	35	36
BL												
MD												
RL												
CH												

Key:

BL = Buccolingual crown diameter

MD = Mesiodistal crown diameter

CH = Crown Height

RL = Root length

Enter code if measurement omitted:

/ = Postmortem loss

X = Antemortem loss

A = Attrition

C = Congenitally absent

D = Damaged/Carious

I = Impacted

M = Malformed

S = Supernumerary

T = Transposed

Comments:

Appendix 3: Major Variables and Codes used to Compile the Database

Demography

Variable	Code	Value Label	
Site	1	Wharram Percy	
	2	Ipswich	
	3	Abingdon	
	4	St Nicholas	
	5	Fishergate 4	
	6	Fishergate 6	
	7	Jewbury	
Skelno	Enter skeleton number		
Sex	1	Male	
	2	Probable male	
	3	Female	
	4	Probable female	
Sex2	1	Male/probable male	(Automatic recode from
	2	Female/probable female	'sex' variable)
Ageyrs	Enter age estimate in years		
Agecat	1	*c.*0-3 years	
	2	*c.*3-13 years	
	3	*c.*13-18 years	
	4	*c.*18-25 years	
	5	*c.*25-35 years	
	6	*c.*35-45 years	
	7	*c.*>45 years	
	8	Immature	
	9	Adult	
Agecat2	1	*c.*18-35 years	(Automatic recode from
	2	*c.*>35 years	'agecat' variable)
Stature	Enter stature estimate		
Notes	String variable for any additional comments		

Inventory

Variable	Code	Value Label
Siteno, Skelno etc. necessary		Variables imported from demography file as
Each element is represented by a single variable, as indicated below	For long bones:	
	1	Entire long bone present
	2	Proximal end and shaft present
	3	Distal end and shaft present
	4	Proximal and distal ends only present
	5	Proximal end only present
	6	Distal end only present
	7	Shaft only present
	For individual vertebrae:	
	1	Complete
	2	Partial
	3	Body only
	4	Arch only
	For all other elements:	
	1	Bone represented
	.	Leave cell blank ('system missing') if bone absent
Notes	String variable for any additional comments	

<u>Examples of the variables used in the inventory file for the various cemeteries (adopt/add/combine/transform as necessary):</u>

Skull	R Clavicle	L Femur	R Hip
Frontal	L Clavicle	R Patella	L Hip
R Parietal	R Scapula	L Patella	R Knee
L Parietal	L Scapula	R Tibia	L Knee
Occipital	R Humerus	L Tibia	R Ankle
R Temporal	L Humerus	R Fibula	L Ankle
L Temporal	R Radius	L Fibula	R Foot
Sphenoid	L Radius	R Calcaneus	L Foot
R Zygomatic	R Ulna	L Calcaneus	R Acetabulum
L Zygomatic	L Ulna	R Talus	L Acetabulum
R Maxilla	R Scaphoid	L Talus	Cervical
L Maxilla	L Scaphoid	R Cuboid	Thoracic
Facial Bones	R Lunate	L Cuboid	Lumbar
Mandible	L Lunate	R Navicular	Sacrum
Hyoid	R Triquetral	L Navicular	Spine
Atlas	L Triquetral	R 1st Cuneiform	R Carpals
Axis	R Pisiform	L 1st Cuneiform	L Carpals
C3	L Pisiform	R 2nd Cuneiform	R Metacarpals
C4	R Trapezium	L 2nd Cuneiform	L Metacarpals
C5	L Trapezium	R 3rd Cuneiform	R Tarsals
C6	R Trapezoid	L 3rd Cuneiform	L Tarsals
C7	L Trapezoid	R 1st Metatarsal	R Metatarsals
T1	R Capitate	L 1st Metatarsal	L Metatarsals
T2	L Capitate	R 2nd Metatarsal	. . . / add further codes as necessary
T3	R Hamate	L 2nd Metatarsal	
T4	L Hamate	R 3rd Metatarsal	
T5	R 1st metacarpal	L 3rd Metatarsal	
T6	L 1st metacarpal	R 4th Metatarsal	
T7	R 2nd metacarpal	L 4th Metatarsal	
T8	L 2nd metacarpal	R 5th Metatarsal	
T9	R 3rd metacarpal	L 5th Metatarsal	
T10	L 3rd Metacarpal	Foot phalanges	
T11	R 4th metacarpal	Sesamoids	
T12	L 4th metacarpal	R Sternoclavicular	
(T13)	R 5th metacarpal	L Sternoclavicular	
L1	L 5th metacarpal	R Acromioclavicular	
L2	Hand phalanges	L Acromioclavicular	
L3	Sesamoids	R Shoulder	
L4	R Ilium	L Shoulder	
L5	L Ilium	R Elbow	
(L6)	R Ischium	L Elbow	
Sacrum	L Ischium	R Wrist	
Ribs	R Pubis	L Wrist	
Manubrium	L Pubis	R Hand	
Sternum	R Femur	L Hand	

Anaemia

Variable	Code	Value Label
Siteno, Skelno etc.		Variables imported from demography file as necessary
Orbit	.	Leave cell blank ('System missing') if orbit not present
(Abingdon/	0	Normal bone surface
Fishergate)	1	Capillary-like impressions on the bone
	2	Scattered fine foramina
	3	Large and small scattered foramina
	4	Foramina linked into trabecular structure
	5	Outgrowth in trabecular form from outer table surface
	6	Remodelled
Orbit	.	Leave blank if orbit not present
(Ipswich/	1	Porotic
Wharram)	2	Cribrotic
	3	Trabecular
Vault	0	Normal bone surface
	1	Mild
	2	Moderate
	3	Severe
Notes	String variable for any additional comments	

Enamel Hypoplasia

Variable	Code	Value Label
Siteno, Skelno etc.		Variables imported from demography file as necessary
Presence	0	Enamel hypoplasia absent in dentition
	1	Enamel hypoplasia present in dentition
Nolines	Enter the number of lines present on the mandibular canine	
Notes	String variable for any additional comments	

Infectious Disease

Variable	Code	Value Label
Siteno, Skelno etc.		Variables imported from demography file as necessary
Infection	1	Periostitis
	2	Osteomyelitis
	3	Periostitis resulting from systemic infection
	4	Periostitis resulting from trauma
	5	Osteomyelitis resulting from trauma
	. . . /add further codes as necessary	
Bone affected	1	Skull
	2	Frontal
	3	R Parietal
	4	L Parietal
	5	Occipital
	6	R Temporal
	7	L Temporal
	8	Facial bones
	9	Maxilla
	10	Mandible
	11	Spine
	12	Ribs
	13	Sternum
	14	Scapula
	15	Pelvis
	16	R Clavicle
	17	L Clavicle
	18	R Humerus
	19	L Humerus
	20	R Radius
	21	L Radius
	22	R Ulna
	23	L Ulna
	24	R Femur
	25	L Femur
	26	R Tibia
	27	L Tibia
	28	R Fibula
	. . . /add further codes as necessary	
Surface	1	Inferior
	2	Superior
	3	Medial
	4	Lateral
	. . . / add further codes as necessary	
Notes	String variable for any additional comments	

Trauma

Variable	Code	Value Label
Siteno. Skelno etc.		Variables imported from demography file as necessary
Trauma	1	Healed fracture
	2	Unhealed fracture
	3	Fracture. healing incomplete
	4	Crush fracture
	5	Parry fracture
	6	Depressed fracture
	7	Stress fracture
	8	Fracture with secondary infection
	9	Fracture with associated osteoarthritis
	10	Dislocation
	11	Spondylolysis
	12	Spondylolisthesis
	13	Blade injury
	14	Projectile injury
	. . . / add further codes as necessary	
Bone	Enter bone affected using the same codes compiled for infectious disease	
Location	1	Proximal
	2	Distal
	3	Shaft
	. . . / add further codes as necessary	
Notes	String variable for any additional comments	

Joint Disease

Variable	Code	Value Label
Siteno. Skelno etc.		Variables imported from demography file as necessary
Joint disease	1	Osteoarthritis
	2	Minor osteoarthritic lipping
	3	Eburnation
	4	Ankylosis
	5	Osteoarthritis resulting from trauma
	6	Osteophytosis
	7	Schmorls node
	8	Ankylosing spondylitis
	9	DISH
	10	Kyphosis
	11	Scoliosis
	. . . / add further codes as necessary	
Joint affected	1	R Sternoclavicular
	2	L Sternoclavicular
	3	R Acromioclavicular
	4	L Acromioclavicular
	5	R Shoulder
	6	L Shoulder
	7	R Elbow
	8	L Elbow
	9	R Wrist
	10	L Wrist
	11	R Hand
	12	L Hand
	13	R Hip
	14	L Hip
	15	R Knee
	16	L Knee
	17	R Ankle
	18	L Ankle
	19	R Foot
	20	L Foot
	21	R TMJ
	22	L TMJ
	23	R Acetabulum
	24	L Acetabulum
	25	Spine
	26	Cervical
	27	Thoracic
	28	Lumbar
	29	Sacrum

Joint disease codes (contd.)

Variable	Code	Value Label
	30	R Carpals
	31	L Carpals
	32	R Metacarpals
	33	L Metacarpals
	34	R Tarsals
	35	L Tarsals
	36	R Metatarsals
	37	L Metatarsals
	38	R Humerus
	39	L Humerus
	40	R Radius
	41	L Radius
	42	R Ulna
	43	L Ulna
	44	R Tibia
	45	L Tibia
	46	R Fibula
	47	L Fibula
	48	R Humerus
	. . . / add further codes as necessary	
Location	1	Superior
	2	Inferior
	3	Proximal
	4	Distal
	. . . / add further codes as necessary	
Notes	String variable for any additional comments	

Dental Disease

Variable	Variable Label	Code	Value label
Siteno. Skelno etc		Variables imported from demography file as necessary	
MAXR_M3	Maxillary right third molar	Enter row of coding to record dentition for each skeleton.	
MAXR_M2	Maxillary right second molar	entering the appropriate code for each tooth variable:	
MAXR_M1	Maxillary right first molar	1	Tooth present
MAXR_PM2	Maxillary right second premolar	2	Ante-mortem loss
MAXR_PM1	Maxillary right first premolar	3	Post-mortem loss
MAXR_C	Maxillary right canine	4	Congenitally absent
MAXR_I2	Maxillary right second incisor	5	Unerupted
MAXR_I1	Maxillary right first incisor	6	Partially erupted
MAXL_I1	Maxillary left first incisor	7	Impacted
MAXL_I2	Maxillary left second incisor	8	Root only
MAXL_C	Maxillary left canine	9	Retained primary
MAXL_PM1	Maxillary left first premolar	10	Supernumerary
MAXL_PM2	Maxillary left second premolar	.../ add further codes as necessary	
MAXL_M1	Maxillary left first molar		
MAXL_M2	Maxillary left second molar	Enter second row of coding to record caries:	
MAXL_M3	Maxillary left third molar	1	Tooth carious
MANDR_M3	Mandibular right third molar	.../add further codes as necessary, such as to record	
MANDR_M2	Mandibular right second molar	the location and size of a cavity	
MANDR_M1	Mandibular right first molar		
MANDR_PM2	Mandibular right second premolar	Enter third row of coding to record presence of alveolar bone:	
MANDR_PM1	Mandibular right first premolar	.	Leave cell blank ('system missing') if bone absent
MANDR_C	Mandibular right canine	1	Alveolar bone present
MANDR_I2	Mandibular right second incisor		
MANDR_I1	Mandibular right first incisor	Enter fourth row of coding to record abscesses:	
MANDL_I1	Mandibular left first incisor	1	Abscess cavity

Dental disease codes (contd.)

Variable	Variable Label	Code	Value label
MANDL_I2	Mandibular left second incisor	2	Unhealed abscess cavity
MANDL_C	Mandibular left canine	.../add further codes/rows of coding as necessary to record	
MANDL_PM1	Mandibular left first premolar	further pathology	
MANDL_PM2	Mandibular left second premolar		
MANDL_M1	Mandibular left first molar		
MANDL_M2	Mandibular left second molar		
MANDL_M3	Mandibular left third molar		
DMAXR_M2	Deciduous maxillary right second molar		
DMAXR_M1	Deciduous maxillary right first molar		
DMAXR_C	Deciduous maxillary right canine		
DMAXR_I2	Deciduous maxillary right second incisor		
DMAXR_I1	Deciduous maxillary right first incisor		
DMAXL_I1	Deciduous maxillary left first incisor		
DMAXL_I2	Deciduous maxillary left second incisor		
DMAXL_C	Deciduous maxillary left canine		
DMAXL_M1	Deciduous maxillary left first molar		
DMAXL_M2	Deciduous maxillary left second molar		
DMANDR_M2	Deciduous mandibular right second molar		
DMANDR_M1	Deciduous mandibular right first molar		
DMANDR_C	Deciduous mandibular right canine		
DMANDR_I2	Deciduous mandibular right second incisor		
DMANDR_I1	Deciduous mandibular right first incisor		
DMANDL_I1	Deciduous mandibular left first incisor		
DMANDL_I2	Deciduous mandibular left second incisor		
DMANDL_C	Deciduous mandibular left canine		
DMANDL_M1	Deciduous mandibular left first molar		
DMANDL_M2	Deciduous mandibular left second molar		
Notes	String variable for any additional comments		

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