Smoking attributable fractions for adult diseases in England

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Introduction

Smoking is recognised to cause several fatal and non-fatal diseases in adult smokers [1, 2]. Smoking attributable fractions (SAFs) are the proportion of cases of a disease that could be prevented if exposure to tobacco was eliminated [3], and are a function of the disease risks and population prevalence of smoking. SAFs are used routinely to monitor the burden of tobacco on population health and health service use. For England, NHS digital annually reports smoking attributable deaths and hospital admissions using SAFs for a list of 26 smoking-related diseases [4]. However, the disease list and effects of smoking on disease risk used by NHS Digital are reported to date from a 2007 review by the Department of Health for fatal diseases, and a 2005 report for non-fatal diseases (Appendix B, Section 1.3 [5]).

Two recent reviews have collated the latest evidence on the association between smoking and disease risk among adult smokers. First, the Royal College of Physicians (RCP) report on treating tobacco dependency in the NHS presents a comprehensive review of the latest evidence on the risk of smoking for a range of conditions (authors of this report also contributed to Chapter 3 of the RCP report, as part of which we estimated SAFs for the full range of conditions considered) [6]. Second, Cancer Research UK updated their estimates of the proportion of cancer cases in the UK that can be considered attributable to a range of modifiable risk factors, including tobacco [7]. We have combined the evidence from these two reviews in a previous report [8], in which we focus on the risks of smoking for 52 diseases in adult smokers.

We use the risks of smoking for these 52 diseases [8] and smoking data from the Health Surveys for England 2015 and 2016 [9] to estimate new SAFs. We stratify our SAF estimates by age-group, sex and socio-economic conditions as measured by quintiles of the 2015 English Index of Multiple Deprivation (IMD) [10].

Methods

All analyses were undertaken in the R environment (version 3.5.2) [11], using code developed as part of the new Sheffield Tobacco and Alcohol Policy Model.

Survey data

We analysed data from the Health Survey for England (HSE), a nationally representative annual cross-sectional survey of households in England [9]. We pooled two years of data (2015, 2016) to increase our sample size to 15,907 adults aged 16–89 years. We categorised survey respondents' ages into seven age-groups: 16–17, 18–24, 25–34, 35–49, 50–64, 65–74, and 75–89 years. All calculations were adjusted for the survey weights, which make the survey sample more representative of the general population.

Our measure of socio-economic conditions was the 2015 English IMD [10], which measures relative levels of deprivation in small areas or neighbourhoods with an average population of around 1,500 people, called Lower-layer Super Output Areas. The IMD is based on 37 separate indicators, organised into seven domains: Income Deprivation; Employment Deprivation; Health Deprivation and Disability; Education, Skills and Training Deprivation; Crime; Barriers to Housing and Services; and Living Environment Deprivation. These indicators are combined to give each area a multiple deprivation score. We investigated variation among quintiles of the IMD, quintile one being the least deprived, and quintile five the most deprived.

We described smoking status according to the HSE's derived variable (cigsta3) for whether an individual is a current regular (current) cigarette smoker, ex-regular (former) cigarette smoker or never regular (never) cigarette smoker. From our data sample, we excluded 99 individuals (0.6% of the sample) due to missing data on smoking status; missing data were concentrated in younger age-groups, with an approximately even distribution by sex and IMD quintile.

Figure 1 shows the IMD variation in the proportion of people who were current, former and never smokers. Figure 2 shows the age variation in current smoking.

A limitation of our approach is that we did not consider the variation among current regular smokers in their quantity and frequency of tobacco consumption, nor did we consider the variation among current and former smokers in their accumulated lifetime tobacco consumption e.g. pack-years. This was to fit with our information on disease risk [8], which does not consider the smoking-related variation in disease risk among people who currently smoke.

For former smokers, we used data on the number of years since quitting to model the gradual decline in the disease risks associated with smoking after quitting.

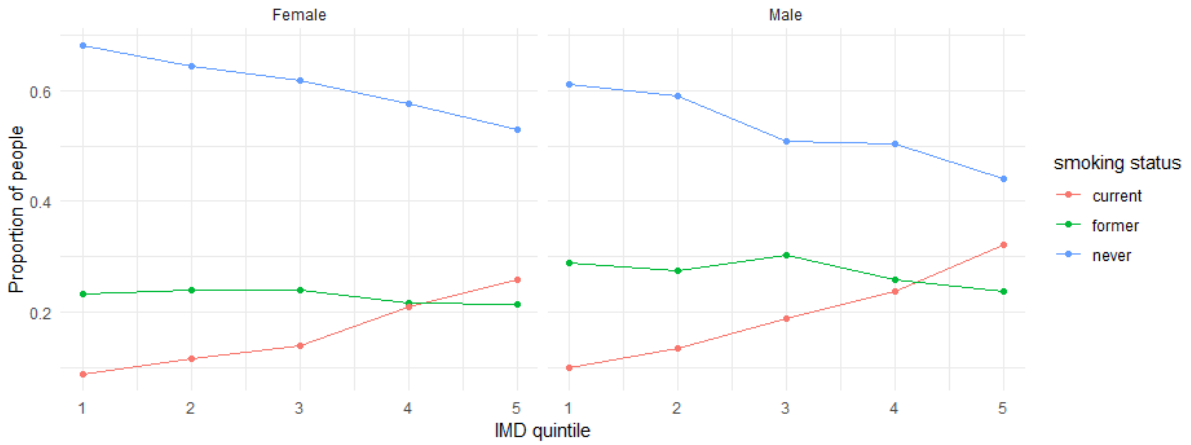

Figure 1. Variation in the distribution of smoking status by socio-economic conditions. The proportion of people sums to 1 within each IMD quintile and sex subgroup. IMD quintile 1 is the least deprived and IMD quintile 5 is the most deprived.

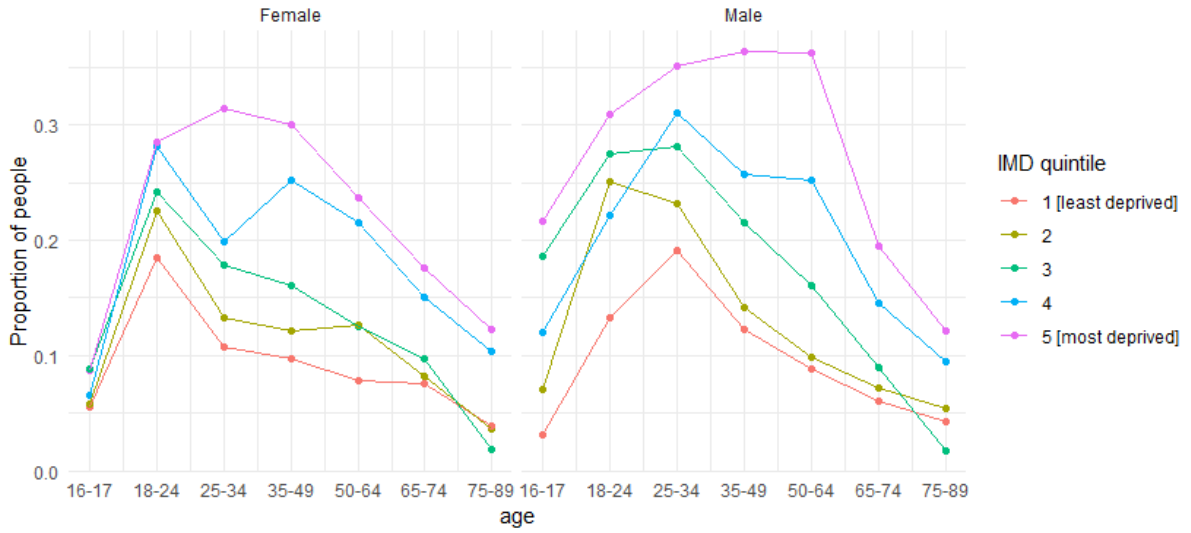

Figure 2. Proportion of current smokers by age, sex and socio-economic conditions. The proportion of current smokers within each age, sex and IMD quintile subgroup. IMD quintile 1 is the least deprived and IMD quintile 5 is the most deprived.

Table 1. Smoking-related conditions.

Category	Condition	ICD-10 code(s)
Cancer	Oral cavity	C00–C06
	Pharyngeal	C09, C10, C12–C14
	Oesophageal AC†	C15
	Oesophageal SCC†	C15
	Colorectal	C18–C20
	Liver	C22
	Pancreatic	C25
	Nasopharynx and sinonasal	C11, C20, C31
	Laryngeal	C32
	Stomach	C16
	Lung	C33, C34
	Cervical	C53
	Kidney	C64
	Lower urinary tract	C65, C66
	Bladder	C67
	Acute myeloid leukaemia	C92
Cardiovascular	Ischaemic heart disease	I20–I25
	Haemorrhagic stroke	I60–I62
	Ischaemic stroke	I63–I67
	Peripheral arterial disease	I73.9
	Abdominal aortic aneurysm	I71
	Venous thromboembolism	I26, I80–I82
Respiratory	Pneumonia	J12–J18
	Influenza clinically diagnosed	J11
	Influenza microbiologically confirmed	J09, J10
	Tuberculosis	A15–A19
	Chronic Obstructive Pulmonary Disease (COPD)	J40–J44, J47
	Asthma	J45–J46
	Idiopathic pulmonary fibrosis	J84.1
	Obstructive sleep apnoea	G47.3
Mental health	Alzheimer's disease	G30
	Vascular dementia	F01
	All cause dementia	F02, F03
	Depression	F32, F33
	Schizophrenia	F20–F25
	Psychosis	F28, F29
	Bulimia	F50.2
Other	Diabetes	E11
	Rheumatoid arthritis	M05–M06
	Age-related macular degeneration	H35.3–H52.4
	Senile cataract	H25
	Hip fracture	S72.0–S72.2
	Chronic kidney disease	N18.1–N18.4, N18.9
	End-stage renal disease	N18.5
	Systemic lupus erythematosus	M32
	Psoriasis	L40
	Multiple sclerosis	G35
	Low back pain	M54
	Crohn's disease	K50
	Hearing loss	H90, H91
Conditions less common in smokers	Ulcerative colitis	K51
	Parkinson's disease	G20

† Oesophageal cancer has two main histological types: Squamous Cell Carcinoma (SCC) and Adenocarcinoma (AC). Smoking is associated differently with SCC and AC [12, 13]. The relative prevalence of SCC and AC varies widely between countries and within population subgroups [14] and it may therefore be necessary to apportion overall oesophageal cancer prevalence between SCC and AC using external data such as that from cancer registries.

Risk of disease

Table 1 shows our list of 52 smoking-related diseases and the corresponding relationship between being a current vs. a never smoker and the risk of morbidity/mortality. Figure 3 shows the relative risks of current vs. never smoking for each disease; in Appendix A we present the values of the relative risks for each disease from [8] for ease of reference.

Sex-specific estimates for other diseases are available, as we present and discuss in our report on smoking-attributable risks [8], and sex-specific estimates have been used previously by NHS Digital [4]. However, due to the high degree of statistical uncertainty around the sex-specific effects, we used the whole-population estimates where they are presented [8].

We estimated SAFs for the age-groups 16–17, 18–24, 25–34, 35–49, 50–64, 65–74, and 75–89 years. The smoking-related risks of disease usually correspond to ages over 35 years but we assumed that the estimated risk also applies to individuals aged under 35 years. For Ischaemic heart disease, risks are reported by age-group (35–64, 65+ years) and here we assumed that individuals aged under 35 years face the same risk of smoking as the youngest age-group.

Residual risks in former smokers

Including the residual risk in former smokers in our SAF estimates gives an insight into the remaining burden of harm among people who have ever smoked regularly. We calculated two alternative sets of SAF estimates that included or excluded the residual risk in former smokers.

We used estimates of the decline in risk over time after quitting from Kontis et al. [15], who re-analysed the change in risk after smoking in the ACS-CPS II study from Oza et al. [16], producing three functions to describe the decline in risk after quitting for each of cancers, cardiovascular disease (CVD) and COPD (Figure 4). The estimates were informed by data on former smokers with known quit dates who were disease-free at baseline. A cross-check for cancer in the larynx, oral cavity, pharynx and oesophagous showed that the estimates were broadly consistent with the findings of the International Agency for Research on Cancer's (IARC) 2007 review of the decline in risk after quitting smoking [17].

The remaining question is how risk declines after quitting smoking for diseases that are not cancers, CVD or COPD. For type II diabetes, Kontis et al. [15] state that "Randomised trials also indicate that the benefits of behaviour change and pharmacological treatment on diabetes risk occur within a few years, more similar to the CVDs than cancers [18]. Therefore, we used the CVD curve for diabetes." In-line with Kontis, we also apply the rate of decline in risk of CVD after quitting smoking to type II diabetes. Due to a lack of evidence, for other diseases we do not calculate SAFs that include the residual risk in former smokers.

Figure 3. The relative risks of current vs. never smoking for 52 conditions attributable to smoking. Error bars show 95% confidence intervals.

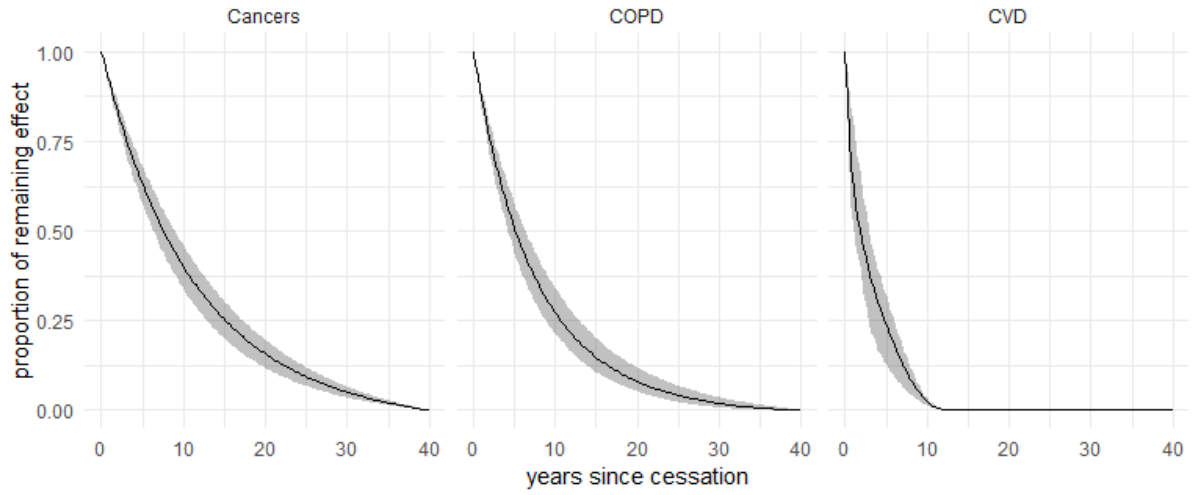

Figure 4. The proportion of remaining excess risk from smoking in former smokers according to the number of years since they quit. Shaded areas show 95% confidence intervals.

Calculation of smoking attributable fractions

The SAF is defined as the proportion of cases of a particular disease that could be prevented if exposure to tobacco was eliminated. Our method to calculate SAFs is given by:

$$SAF = \frac{P_{current}(RR_{current} - 1) + P_{former}(RR_{former} - 1)}{P_{current}(RR_{current} - 1) + P_{former}(RR_{former} - 1) + 1}, \quad (1)$$

where $RR_{current}$ is the relative risk of disease in current smokers, RR_{fomer} is the relative risk of disease in former smokers, and P is the proportion of people with each smoking status. We apply (1) to the whole population and to subgroups defined by age-group, sex and IMD quintile. To exclude the residual risks of smoking in former smokers we set $RR_{fomer} = 1$.

For ulcerative colitis and Parkinson's disease, the evidence indicates a protective effect of smoking (for ulcerative colitis this is suggested to result from the immunosuppressive effects of smoking; for Parkinson's disease nicotine has potential beneficial effects [2]). Protective effects result in negative SAFs, which indicate that there are currently fewer cases of a condition than would be the case if nobody smoked. Negative SAFs can be used to estimate this hypothetical higher number of cases (b) according to:

$$b(no\ exposure) = \frac{b(observed\ exposure)}{1 + SAF}. \quad (2)$$

SAF estimates

We provide our complete set of SAF estimates stratified by age-group, sex and IMD quintiles in a supplementary spreadsheet. Below we highlight the main findings. It will help to note that for cancers, CVD, COPD, and type II diabetes we estimated an alternative set of SAFs that include the residual risks of smoking in former smokers (in the figures we focus presentation on the SAFs that consider only the risks of current smoking; we show the SAFs that include the residual risks in former smokers using crosses).

Figure 5 shows our SAF estimates by condition. Lung cancer is the condition for which the highest proportion of cases were caused by smoking. We estimated that 64% of lung cancer cases were caused by current smoking, compared to 73% by the combination of current and former smoking. We note that we used an estimate of the relative risk of lung cancer in current vs. never smokers (10.92 [19], Table A1) that is smaller than that used by NHS Digital (23.26 in men, 12.69 in women [4]), leading to a smaller SAF estimate. The respiratory conditions with the highest SAFs (considering only current smoking) were micro-biologically confirmed influenza with 45% of cases caused by smoking, and COPD with 35% of cases caused by smoking.

Figure 6 shows SAF stratified by condition and sex. In general, SAFs are higher in males than females. Since our estimates of the relative risk of current vs. never smoking are not stratified by sex (except for ischaemic heart disease and stroke, Table A2), higher SAFs in males reflects their higher rates of smoking. For ischaemic heart disease and stroke, females have a slightly higher SAF than males, reflecting the slightly higher risk of smoking for females (although this difference was not statistically significant at the 95% level [20], Table A2).

Figure 7 shows SAFs stratified by condition and IMD quintiles; Figure 8 focuses on lung cancer and shows the pattern in SAFs by age, sex and IMD quintiles. SAFs for all conditions increase with increasing levels of deprivation, reflecting the higher prevalence of smoking among people who live in more deprived conditions (Figure 1). Similarly, the age-pattern in the SAFs (Figure 6) reflects the age-pattern in the prevalence of smoking (Figure 2). None of our risk estimates are stratified socio-economically; the socio-economic differences in our SAF estimates are therefore caused by the socio-economic differences in the prevalence of smoking. Conditions with higher smoking-related risks show higher socio-economic variation in SAFs. These are therefore the conditions for which further declines in smoking would cause the greatest reduction in the total number of cases, and in the inequality in number of cases.

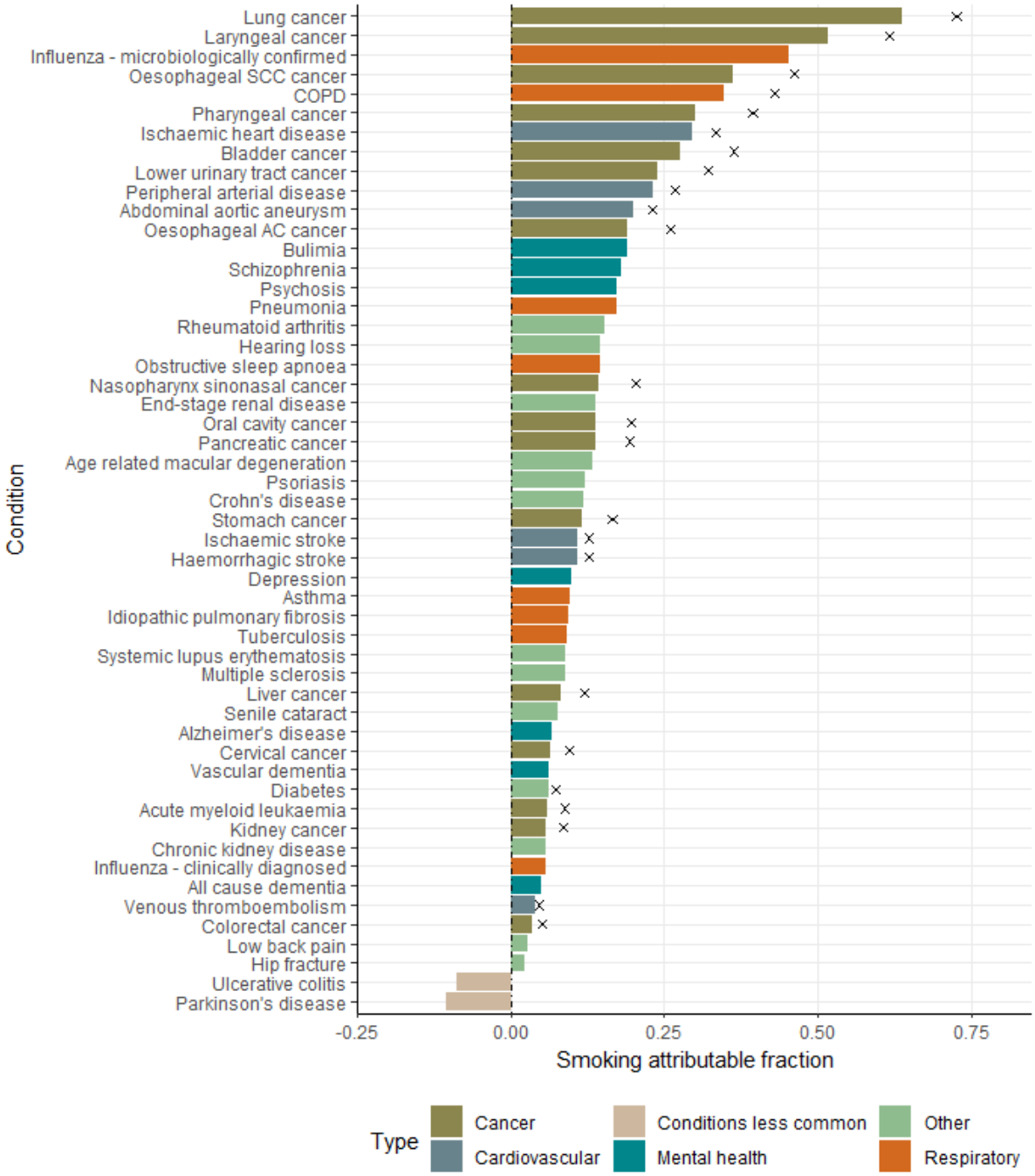

Figure 5. Smoking attributable fractions by condition. Negative SAFs indicate that smoking has a protective effect. Colours show the category of condition. Each bar shows the SAF for each condition considering only the risks from current smoking (i.e. excluding the residual risk from past smoking in former smokers). For conditions with evidence of how risk declines over time after quitting smoking, crosses show the higher SAFs when the risk from former smokers is included.

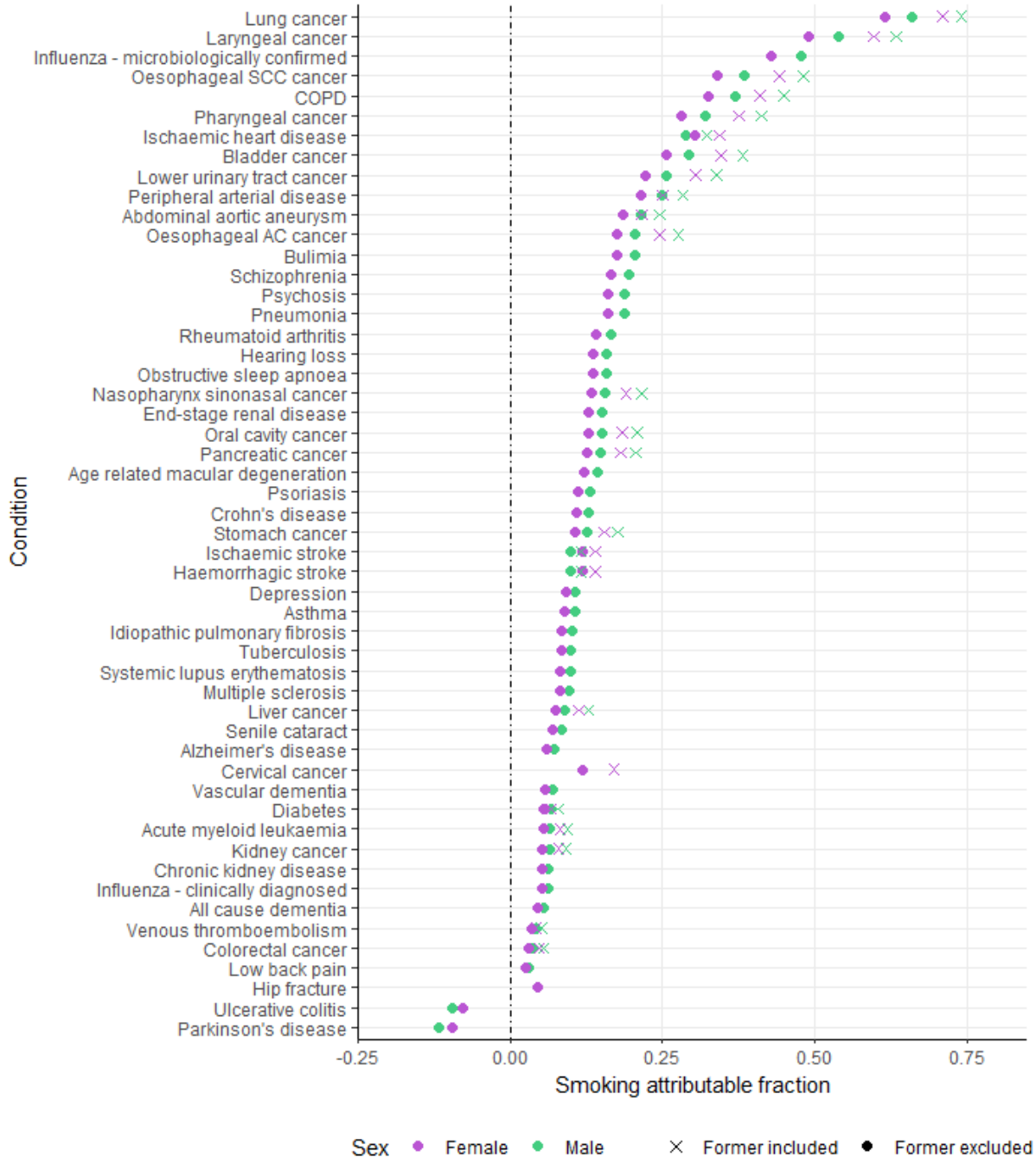

Figure 6. Smoking attributable fractions by condition and sex. Negative SAFs indicate that smoking has a protective effect. Each solid point shows the SAF for each condition considering only the risks from current smoking (i.e. excluding the residual risk from past smoking in former smokers). For conditions with evidence of how risk declines over time after quitting smoking, crosses show the higher SAFs when the risk from former smokers is included.

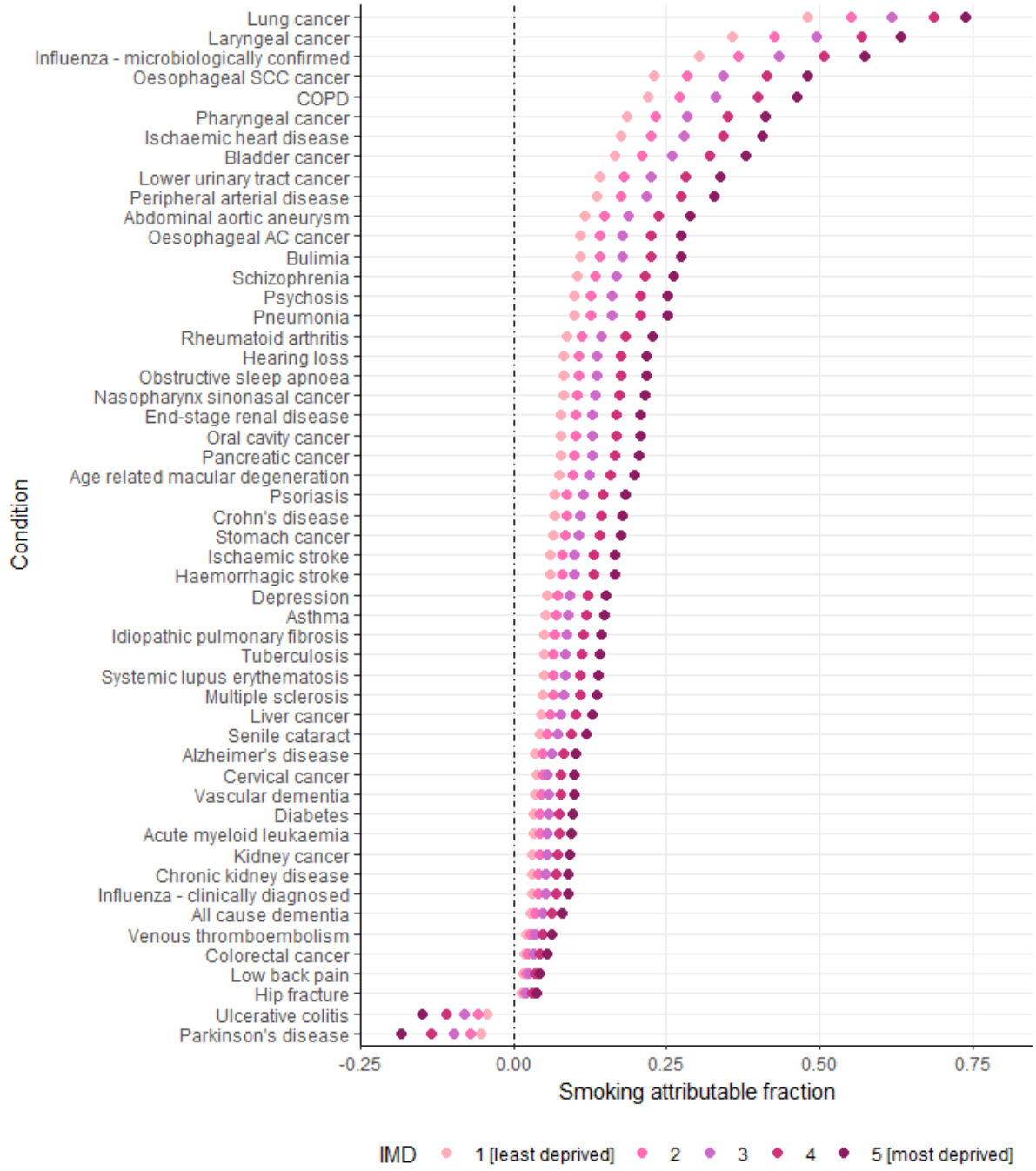

Figure 7. Smoking attributable fractions by condition and socio-economic conditions. Each solid point shows the SAF for each condition considering only the risks from current smoking (i.e. excluding the residual risk from past smoking in former smokers). Each colour represents a different quintile of the 2015 English Index of Multiple Deprivation.

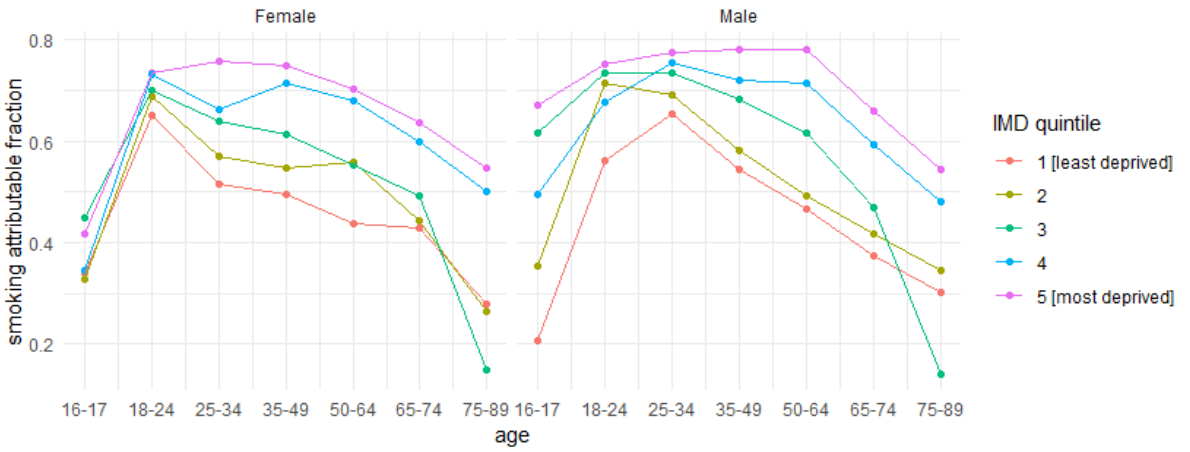

Figure 8. Smoking attributable fractions for lung cancer by age, sex and socio-economic conditions. This figure shows the SAFs for lung cancer considering only the risks from current smoking (i.e. excluding the residual risk from past smoking in former smokers). Each colour represents a different quintile of the 2015 English Index of Multiple Deprivation.

Appendix A. Relative risks

Cancers

Table A1. Relative risks for current vs. never smoking for 16 cancer types.

Grouping	Cancer	ICD10 code	Relative risk	Reference
Lung	Lung	C33–C34	10.92 (8.28–14.40)	Jayes et al (2016) [19]
Head and neck	Nasal sinus and nasopharyngeal	C11, C30–C31	1.95 (1.31–2.91)	Gandini et al (2008) [21]
Head and neck	Oral cavity	C00–C06	1.91 (1.06–3.42)	Maasland et al.(2014) [22]
Head and neck	Pharyngeal	C09, C10, C12–C14	3.43 (2.37–4.94)	Gandini et al (2008) [21]
Head and neck	Laryngeal	C32	7.01 (5.56–8.85)	Zuo et al. (2017) [23]
Gastrointestinal	Oesophageal SCC	C15*	4.21 (3.13–5.66)	Prabhu et al. (2013) [12]
Gastrointestinal	Oesophageal AC	C15*	2.32 (1.96–2.75)	Tramacere et al. (2011) [13]
Gastrointestinal	Stomach	C16	1.74 (1.50–2.02)	Ordóñez-Mena et al (2016) [24]
Gastrointestinal	Pancreatic	C25	1.90 (1.48–2.43)	Ordóñez-Mena et al (2016) [24]
Gastrointestinal	Liver	C22	1.51 (1.37–1.67)	Lee et al (2009) [25]
Gastrointestinal	Colorectal	C18–C20	1.20 (1.07–1.34)	Ordóñez-Mena et al. (2016)
Urinary system	Kidney	C64	1.35 (1.13–1.60)	Cumberbatch et al. (2016) [26]
Urinary system	Lower urinary tract	C65–C66	2.77 (2.17–3.54)	Gandini et al (2008) [21]
Urinary system	Bladder	C67	3.14 (2.53–3.75)	van Osch et al (2016) [27]
Cervical	Cervical	C53	1.83 (1.51–2.21)	Gandini et al (2008) [21]
Blood and bone marrow	Acute Myeloid Leukaemia	C92	1.36 (1.11–1.66)	Colamesta et al (2016) [28]

* Oesophageal cancer has two main histological types: Squamous Cell Carcinoma (SCC) and Adenocarcinoma (AC). Smoking is associated differently with SCC and AC [12, 13]. The relative prevalence of SCC and AC varies widely between countries and within population subgroups [14] and it may therefore be necessary to apportion overall oesophageal cancer prevalence between SCC and AC using external data such as that from cancer registries.

Cardiovascular conditions

Table A2. Relative risks for current vs. never smoking for 6 cardiovascular conditions.

Disease	ICD10 code	Relative risk	Reference
Ischaemic heart disease	I20–I25	Male 35–64: 3.18 (2.34–4.33) Male 65+: 1.96 (1.62–2.37) Female 35–64: 3.93 (2.56–6.05) Female 65+: 1.95 (1.60–2.37)	Rostron (2013) [20]
Haemorrhagic stroke	I60–I62	Male: 1.57 (1.49–1.88) Female: 1.83 (1.58–2.12)	Peters et al (2013) [29]
Ischaemic stroke	I63–I67	Male: 1.57 (1.49–1.88) Female: 1.83 (1.58–2.12)	Peters et al (2013) [29]
Peripheral arterial disease	I73.9	2.71 (2.28–3.21)	Lu et al (2014) [30]
Abdominal aortic aneurysm	I71	2.41 (1.94–3.01)	Cornuz et al (2004) [31]
Venous thromboembolism	I26, I80–I82	1.23 (1.14–1.33)	Cheng et al (2013) [32]

Respiratory conditions

Table A3. Relative risks for current vs. never smoking for 8 respiratory conditions.

Grouping	Disease	ICD10 code	Relative risk	Reference
Chronic Obstructive Pulmonary Disease (COPD)	Chronic Obstructive Pulmonary Disease (COPD)	J40–44, J47	4.01 (3.18–5.05)	Jayes et al (2016) [19]
Asthma	Asthma	J45–J46	1.61 (1.07–2.42)	Jayes et al (2016) [19]
Tuberculosis	Tuberculosis	A15–A19	1.57 (1.18–2.10)	Jayes et al (2016) [19]
Lower respiratory tract infections	Pneumonia	J12–J18	2.18 (1.69–2.80)	RCP report (2018) [33]
Lower respiratory tract infections	Influenza – clinically diagnosed	J11	1.34 (1.13–1.59)	RCP report (2018) [33]
Lower respiratory tract infections	Influenza – microbiologically confirmed	J09, J10	5.69 (2.79–11.60)	RCP report (2018) [33]
Idiopathic Pulmonary fibrosis	Idiopathic Pulmonary fibrosis	J84.1	1.58 (1.27–1.97)	Taskar et al (2006) [34]
Obstructive sleep apnoea	Obstructive sleep apnoea	G47.3	1.97 (1.02–3.82)	Jayes et al (2016) [19]

Mental health

Table A4. Relative risks for current vs. never smoking for 7 mental health conditions.

Disease	ICD10 code	Relative risk	Reference
Alzheimer's disease	G30	1.40 (1.13–1.73)	Zhong et al (2015) [35]
Vascular dementia	F01	1.38 (1.15–1.66)	Zhong et al (2015) [35]
All-cause dementia	F02, F03	1.30 (1.18–1.45)	Zhong et al (2015) [35]
Depression	F32, F33	1.62 (1.10–2.40)	Luger et al (2014) [36]
Psychosis	F28, F29	2.18 (1.23–3.85)	Gurillo et al (2015) [37]
Schizophrenia	F20–F25	2.24 (1.10–4.55)	RCP report (2018) [33]
Bulimia	F50.2	2.32 (1.12–4.78)	Solmi et al (2016) [38]

Other adult diseases

Table A5. Relative risks for current vs. never smoking for 13 other adult diseases.

Disease	ICD10 code	Relative risk	Reference
Rheumatoid arthritis	M05–M06	2.02 (1.75–2.33)	Di Giuseppe et al (2014) [39]
Chronic Kidney Disease	N18 (excluding N18.5)	1.34 (1.23–1.47)	Xia et al (2017) [40]
End-stage renal disease	N18.5	1.91 (1.39–2.64)	Xia et al (2017) [40]
Systemic Lupus Erythematosis	M32	1.56 (1.26–1.95)	Jiang et al (2015) [41]
Diabetes (type 2)	E11	1.37 (1.33–1.42)	Pan et al (2015) [42]
Psoriasis	L40	1.78 (1.52–2.06)	Armstrong et al (2014) [43]
Multiple sclerosis	G35	1.55 (1.48–1.62)	Zhang et al (2015) [44]
Senile cataract	H25	1.47 (1.36–1.59)	Ye et al (2012) [45]
Age-related macular degeneration	H35.3–H52.4	1.86 (1.27–2.73)	Chakravarthy et al (2010) [46]
Low back pain	M54	1.16 (1.02–1.32)	Shiri et al (2010) [47]
Crohn's disease	K50	1.76 (1.40–2.22)	Mahid et al (2006) [48]
Hip fracture in women	S72.0–S72.2	1.30 (1.16–1.45)	Shen et al (2015) [49]
Hearing loss	H90, H91	1.97 (1.44–2.70)	Nomura et al. (2005) [50]

Conditions less common among smokers

Table A6. Relative risks for current vs. never smoking for 2 conditions less common among smokers.

Disease	ICD10 code	Relative risk	Reference
Ulcerative colitis	K51	0.55 (0.33–0.91)	Dias et al (2015) [51]
Parkinson's disease	G20	0.46 (0.42–0.51)	Breckenridge et al (2016) [52]

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