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Anthropometric Variation and Health: A Biocultural Model of Human Growth

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ABSTRACT

This review is a synthesis of the many strands of evidence for a biocultural model of human growth. The model allows us to better understand the causes of variation and plasticity in human growth and development. The model helps us to identify and ameliorate factors that impair health, growth, and development. The biocultural perspective focuses on the recurring interaction between the biology of human development and the sociocultural environment. Not only does the latter influence the former, but human developmental biology modifies social and cultural processes as well. There are two essential messages of this synthesis. First, the biocultural nature of human growth and development is best understood via a life history perspective. The second essential message is that neither biology nor culture has primacy in human development. Rather, both work simultaneously and subtly during all stages of life to produce human phenotypic variability. That variability leads to individual and population differences in susceptibility to environmental disease. To illustrate these points, examples are given of the growth of ethnic Maya children and juveniles living in Guatemala and the United States, and Cape Verde immigrants living in Lisbon, Portugal.

Key Words: growth, development, immigrants, health status, Guatemala Maya, Cape Verde, Portugal, biocultural model.

INTRODUCTION

There is a persistent tendency in both the popular media and some branches of the scientific community to find the causes of human health and disease in either the biology of people or in the environments in which we live. This Pygmalion dichotomy has ancient roots in Western culture, and it is still expressed in the news about the Human Genome Project and stem cell research. Some pundits find comfort in an unproductive debate about the importance of "genes versus the

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environment" as the cause for ailments such as obesity, Alzheimer's disease, and breast cancer. However, those workers taking a more holistic approach, an approach that we call biocultural, are carrying out the most productive research. This review is a synthesis of the many strands of evidence for a biocultural model of human growth and health. The model allows us to better understand the causes of variation and plasticity in human growth and development. The model also helps us to identify and ameliorate factors that impair healthy growth and development.

The biocultural perspective focuses on the recurring interaction between the biology of human development and the sociocultural environment. Not only does the latter influence the former, but human developmental biology modifies social and cultural processes as well. There are two essential messages of this synthesis. First, the biocultural nature of human growth and development is best understood via a life history perspective. The second essential message is that neither biology nor culture has primacy in human development. Rather, both work simultaneously and subtly during all stages of life to produce human phenotypic variability. That variability leads to individual and population differences in susceptibility to environmental disease. To illustrate these points, three examples of human growth and development are given here. The first is a study of ethnic Maya children and juveniles living in Guatemala and the United States. The second is a study of the population living in a small village on the Caribbean island of Dominica. The third is a study of the juvenile and adolescent offspring of Cape Verde immigrants living in Lisbon, Portugal.

HUMAN LIFE HISTORY

The study of the evolution and function of life stages is called Life History Theory. Life history may be defined as the strategy an organism uses to allocate its energy toward growth, maintenance, reproduction, raising offspring to independence, and avoiding death. For a mammal, it is the strategy of when to be born, when to be weaned, how many and what type of prereproductive stages of development to pass through, when to reproduce, and when to die. Different species of living things have greatly different life history strategies, and understanding what shapes these histories is one of the most active areas of research in whole-organism biology.

One way to view human life history is from curves of growth. The classic curves of normal human growth are shown in Figure 1. The human "distance" curve, showing the amount of growth in height from birth to age 22 years, is labeled on the right side of the graph. This curve has three phases: an initial phase of rapid growth during infancy, a second prolonged phase of moderate and near-constant growth during the childhood and juvenile stages, and a third phase with the adolescent growth spurt.

These phases are more clearly seen in the velocity curves. The increments of the velocity curve, which represents the rate of growth in height during any year, is

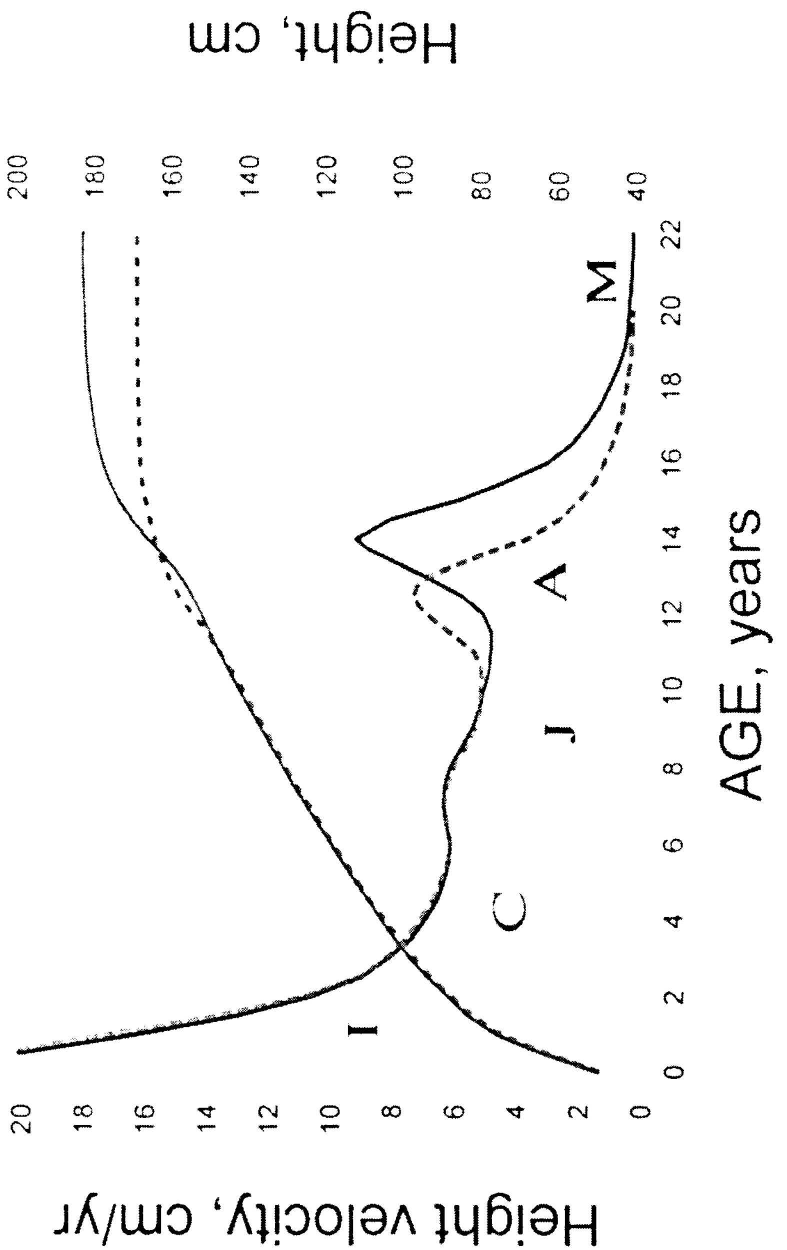

Figure 1. Distance and velocity curves of growth for human beings. The stages of post-natal growth are abbreviated as follows: I = infancy, C = childhood, J = juvenile, A = adolescence, M= mature adult.[1]

labeled on the left side. Changes in the velocity of growth may be divided into five life history stages of human development. Below the velocity curve are symbols indicating the average duration of each life history stage. These are (1) infancy; (2) childhood; (3) juvenile; (4) adolescent; and (5) adult stages. In addition to changes in growth rate, each stage may also be defined by characteristics of the dentition, by changes related to methods of feeding, by physical and mental competencies, and by maturation of the reproductive system and sexual behavior. A summary of criteria for the major stages of the human life cycle may be found in Table 1. At this point our focus is only on changes in the rate of growth.

The most rapid velocity of growth of any of the postnatal stages characterizes infancy, a stage that begins at birth and lasts until about age three years, which corresponds to the lactation period for humans. The infant's rate of growth is also characterized by a steep decline in velocity, a deceleration. The infant's curve of growth, rapid velocity, and deceleration is a continuation of the fetal pattern. During the fetal period the rate of growth in length reaches a peak in the second trimester of gestation, and then begins a deceleration that lasts until childhood. The childhood stage follows infancy, encompassing the ages of about 3 to 7 years. The growth deceleration of infancy ends at the beginning of childhood, and the rate of growth levels off at about 5 cm per year. This slower and steady rate of human growth maintains a relatively small-sized body during the childhood years. This leveling-off in growth rate is unusual for mammals, as virtually all other species continue a pattern of deceleration after infancy. Typical mammalian growth velocities are presented for the rat in Figure 2 and the cow in Figure 3. Note that both species have but a single peak in rate of growth, which occurs at about the time of weaning (the cessation of lactation). Following weaning, growth rate decelerates rapidly, and the infancy stage merges into puberty and the adult reproductive stage almost seamlessly (Ref. 1 provides a review of mammalian comparative growth).

Another feature of the childhood phase of growth is the modest acceleration in growth velocity at about 6 to 8 years, called the mid-growth spurt (shown in Figure 1). Some studies note the presence of the mid-growth spurt in the velocity curve of boys, but not girls. Others find that up to two-thirds of boys and girls have mid-growth spurts. The mid-growth spurt is linked with an endocrine event called adrenarche, which results in a progressive increase in the secretion of adrenal androgen hormones. Adrenal androgens may produce the mid-growth spurt in height, a transient acceleration of bone maturation, the appearance of a few axillary and pubic hairs, and seem to regulate the development of body fatness and fat distribution.[2,3] We draw attention to adrenarche because some researchers use the appearance of a few pubic hairs at the time of adrenarche to suggest that environmental pollutants may be lowering the age at puberty. Much research, from clinical medicine to anthropological fieldwork, shows that there is virtually no connection between adrenarche and puberty (also called gonadarche), as each are independently controlled events.[4] One role of adrenarche is that it signals the end of the childhood stage of growth.

Table 1. Stages in the human life cycle.

Stage	Growth Events/Duration(approximate or average)
Prenatal Life	
Fertilization	
First trimester	Fertilization to twelfth week: Embryogenesis
Second trimester	Fourth through sixth lunar month: Rapid growth in length
Third trimester	Seventh lunar month to birth: Rapid growth in weight and organ maturation
Birth	Transition to extra-uterine life
Postnatal Life	
Neonatal period	Birth to 28 days: Extrauterine adaptation, most rapid rate of post-natal growth and maturation
Infancy	Second month to end of lactation, usually by age 36: Rapid growth velocity steep deceleration in velocity with time, feeding by lactation, deciduous tooth eruption, many developmental milestones in physiology, behavior, and cognition
Childhood	Third to seventh year: Moderate growth rate, dependency for and feeding, mid-growth spurt, eruption of first permanent molar and incisor, cessation of brain growth by end of stage
Juvenile	Ages seven to ten for girls, or 12 for boys: Slower growth rate, most permanent teeth erupt, capable of self-feeding, cognitive transition leading to learning of economic and social skills
Puberty	Occurs at end of juvenile stage and is an event of short duration (days or a few weeks): Reactivation of central nervous system mechanism for sexual development, dramatic increase in secretion of sex hormones

Table 1. (continued)

Adolescence Five to eight years after the onset of puberty: Adolescent growth spurt in height and weight, permanent tooth eruption virtually complete, development of secondary sexual characteristics, sociosexual maturation, intensification of interest and practice adult social, economic, and sexual activities

Adulthood

Prime and transition From 20 years of age to end of child-bearing years: homeostasis in physiology, behavior, and cognition, menopause for women by age 50 years

Old age and senescence From end of child-bearing years to death: decline in the function of many body tissues or systems

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The human juvenile stage begins at about age 7 years. The juvenile stage is characterized by the slowest rate of growth since birth. In girls, the juvenile period ends, on average, at about the age of 10, 2 years before it usually ends in boys, the difference reflecting the earlier onset of adolescence in girls. Human adolescence is the stage of life when social and sexual maturation takes place. In terms of growth, both boys and girls experience a rapid acceleration in the growth velocity of virtually all of the bones of the body. This is called the adolescent growth spurt. Adolescence ends and early adulthood begins with the completion of the growth spurt and the attainment of adult stature. Height growth stops when the long bones of the skeleton (e.g., the femur, tibia, humerus) lose their ability to increase in length. Adulthood also signals the achievement of full reproductive maturity, meaning that men and women have the physical capacity, the socioeconomic skills, and the cognitive and emotional maturity required for successful reproduction.

LIFE HISTORY — THE LINK BETWEEN GROWTH AND HEALTH

All mammals have the infancy and adult stages of life history. Social mammals, such as wolves, lions, elephants, primates, and some cetaceans (whales and dolphins), have an infant, juvenile, and adult stage. The human species has these three stages and adds childhood and adolescence. It seems that during human evolution, perhaps about two million years ago, our ancestors added a childhood stage to the life cycle. Within the last 100,000 years our ancestors added a distinct adolescent stage to the life cycle.[1,4] The additional life history stages prolong the total time from

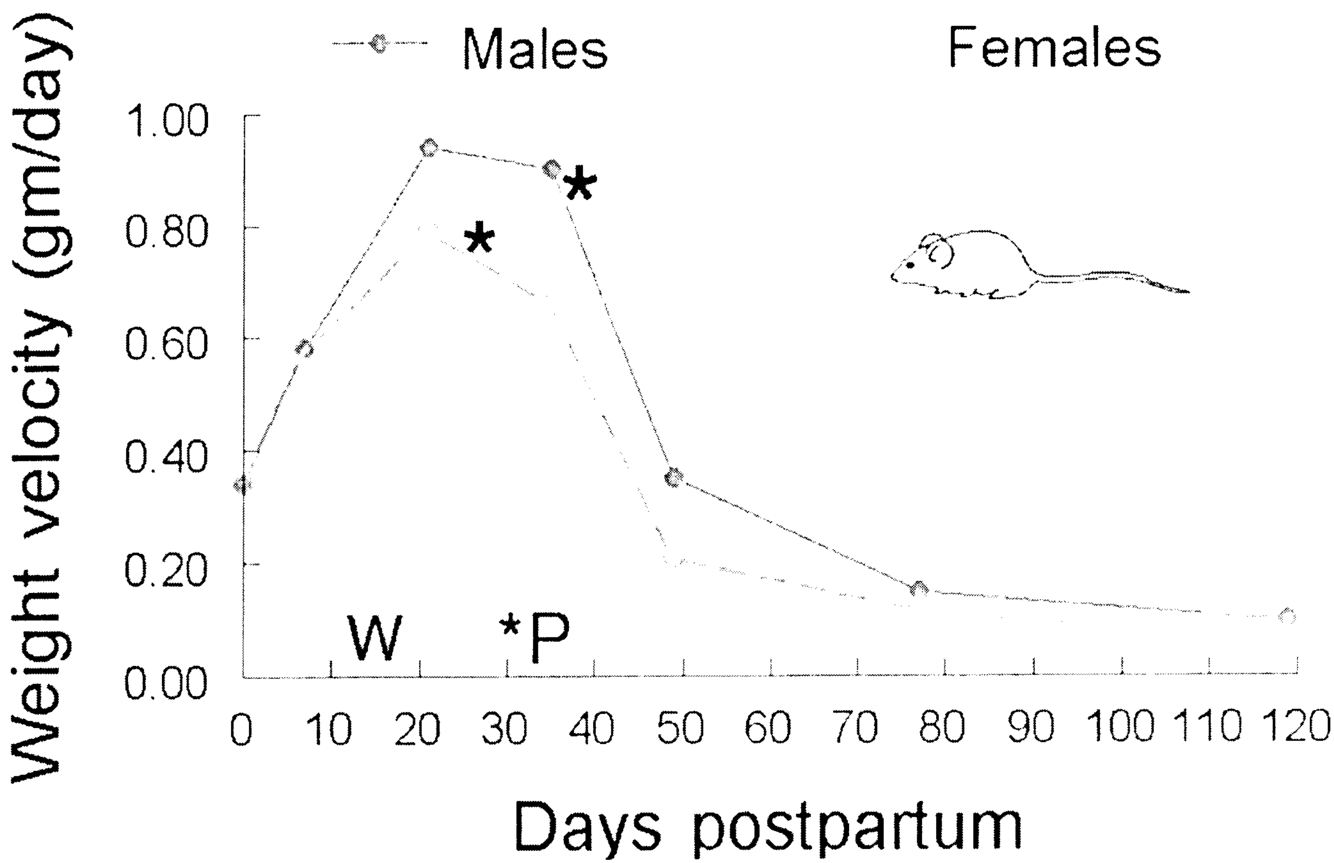

Figure 2. Velocity curves for weight growth in the mouse. Weaning (W) takes place between days 15 and 20. In both sexes puberty (P), meaning vaginal opening for females or spermatocytes in testes of males, occurs just after weaning and maximal growth rate (redrawn from data reported in Ref. 24).

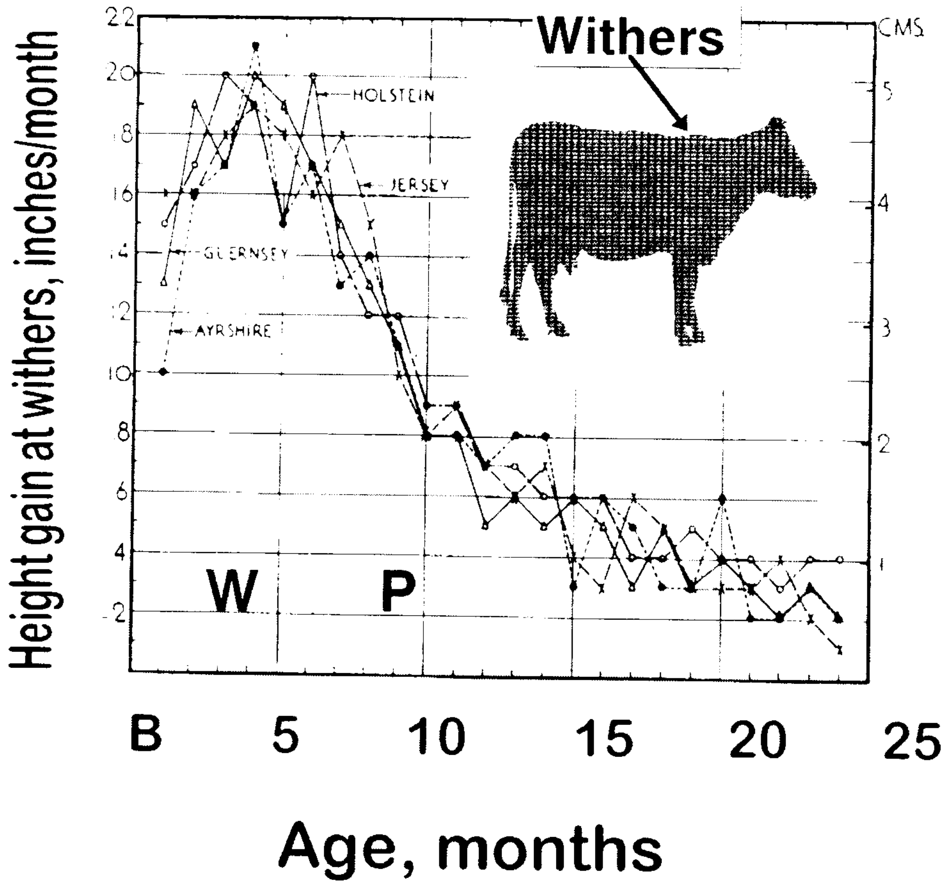

Figure 3. Monthly gains in height at the withers for the several varieties of cows. The data are from Ref. 25 who reports monthly values for height as the mean value for many animals (sample size varies from 67 to 239 at each age) measured monthly from birth to 24 months.

birth to adulthood. The additional time allows for both advantages and risks to human health.

The advantages accrue to those infants, children, juveniles, and adolescents who grow up under favorable environmental condition. Appropriate nutrition, medical care, psychosocial support, education, economic investment, and protection from hazards is required for healthy development. This holds for all human societies, from the traditional non-Western cultures, to the industrialized capitalistic or socialistic nations, to the emerging post-industrial, electronic, transglobal society. The risks to health impair the growth and development of those who suffer from inadequate nutrition, poor or nonexistent medical care, lack of formal and informal education, economic neglect, and exposure to hazards.

Growth and Health

For more than 25 years, one aspect of the senior author's research has focused on the consequences for human growth and development when children, juveniles, and adolescents growup in less than favorable environments. We report here on a recent analysis of the growth of Guatemala Maya children and juveniles living in Guatemala and the in the United States. This research focuses on the developmental plasticity of height, weight, and body proportions of these Maya.

It is well known that environmental factors are powerful determinants of body size and body proportion. Some existing research shows that under favorable environmental conditions people grow taller, and that much of the increase in stature is due to proportionately longer legs. Taller, longer-legged people tend to be healthier and more productive.[1] Body weight, especially body fatness, is another indicator of health. Young people who are wasted (low weight for height) and young people who are overweight or obese tend to have more health problems. Undesirable body weight is not only linked with poor health during the years of growth, but also in adulthood.

Our initial research, conducted in 1992, showed that Maya children living in the United States are significantly taller and heavier than Maya children living in Guatemala.[5] We did not measure body proportions in that study, but we hypothesized that an increase in relative leg length accompanies the increase in stature. We base this hypothesis on growth patterns that occur during different stages of human life history. As illustrated in Figure 4, the growth of the human body proceeds in a cephalo-caudal gradient. After birth, the growth of the legs proceeds at a faster rate than the growth of the head and trunk. Insults to healthy growth during the infant and childhood stage of life history will have their strongest effect on growth of the legs. The Maya living in Guatemala are known to suffer from chronic undernutrition and disease during early postnatal life. Hence, their short stature should be due in large part to stunting of the legs. In the United States the environment for growth is better, and we predict that the legs of Maya immigrant children and juveniles will be longer.

In our initial research we did not analyze body fatness in detail. In the new research reported here we do so here using the body mass index. We believe that the analysis of fatness is important because the childhood and juveniles stages of life are critical periods for the patterning of body fatness.[6] These fat patterns may persist into adulthood and contribute to several diseases.

MAYA IN THE UNITED STATES

A new study of the growth of the children of Maya immigrants began in 1999. We measured the height, weight, and sitting height of 360 Maya children ages 6 to 12 years old, living in south central Los Angeles in February 1999, and Indiantown, Florida, in March 2000. With these data we computed the sitting height ratio [(sitting height/height) * 100] and body mass index (body weight, kg/height, kg^2). We compared these newer data with our Maya sample from 1992 children living in

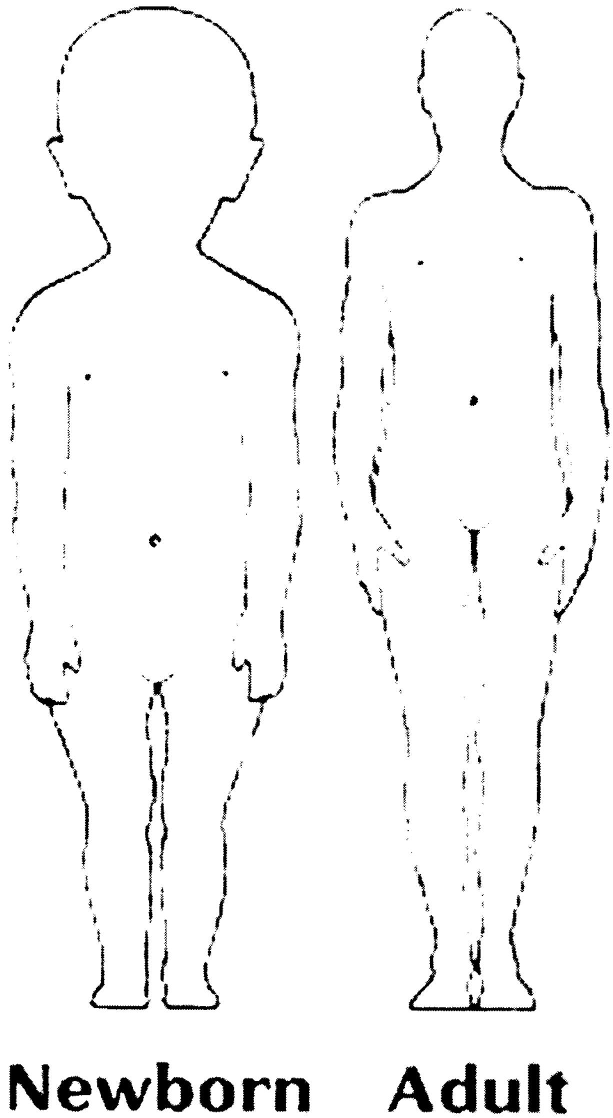

Figure 4. Diagrams illustrating the changes in body proportions of human beings that occur during prenatal and postnatal growth. Depicted on the left is a newborn and on the right is an adult. Human body segments (head, trunk, arms, legs) grow at different rates and mature, generally, from a head to foot direction.

USA (n=171) and a sample of Maya schoolchildren living in rural Guatemala measured in 1998 to 1999 (n=1297). Luis Rios of the Universidad Autonoma de Madrid kindly supplied the Guatemalan data. Informed consent was obtained prior to measurement for human subjects in all samples.

Analysis

Mean values for height, weight, BMI, and sitting height ratio for each sample are shown in Figures 5 to 8. Anthropometric reference data from the NHANES I and II surveys of the United States[7] are used as a baseline for comparison in each graph. Analysis of variance (ANOVA) was used to evaluate differences between samples. After adjusting for the effect of age and sex, our results show that the Maya children of both the 1992 (Maya-USA 1992) and the 1999 and 2000 (Maya-USA 2000) samples are significantly taller (Figure 4) and heavier (Figure 5) than Maya children living in Guatemala (Maya-Guat). The Maya living in the USA also have greater BMI values (Figure 6) and smaller sitting height ratios (Figure 7). All differences are significant at p<.01. Higher BMI values usually indicate greater fatness. A smaller sitting height ratio generally indicates a child with relatively longer legs.

The Maya-USA 2000 sample is significantly taller, heavier, and has higher BMI than the Maya-USA 1992 sample. Sitting height was not measured in 1992. Com-

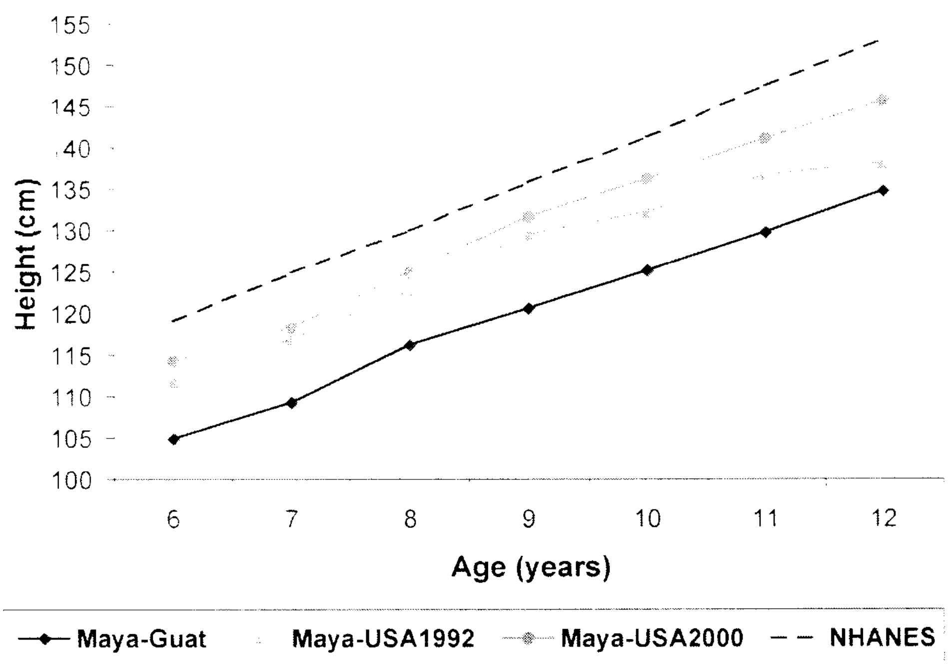

Figure 5. Mean height of Maya samples compared with the median height of the NHANES reference data.

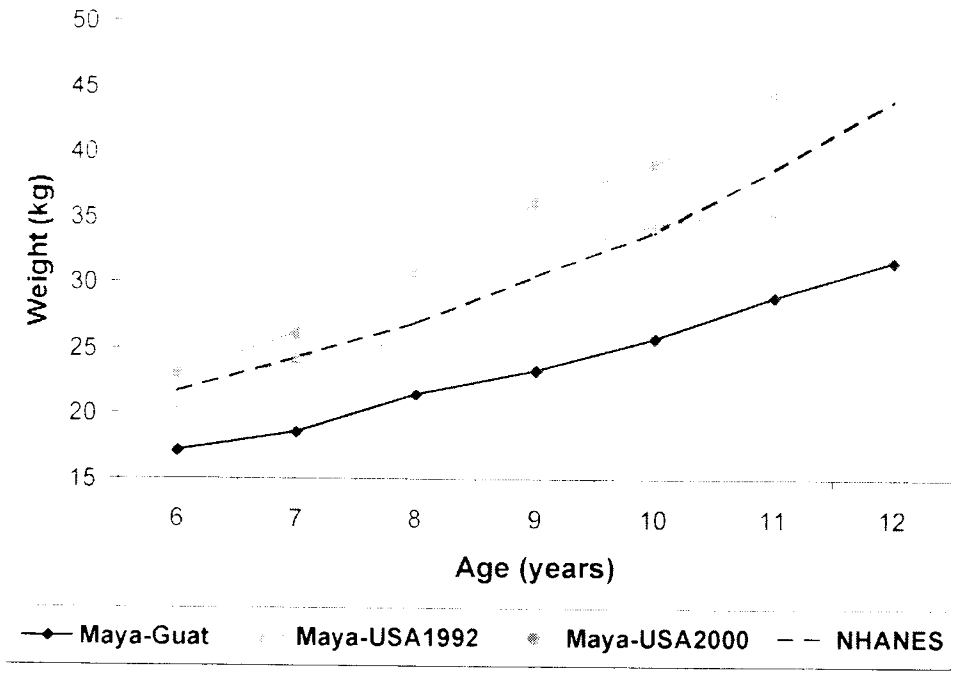

Figure 6. Mean weight of Maya samples compared with median weight of NHANES reference data.

pared with the NHANES references, all of Maya are shorter and have higher sitting height ratios, that is, relatively shorter legs. The Maya-USA 1992 sample is equal in body weight to the reference, but the Maya-USA 2000 is above the reference. Both samples are above the reference for body mass index.

Our findings add further support to the literature of developmental plasticity in body proportions. The results indicate that between 1992 and the present there is a clear, and positive, trend in growth of Maya children living in United States. The reasons for this trend are likely due to improvements in the environment for growth. All Maya in the USA have access to clean drinking water, health services, and education that may not exist in Guatemala. The Florida Maya children participate in school breakfast and lunch programs. These health and nutritional changes are known to result in greater stature. Our findings support the hypothesis that the increase in stature is due mostly to relatively longer legs.

Both the body weight and the body mass index of Maya children in USA have increased at a faster pace than their height. The disharmony in growth results in what Martorell et al.[8] call the "short and plump syndrome." The disharmony is seen most clearly in the BMI data. The Maya-USA1992 and Maya-USA2000 samples are well above the reference data. Indeed, the 50th percentile of the Maya-USA2000 sample equals the 85th percentile of the NHANES reference data. This indicates a

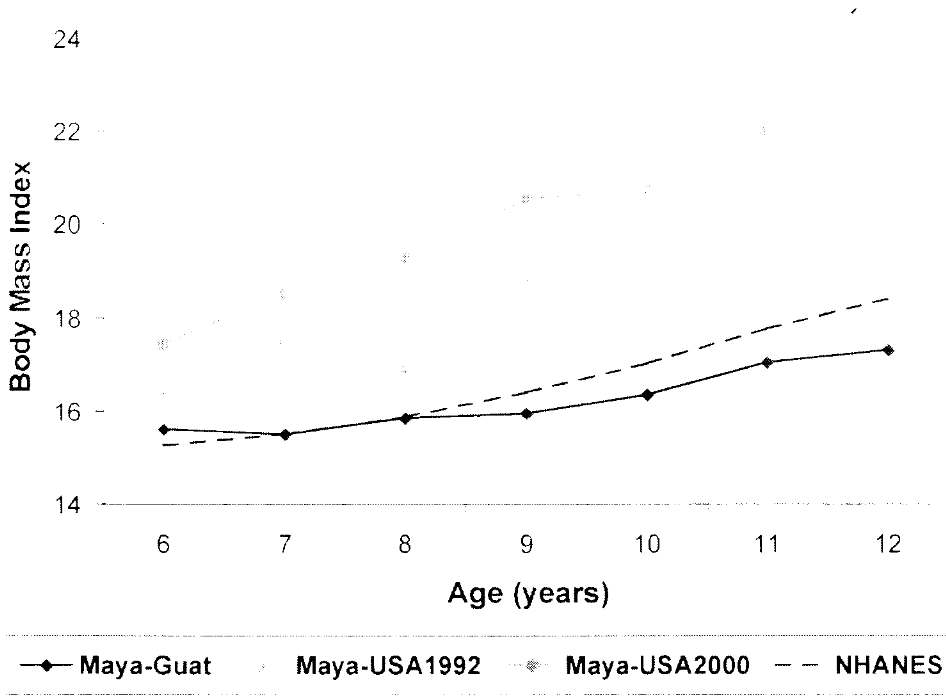

Figure 7. Mean body mass index (BMI) of Maya samples compared with median BMI of NHANES reference sample.

trend to childhood obesity. Similar risk for obesity has been observed in other samples of second-generation immigrant children to the USA from Latin America and elsewhere.[9] The disharmony between weight and height may predispose these children to greater risks for obesity-related disease.

We find that the length of exposure to the environment of the United States influences these effects on leg length and fatness. Those individuals who were born in the United States or migrated to the U.S. at earlier ages are both longer legged and have higher BMI than those migrating at later ages.

The size and shape of the human body are often used as indicators of health status. In addition, the size and shape of the human body determine many functional capabilities, including physical performance capabilities. Poor health can obviously impair a young person's successful transition to a productive adulthood. For example, the work performance of manual laborers is influenced by body shape. Taller, longer-legged agricultural workers and assembly line laborers — professions open to Maya immigrants — earn more money than their smaller, shorter-legged co-workers.[10] Thomas and Strauss[11] find that in Brazil, taller adults earn higher wages on average. Obesity is associated with reduced educational attainment and limited earning capacity throughout life, particularly among women.[12,13,14] In sum, body shape is one variable that contributes to human work performance, social develop-

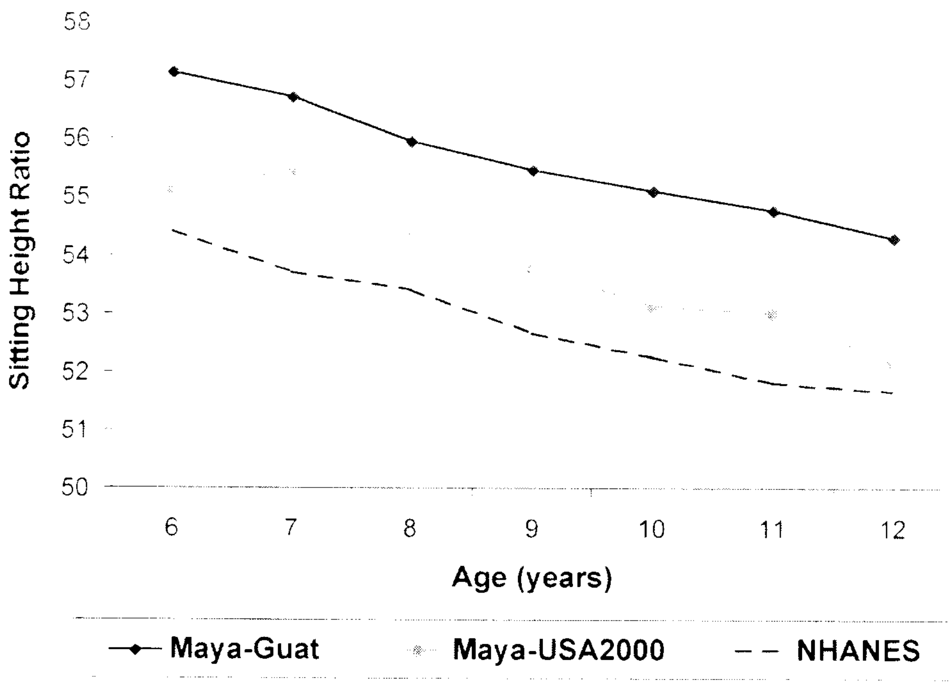

Figure 8. Mean sitting height ratio of Maya samples compared with median of NHANES reference sample.

ment, and economic potential. The morphology of body shape is molded by the impact of environmental factors during the childhood and juvenile stage of life history.

THE NEW BIOCULTURAL MODEL

Body shape, which is a biological characteristic, is molded by many environmental factors, including nutrition, health care, and socioeconomic status. In turn, body shape influences socioeconomic development, and this feeds back to further mold the body shape of the next generation. The constant, recurring interaction between biology and environment is at the heart of the new biocultural model of human growth and development. However, the concept of biocultural interactions has not always been so.

Since the late 19^{th} century, anthropologists have used biocultural models to explain human growth and development. Physicians and anthropologists, such Henry Pickering Bowditch and Franz Boas, for example, used simple biocultural models to dispel unscientific notions that human phenotypes were genetically fixed and not amenable to environmental influences.[15] Some years later, with the discovery of the nature of DNA and other fundamentals of developmental biology, biocultural models adopted a linear perspective. Biocultural models of the 1960s and 1970s considered human development as, basically, a biological process, which could be influenced to a greater or lesser extent by the social and cultural environment. By the late 1980s a newer, expanded biocultural view took hold. That view emphasizes that there is a recurring interaction between the biology of human development and the sociocultural environment. Not only does the latter influence the former, but human developmental biology modifies social and cultural processes as well. It is now understood that environmental forces, including the social, economic, and political environment, regulate the expression of DNA as much, or more so, than DNA regulates the growth process.

ENVIRONMENTAL STRESS AND GROWTH

There is considerable evidence for direct connections between various types of stress, growth, and health.[1] A life history approach to the study of stress, growth, and health is described by Stratakis et al. (Ref. 16, p. 162): "In childhood and adolescence, appropriately functioning neuroendocrine responses to stressors are necessary to allow growth and psychosexual maturation to progress normally. Maladaptive neuroendocrine responses, that is, dysregulation of the stress system, may lead to disturbances in growth and development and cause psychiatric, endocrine metabolic, and/or autoimmune diseases or vulnerability to such diseases, not only during childhood and adolescence, but also in adulthood." Here we present a summary of two studies that use a life history approach combined with the newer biocultural model of human development to better understand the influence of environmental stress on growth and health.

Island Life and Family Stress

The first is a study started in 1988 by Mark Flinn and his colleagues. They have been studying the interplay between socioeconomic conditions, psychosocial stress, and health of the people living in a rural village on the Caribbean Island of Dominica. The study sample includes, "...264 infants, children, adolescents, and young adults aged 2 months to 18 years" (Ref. 17, p. 33). This is a biocultural study, and the field research methods include ethnographic observation of people's behavior via participant observation, systematic behavioral observations, informal interviews, psychological questionnaires, clinical medical examinations, reviews of medical records, and repeated measures of salivary cortisol levels. Cortisol is one of the primary hormones released in response to psychosocial or physical stress. By 1996, a total of 22,438 salivary cortisol sample were collected and analyzed by radioimmunoassay.

The hypothesis that directs the research is illustrated in Figure 9. "Health" is the outcome of a complex relationship between the "Family environment" and the "Physical environment," both of which are influenced by socioeconomic conditions, or "SECs." The social dynamic of the "family environment" regulate levels of "Stress" in family members. The research team evaluates health in terms of the immunologi-

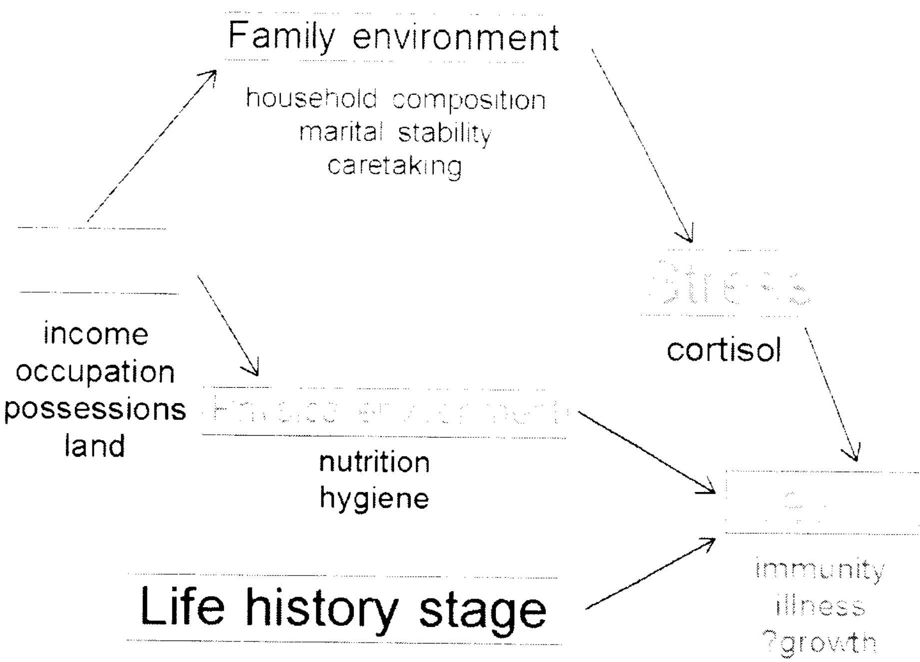

Figure 9. A model of the hypothesized relationships between socioeconomic conditions (SECs), family environment, physical environment, stress, and health. (After Ref. 16.)

cal status and illnesses of the study subjects. Longitudinal measurements of weight, and perhaps, other anthropometric variables, are also part of the database, but have not been published — hence the question mark for "growth?"

The most consistent finding of the study is that the quality of the family environment influences directly both the cortisol levels in the subjects and their health. High average levels of cortisol, or widely fluctuating levels of cortisol in individual infants, children, juveniles, or adolescents are associated with significantly diminished immunity and a statistically higher frequency of illness. These high or unstable cortisol profiles in the subjects are more likely to be found when they are living in unstable families or households. Discord and separation of parents/caretakers and changes in the composition of the household are two stressors that elevate cortisol levels. Another important stressor is the degree of genetic relationship between caretakers and the study subjects. Mean cortisol levels and the percentage of days ill are lower for subjects living in households where they are the genetic offspring of the adult caretakers. Mean cortisol levels are highest when the subjects live with a stepfather and half-sibs, or when they live with distant relatives. The next highest mean cortisol levels are found in subjects living in single-mother households, where there was little or no social or economic support from a mate or other kin.

Urban Life and Generalized Stress

The second study focuses on the growth and health of the juveniles and adolescents in Portugal born to either migrants from the Cape Verde Islands or to Portuguese nationals. One purpose of this study is to investigate the influence of living conditions, migration, and ethnicity as determinants of body size and body proportions. The Cape Verde community in Portugal maintains many of the ethnic traditions of their homeland, including the cuisine, music, kinship organization, and other cultural behaviors. The Cape Verdeans in Portugal are also exposed to and may adopt Portuguese cultural traditions and behaviors. In recognition of their migration, legal, and ethnic status, we refer to this community as "Cape Verde-Portuguese" or CV-P.

All of the CV-P live in a highly urbanized town adjacent to Lisbon. This town includes one of the worst urban slums of Portugal, where more than 95% of the CV-P families live. Housing in the slums is, for the most part, substandard. The house construction is based old and previously used materials. There is no predetermined plan to the placement of homes. The homes may be used for business activities as well as for family housing. Most of these buildings are not connected to city utilities and, therefore, are not equipped with running water and electricity, or with suitable systems for drainage and waste management.[18] The town also includes neighborhoods inhabited mostly by middle-class Portuguese families. These Portuguese families live in "regular" homes, meaning that their only purpose is to lodge a family. The middle-class areas have a predetermined plan and have city services for water, electricity, drainage, and waste management.

Portuguese and CV-P juveniles and adolescents attend the same public school in this neighborhood, and this is where the biocultural data for the study are collected. In 1993 and 1999 samples of juveniles and adolescents were measured for a variety of anthropometric, maturation, physical performance, and physical activity variables. In 1993 a sample of Cape Verde boys and girls living in the Cape Verde Islands was also measured. This sample may serve as reference against which changes in growth and health of the CV-P sample may be compared. The total sample of CV-P, Portuguese, and Cape Verde boys and girls numbers 1211. They are between the ages of 10.0 to 15.99 years old (mean age $\pm$ sd = 12.04 $\pm$ 1.36). A description of each ethnic group, including numbers of boys and girls, mean ages (and standard deviation), and type of home dwelling is presented in Table 2.

It is well known that slums concentrate a social, economic, and political environment of poverty and violence.[19] As previously discussed, youngsters with long-term exposure to these negative stressors often become adults handicapped by poor health, impaired intellectual capacity, and limited earning potential. The CV-P students, then, are likely to be at greater risk for these biosocial problems than are the Portuguese students. To test this expectation we present data for growth in height, weight, and body mass index (BMI) for both ethnic groups. To facilitate the interpretation of the data we used analysis of covariance (ANCOVA) with chronological age as the covariant. This allows us to estimate a single mean value for height,

Table 2. Sample sizes, mean age (and standard deviation), and type of home dwelling.

	N	Mean age ± SD	Type of dwelling (%) Regular	Run-down
Portuguese boys 99	81	11.52±0.99	98.5	1.5
Portuguese girls 99	73	11.54±1.02	100	0
CV-P[1] boys 99	70	11.80±1.24	5	95
CV-P girls 99	80	11.99±1.25	3	97
Portuguese boys 93	121	11.53±1.27	100	0
Portuguese girls 93	319	11.39±1.05	100	0
CV-P boys 93	54	12.48±1.15	0	100
CV-P girls 93	190	12.81±1.35	1	99
Cape Verdean boys 93	101	12.60±1.07	Standard dwellings in the Cape Verde Islands[2]	
Cape Verdean girls 93	139	12.41±1.26	Standard dwellings in the Cape Verde Islands	

[1]CV-P refers to Cape Verdean youth living in Portugal. Almost all were born in Portugal.

[2] Standard dwellings in the Cape Verde Islands usually have running water, electricity, and flush toilets.

weight, and BMI for boys and girls in each ethnic group. The ANCOVA method does not take into account maturation differences between individuals (i.e., early maturers may be taller than average at younger ages, but shorter than average at later ages). Nevertheless, with our reasonably large sample sizes the mean values estimated by ANCOVA should be reliable for group comparisons.

In 1993 the heights (Figure 10) of the Portuguese, CV-P, and Cape Verde (CV) girls did not differ significantly, but CV-P boys were significantly taller than Portu-

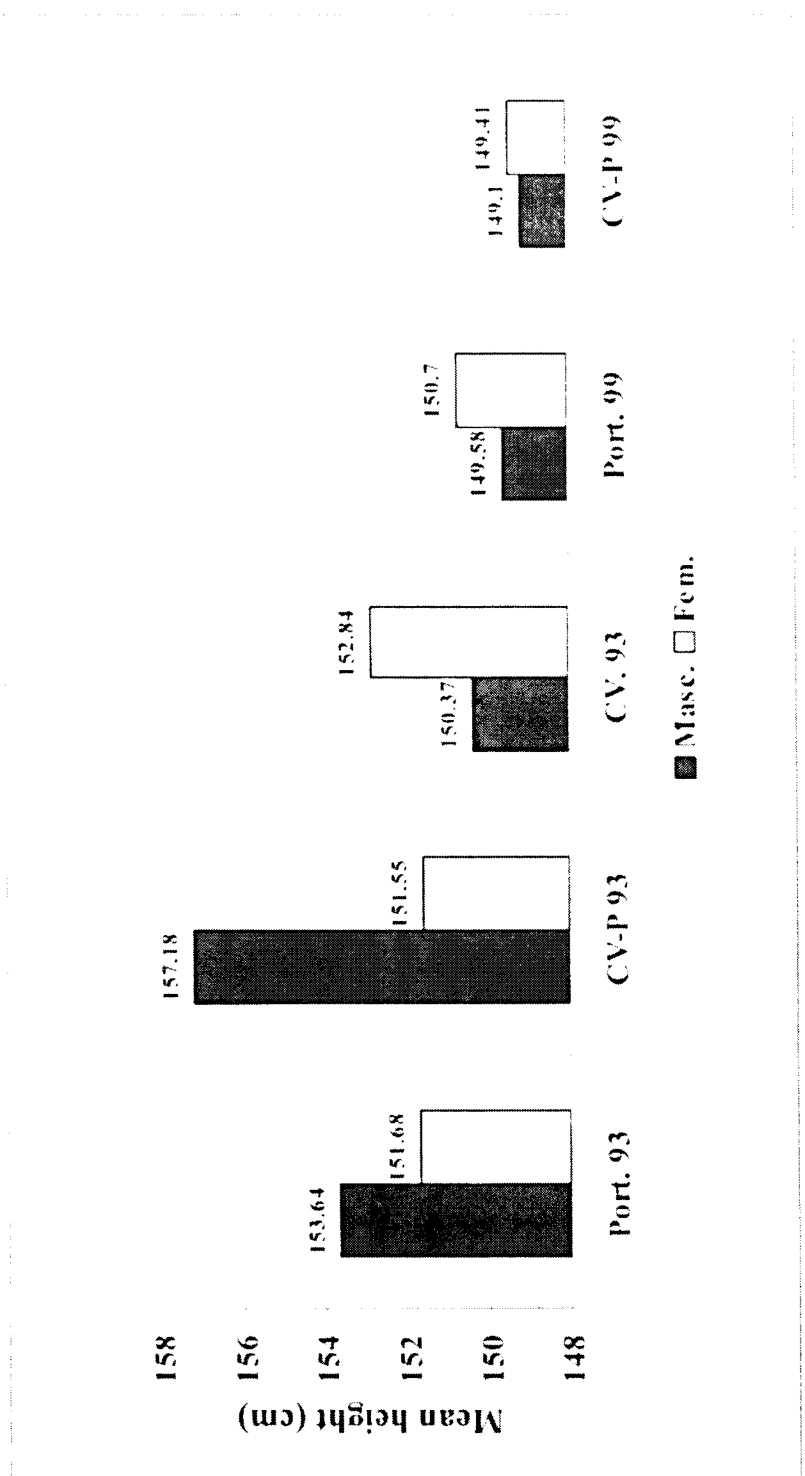

Figure 10. Mean values of height for Portuguese and Cape Verde-Portuguese (CV-P) boys and girls, 10 to 15 years old, measured in Portugal and Cape Verde boys and girls measured in the Cape Verde Islands. Mean values are estimated by analysis of covariance using chronological age as the covariate.

guese boys. Boys living in the Cape Verde Islands were significantly shorter than either Portuguese or CV-P boys. The Portuguese and CV-P measured in 1999 do not differ significantly by ethnicity or sex. However, unexpectedly, the mean heights of both the Portuguese and CV-P boys measured in 1999 declined, and equal the mean height of boys in the Cape Verde Islands in 1993.

The data for weight (Figure 11) indicate that in 1993 there was only one difference between any of the ethnic or sex groups. Portuguese girls measured in 1999 were significantly heavier than girls in the Cape Verde Islands measured in 1993. We used the results for height and weight to calculate body mass index (BMI), which serves as an estimate of fatness. The data are shown in Figure 12. The boys and girls living in the Cape Verde Islands have the lowest values of BMI, significantly lower than all the other groups measured in 1993 and 1999.

These findings are surprising because the general economic conditions of Portugal improved between 1993 and 1999. We expected that the rising economic tide would elevate health and growth status of all the groups in 1999. Yet, both the Portuguese and CV-P boys measured in 1999 were significantly shorter than the boys measured in 1993. We cannot "blame" the extremely bad environment of the slums for the decline in height, because the Portuguese subjects do not live in the slums and they also showed a decline in mean height. One possible explanation for the decline in height may be a change in diet. In 1993 the schools provided to children two cartons of milk everyday. The milk supplement was discontinued in 1994 in this group of children. Several studies show that the inclusion of milk in the diet of children, juveniles, and adolescents is associated with greater growth in height as well as greater bone density.[1] Another possible reason for the decline in stature from 1993 to 1999 is an increase in adverse or toxic substances in the local environment. The general economic improvement in Portugal lead to an increase in construction, especially in the Lisbon urban area. Near the neighborhoods of the Portuguese and CV-P samples, there were several road construction projects started during the 7 years between 1993 and 1999. These projects may have raised the levels of several contaminants that are adverse to health growth.

CONCLUSION

The examples provided in this review confirm that the physical growth of human populations serve as a sensitive indicator of the quality of the environment. The precision of this gauge of environmental quality is increased when the plasticity and variability of human growth are viewed from life history and biocultural perspectives. These perspectives are not new, for as mentioned earlier the anthropologist Franz Boas argued for nearly 50 years that the study of human growth provides a mirror of the human condition.[20,21] What is new is the understanding that biological and environmental conditions for life are in a constant interaction. We now know that in the patterns of growth of human populations we see a reflection of the "material and moral conditions of that society" (Ref. 22, p. 3). We now know that

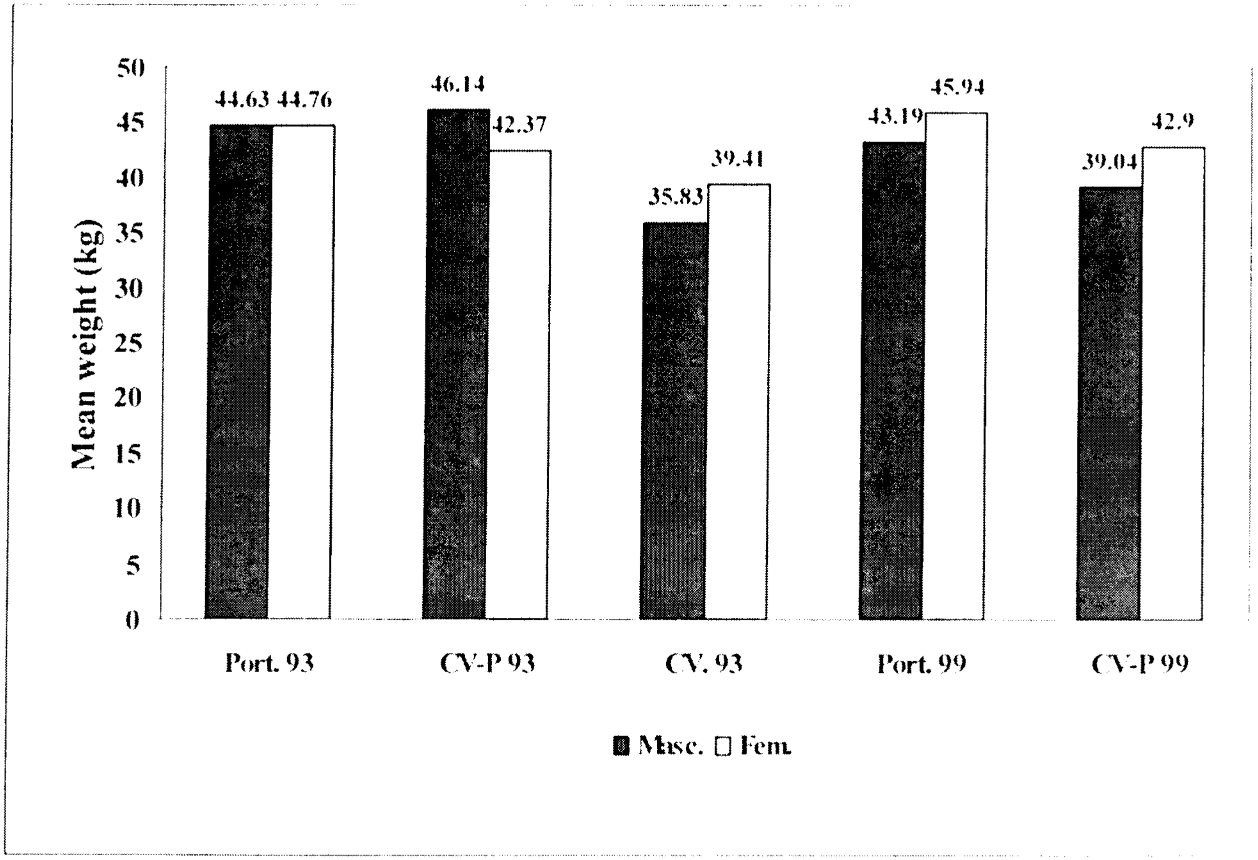

Figure 11. Mean values of weight for Portuguese and Cape Verde-Portuguese (CV-P) boys and girls, 10 to 15 years old, measured in Portugal and Cape Verde boys and girls measured in the Cape Verde Islands. Mean values are estimated by analysis of covariance using chronological age as the covariate.

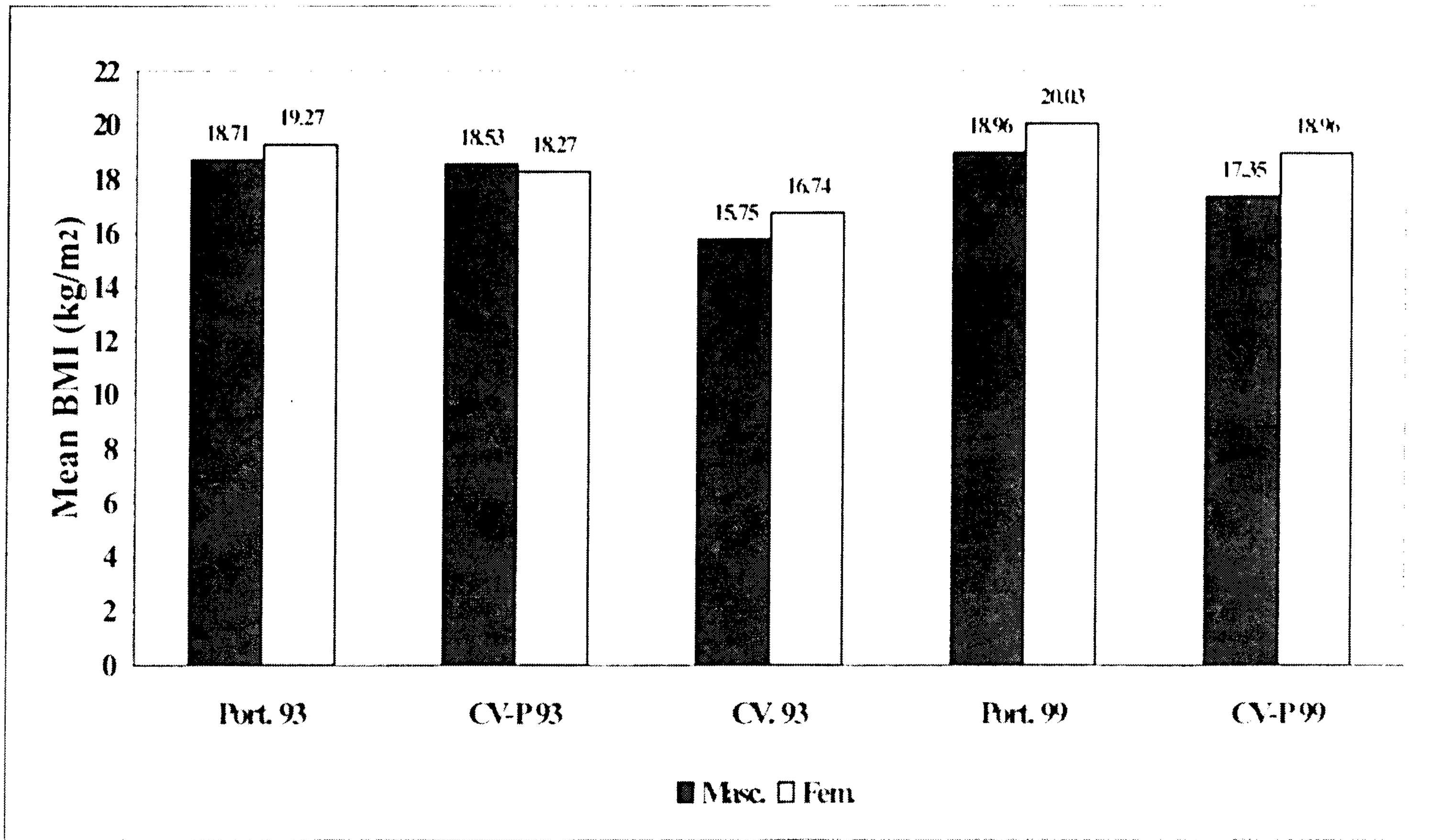

Figure 12. Mean values of body mass index (BMI) for Portuguese and Cape Verde-Portuguese (CV-P) boys and girls, 10 to 15 years old, measured in Portugal and Cape Verde boys and girls measured in the Cape Verde Islands. Mean values are estimated by analysis of covariance using chronological age as the covariate.

the forces capable of holding back growth may be biological, social, economic, or political in nature.[24] It is also well known that adverse growth in the first 20 years of life is associated with poor health during both the growing years and in adulthood. It is imperative then that those of us with knowledge and power do all that we can to improve the material and moral conditions of our society.

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