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Estimation of smoking-related mortality and its contribution to educational inequalities in life expectancy in Spain: an observational study, 2016–2019

Bárbara Piñeiro [1], Sergi Trias-Llimós [1], Jeroen J A Spijker [1], Amand Blanes Llorens [1], Iñaki Permanyer [1,2]

¹Centre d'Estudis Demogràfics, Centres de Recerca de Catalunya (CERCA), Universitat Autònoma de Barcelona, Bellaterra-Barcelona, Catalonia, Spain
²ICREA, Passeig de Lluís Companys 23, Barcelona, Spain

Correspondence to
Dr Bárbara Piñeiro;
bpineiro@ced.uab.es

ABSTRACT

Objective To estimate smoking-related mortality and its contribution to educational inequalities in life expectancy in Spain.

Design Nationwide, observational study from 2016 to 2019. Population-attributable fractions were used to estimate age, sex and education-specific cause-of-death smoking-attributable mortality. Life table techniques and decomposition methods were used to estimate potential gains in life expectancy at age 35 and the cause-specific contributions of smoking-related mortality to life expectancy differences across educational groups.

Setting Spain.

Participants We use cause-specific mortality data from population registers and smoking prevalence from the National and the European Health Survey for Spain from 2017 and 2019/2020, respectively.

Results We estimated 219 086 smoking-related deaths during 2016–2019, equalling 13% of all deaths, 83.7% of those in men. In the absence of smoking, potential gains in male life expectancy were higher among the low-educated than the high-educated (3.1 vs 2.1 years). For women, educational differences were less and also in the opposite direction (0.6 vs 0.9 years). The contribution of smoking to life expectancy differences between high-educated and low-educated groups accounted for 1.5 years among men, and −0.2 years among women. For men, the contribution of smoking to these differences was mostly driven by cancer in middle age, cardiometabolic diseases at younger ages and respiratory diseases at older ages. For women, the contribution to this gap, although negligible, was driven by cancer at older ages among the higher educated.

Conclusions Smoking remains a relevant preventable risk factor of premature mortality in Spain, disproportionately affecting life expectancy of low-educated men.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ We used cause-specific smoking-related mortality data for the period 2016–2019 retrieved from the Spanish National Statistics Institute.
⇒ Smoking per se is not a cause of death within the International Classification of Diseases.
⇒ We estimated smoking-attributable mortality using the population attributable fractions method.
⇒ We estimated life expectancies at age 35 by educational attainment using life table calculations.
⇒ Estimates of smoking-related mortality need to rely on indirect techniques and the results should be interpreted with this caution in mind.

smoking epidemic varies considerably across countries.[2] Yet, all countries with available data have this commonality: the smoking prevalence decline has tended to start earlier among those populations with higher levels of education, occupation and income. These widening socioeconomic inequalities in smoking prevalence have resulted in a rise in smoking-related mortality inequalities.[3–10]

In Spain, the smoking prevalence has declined during the last 15 years, among men from 31.2% in 2009, to 27.6% in 2014, and 23.3% in 2019/2020; and among women from 21.3% in 2009, to 18.6% in 2014, and to 16.4% in 2019/2020; in part due to the introduction of the tobacco control policies in 2006 and 2011.[11] However, smoking prevalence is still relatively high (19.8%) overall[12] compared with other European countries.[13]

Like in other European countries, the burden of smoking-related diseases has always been more prevalent among men in Spain because women began to smoke in large numbers several decades later, initially among the higher educated. Although women never reached the same peak in smoking prevalence as men did, from about 1980 smoking prevalence slowly began to converge.[14] As a result,

BACKGROUND

Even though smoking prevalence has been declining over the last decades in many high-income countries, particularly among men, smoking remains an important preventable risk factor of premature death worldwide, accounting for >7 million deaths per year.[1] In Europe, the timing and impact of the

the generation of Spanish women who have smoked the most are those born in the 1960s. It should be noted that more than 50 years of educational expansion in Spain have led to a complete reversal in the educational composition by age group/birth cohort. While most of the Spanish elderly population never completed more than primary level education and only a small and highly selected minority obtained a university degree, about 80% of today's adults aged 35–44 have at least completed secondary school. Moreover, among younger generations, women have already overtaken men, and the lower-educated the higher-educated, thereby exacerbating the already existing socioeconomic differences in health and mortality.[9 15–17]

There is evidence suggesting that using nationally representative data and statistically controlling for sociodemographic characteristics such as age, sex and education, are essential for accurately estimating mortality attributable to smoking.[18] Previous studies assessing social inequalities in smoking-related mortality for European populations did not consider Spain as a whole but only included data for just a few Spanish regions (ie, Barcelona, Basque Country and/or Madrid) with data that is over a decade old.[19] This is fundamentally due to the lack of national-level databases and the fact that cause-specific mortality data according to educational level was not collected and made available to researchers until recently. As cause-specific mortality data according to educational attainment has recently become available in Spain, it provides an excellent opportunity to analyse in detail sociodemographic and socioeconomic characteristics in mortality attributed to smoking. Having an estimation about the smoking-attributable mortality is necessary to accurately monitor the smoking epidemic at the population level, for example, estimating life expectancies, one of the most popular indicators to monitor population-level health.[20] This information can be used to reinforce the importance of comprehensive tobacco control policies and programmes, one of the priorities set out in the WHO Framework Convention on Tobacco Control.[21] In Spain, a recent study has estimated the country wide smoking-attributable mortality in Spain with data from 2016.[22] This study suggests the presence of social inequalities in smoking-related mortality, and it is highest among the low-educated men. However, it is unknown to what extent smoking contributes to the existent gender gaps in life expectancy. While recent studies found notable educational differences in life expectancy in Spain,[23 24] little is yet known about the role of smoking in causing these differences.

The aim of this study is to estimate the contribution of smoking to life expectancy by educational attainment, and the contribution of cause-specific smoking-related mortality to educational inequalities in life expectancy in Spain. To our knowledge, this is the first study conducted in Spain that will estimate smoking-attributable mortality in recent years and will quantify the educational differences in terms of potential gains in life expectancy (PGLE) by eliminating smoking-related mortality according to age, sex and smoking-related cause of death.

METHODS
Data
We use sex, age, education and cause-specific mortality data for individuals aged 35 and over for the period 2016–2019 retrieved from the Spanish National Statistics Institute (INE). The total number of deaths used in this study was 1 667 741 and the person-years at risk was 130 568 843. INE obtained the deaths according to educational attainment through multiple data linkages, including municipal population registers (Padrón), the 2011 census or data on official degrees issued by the Ministry of education.[25] Population estimates from 2018 by age, sex and educational attainment, also retrieved from INE, were used as denominators to produce our mortality indicators. Based on both data sources, three International Standard Classification of Education (ISCED) categories have been distinguished: low (primary education or less, ISCED 0–1), middle (completed lower-level and upper-level secondary education and intermediate vocational training, ISCED 2–3) and high (postsecondary vocational training and university, ISCED 4+). Educational attainment was unknown in 1.96% of the deaths. In those cases, educational attainment was distributed following the educational distribution of deaths for each specific cause, sex and age group. Figure 1 shows the educational composition of the population by sex and age group/birth cohort.

We selected and grouped causes of death related to smoking according to the Report of the Surgeon General[26] following the 10th revision of the International Classification of Diseases (ICD-10),[27] namely cancer, cardiometabolic and respiratory diseases (see table 1).

Smoking prevalence by sex, age groups (35–54; 55–64; 65–74 and 75+) and education (low, medium, high) was required to estimate cause-of-death specific smoking-attributable mortality. Smoking prevalence was derived from combined estimates of the 2017 National Health Survey and the 2019/2020 European Survey of Health in Spain (table 2). Individuals who either smoked daily or occasionally were considered as 'smokers', and those who had smoked in the past as 'former smokers'. The 0.1% that did not know or did not respond were removed from the sample.

The relative risks (RRs) of cause-specific mortality for current and former smokers compared with lifetime non-smokers were derived from the follow-up of five cohort studies: the National Institutes of Health-AARP Diet and Health Study, the American Cancer Society's CPS-II Nutrition Cohort, the Women's Health Initiative (WHI), the Nurses' Health Study and the Health Professionals Follow-Up Study[26 28] and were retrieved from Haeberer et al.[22]
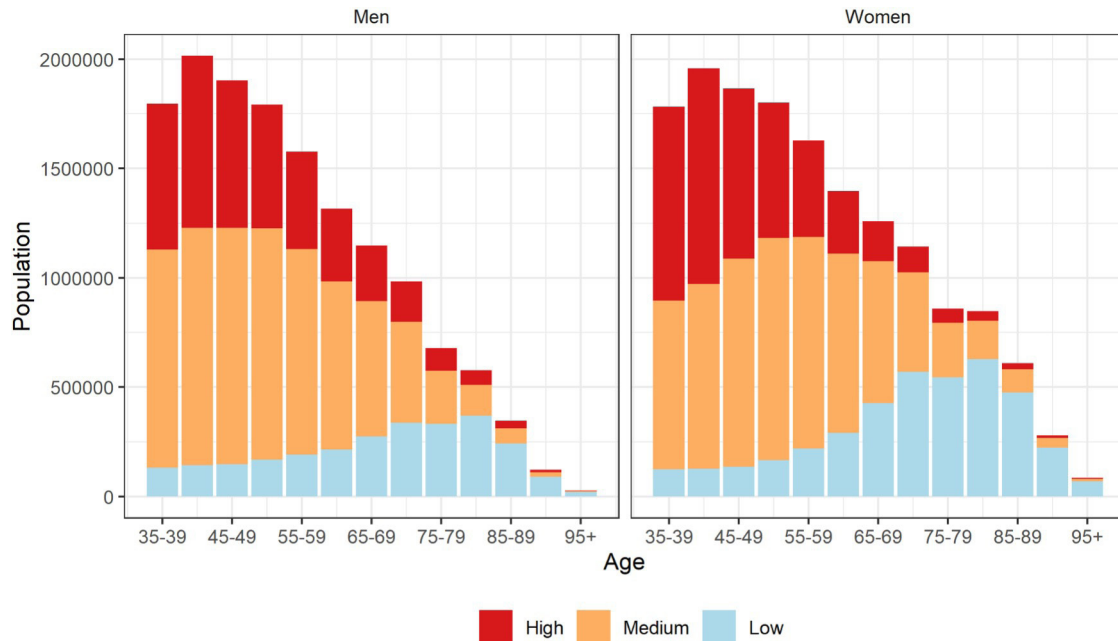
Figure 1 Distribution of the Spanish population by sex, age and educational attainment, 2018.

Data analysis

We estimated smoking-attributable mortality using population attributable fractions (PAFs) by age groups, cause of death, sex and educational level.[26] For each subpopulation group, the share of deaths attributable to smoking was estimated as follows:

$$PAF = \frac{prev_{smokers} \times (RR_{smokers} - 1) + prev_{former} \times (RR_{former} - 1)}{prev_{smokers} \times (RR_{smokers} - 1) + prev_{former} \times (RR_{former} - 1) + 1}$$

Where $prev_{smokers}$ is the smoking prevalence, $prev_{former}$ is the prevalence of former smokers, $RR_{smokers}$ are the relative risks in smokers compared with never smokers and RR_{former} are the relative risks of former smokers compared with never smokers.

The estimates of cause-specific mortality attributable to smoking was estimated for each subpopulation by multiplying the PAFs by the corresponding death counts. We assumed that the PAFs remain constant within age groups (ie, we applied the fraction estimated for the age group 35–54 to all 5-year age groups (35–39, 40–44, 45–49 and 50–54). The intermediate results of PAFs and cause-specific death counts by age, sex and educational level is attached as online supplemental material 1.

We estimated sex-specific and education-specific life expectancies at age 35 using standard life table calculations.[29] We used single-decrement life tables where it was assumed that the time lived for those who died was identical in each age interval ($_{n}a_{x}=n/2$, where n is the length of the age interval) in both the life table for all-cause mortality and the life table for all-cause mortality excluding smoking-related mortality. This implies that smoking-related deaths are assumed to occur, on average, in the middle of the interval. We then examined the contribution of smoking-related mortality on life expectancy at age 35 by calculating PGLE by re-estimating our life tables after eliminating smoking-attributable mortality. We studied

the contribution of smoking to life expectancy differences between high and low-educated groups. To do so, we used the approach developed by Andreev et al.[30] In mortality studies, decomposition analysis is based on the principle of separating life expectancy into demographic components that contribute to their dynamics, for instance, to assess the contribution that age and cause of death groups make to differences in life expectancy between populations (eg, between men and women, different time periods or educational attainment categories). The approach developed by Andreev et al[30] consisted of: (i) decomposing the differences in life expectancy between two populations (high and low educational groups in our case) into the contribution of each age-specific group and (ii) decomposing these age-specific contributions (estimated in (i)) into the contribution of individual smoking-related and non-smoking-related causes of death (for both smoking and non-smoking related mortality), which was done by multiplying the age-specific contributions by the relative importance each cause to total mortality differences in each age group.

Finally, we grouped the causes of death into three groups of smoking-related causes (cancer, cardiometabolic diseases and respiratory diseases) and one group for all non-smoking-related causes to visualise the contribution of age groups and groups of causes of death to the educational differences in life expectancy.

Patient and public involvement

There was no formal patient or public involvement in the project design, data collection or analysis.

RESULTS

Sample characteristics

For the period 2016–2019, we estimated 219 086 smoking-related deaths among the individuals aged 35 years and

Table 1 Smoking-related deaths coded according to the 10th revision of the International Classification of Diseases (ICD-10)

Diseases	ICD-10 code
Cancer	
Malignant neoplasms of the lung, bronchus, trachea	C33-C34
Lip, oral cavity, pharynx	C00-C14
Oesophagus	C15
Stomach	C16
Pancreas	C25
Larynx	C32
Cervix uteri	C53
Kidney, renal pelvis	C64-C6
Urinary bladder	C67
Acute myeloid leukaemia	C92.0
Colon and rectum	C18-C20
Liver	C22
Cardiometabolic	
Ischaemic heart diseases	I20-I25
Other heart diseases	I00-I09, I26-I28, I30-I51
Cerebrovascular diseases	I60-I69
Atherosclerosis	I70
Aortic aneurysm	I71
Other vascular diseases	I72-I78
Diabetes mellitus	E10-E14
Respiratory	
Influenza	J09-J11
Pneumonia	J12-J18
Tuberculosis	A15-A19
Chronic obstructive pulmonary disease	J40-J44

older, equalling 13.0% of all deaths. Of those who died from smoking-attributable mortality, 83.7% were men, 51.6% were only aged 35–74 years and 48.5% had low educational attainment.

PGLE if smoking is eliminated

The educational differences in the excess number of smoking-related deaths also translated to differences in life expectancy. Consistent with their higher levels of smoking-attributable mortality, less educated men would experience the greatest life expectancy gains if smoking was eliminated (table 3). Overall, life expectancy at age 35 equalled 46.1 years for men and 51.3 years for women in 2016–2019 but was 5.3 years higher among the high-educated than among the low-educated in the case of men, while the difference was 2.9 years among women. Life expectancy for both sexes and all three educational groups would have been higher in the absence of smoking. However, while for men PGLE were greatest

among the low educated (3.1 years) and lowest among the high educated (2.1 years), for women, there were few educational differences in PGLE when smoking was eliminated. In fact, the PGLE were slightly higher among the high-educated (0.9 years) compared with the low-educated (0.6 years).

Table 3 also shows that smoking has made a noticeable contribution to sex differences in life expectancy. At age 35, women outlived men by 5.2 years but that gap would have been only 3.2 in the absence of smoking.

Contribution of cause-specific smoking-related mortality to educational gaps in life expectancy

Among men, out of the 5.3 years' high-low education gap in life expectancy at age 35, smoking-related causes of death accounted for 1.5 years (28.2%) (figure 2). In the case of women, the corresponding contribution was −0.2 years out of the 2.9 years (−5.5%). These smoking contributions to educational differences in life expectancy were found to vary across age and cause of death. Among men, the contributions of smoking showed an inverse U-shape pattern peaking at around age 60–64 and with low contributions at young and old age groups. Smoking-related cancer deaths were most prominent among 50–74 years old, and showed overall the highest contributions. Cardiometabolic causes attributed to smoking played an important role in middle-aged (35–64), whereas smoking-related respiratory diseases were proportionally most important above age 75. Among women, contributions from smoking-related causes were rather small at ages under 60 years, and they were negative after age 60 as smoking and smoking-attributable mortality was higher among higher educated groups compared with their low educated counterparts. For additional analyses of high-medium and medium-low educated groups (see online supplemental figures S1 and S2).

DISCUSSION
Summary of the main results

With this study, we aimed to estimate the contribution of smoking to life expectancy by educational attainment and the contribution of cause-specific smoking-related mortality to educational inequalities in life expectancy among Spanish men and women. Our findings show that life expectancy would have been around 2.6 years higher among men and 0.6 years among women if smoking was eliminated. This means that smoking translates in lower life expectancy for both sexes but the contribution is noticeably larger among men.

Our findings also reveal that life expectancy was lower among the group with low levels of education than those with high levels of education, which goes in line with previous studies.[23 24 31] However, life expectancy and gaps differed between sex when smoking was taken into consideration. While for men smoking had a higher contribution on life expectancy among low-educated (3.1 years) and a lower contribution among high-educated

Table 2 Proportions of current and former smokers by age groups, sex and education level

		Men								Women							
		Education								Education							
Smokers	Age	Low		Medium		High		Total		Low		Medium		High		Total	
Current		Prop	N	Prop	N	Prop	N	**Prop**	**N**	Prop	N	Prop	N	Prop	N	**Prop**	**N**
	35–54	0.43	399	0.36	1555	0.21	623	**0.32**	**2577**	0.25	204	0.32	1275	0.20	742	**0.26**	**2221**
	55–64	0.33	341	0.30	556	0.22	202	**0.29**	**1099**	0.22	254	0.25	520	0.21	234	**0.23**	**1008**
	65–74	0.17	251	0.18	184	0.14	92	**0.17**	**527**	0.06	132	0.13	176	0.11	62	**0.09**	**370**
	75+	0.08	149	0.10	62	0.08	23	**0.09**	**234**	0.01	41	0.05	25	0.07	14	**0.02**	**80**
	Total	**0.25**	**1140**	**0.33**	**2357**	**0.21**	**940**	**0.28**	**4437**	**0.10**	**631**	**0.27**	**1996**	**0.19**	**1052**	**0.20**	**3679**
Former																	
	35–54	0.21	184	0.26	1056	0.26	706	**0.25**	**1946**	0.13	101	0.22	805	0.26	916	**0.22**	**1822**
	55–64	0.42	416	0.45	799	0.41	417	**0.43**	**1632**	0.18	186	0.28	572	0.38	382	**0.28**	**1140**
	65–74	0.54	795	0.52	524	0.55	315	**0.53**	**1634**	0.12	244	0.21	258	0.31	139	**0.17**	**641**
	75+	0.54	982	0.55	302	0.57	190	**0.54**	**1474**	0.04	153	0.11	77	0.20	66	**0.06**	**296**
	Total	**0.42**	**2377**	**0.31**	**2681**	**0.30**	**1628**	**0.33**	**6686**	**0.10**	**684**	**0.21**	**1712**	**0.25**	**1503**	**0.19**	**3899**
Never																	
	35–54	0.36	315	0.37	1471	0.53	1501	**0.43**	**3287**	0.63	477	0.46	1628	0.54	1844	**0.51**	**3949**
	55–64	0.26	259	0.25	453	0.37	335	**0.28**	**1047**	0.60	669	0.47	852	0.40	388	**0.49**	**1909**
	65–74	0.29	441	0.31	314	0.31	183	**0.30**	**938**	0.82	1665	0.66	761	0.58	241	**0.74**	**2667**
	75+	0.38	739	0.35	180	0.35	121	**0.37**	**1040**	0.95	3460	0.84	608	0.74	194	**0.92**	**4262**
	Total	**0.33**	**1754**	**0.35**	**2418**	**0.50**	**2140**	**0.39**	**6312**	**0.80**	**6271**	**0.52**	**3849**	**0.56**	**2667**	**0.61**	**12 787**

51 cases out of 37 851 (0.1%) did not have information on smoking status and were removed from the database. To correct for sample bias, sample weights that were included in the datasets were applied to obtain the smoking status prevalences.
Source: National Health Survey 2017 and European Survey of Health in Spain 2019/2020.

(2.1 years), the contribution of smoking among women resulted in narrower differences across educational groups. The higher PGLE values among men also suggest that they (especially lower educated men) have the most to gain from quitting smoking.

Comparison and explanation of results

Our findings are consistent with previous studies on the impact of smoking-attributable mortality on life expectancy that have found that smoking played an important role in the stagnation of life-expectancy increases among men in many North-Western European countries in the 1950s and 1960s, and in other European countries and among women in more recent decades.[4 6 32]

Our findings also show an important educational gradient with a high contribution of smoking to educational inequalities in life expectancy among men, but not among women. The contribution of smoking on the life expectancy gap between the highest and the lowest educated groups was substantial among men as it accounted for 28% of the gap, but among women, the gap was negligible (−6%). Regarding specific smoking-related causes of death, our results show that cancer is the group of causes with the greatest burden of mortality. Yet, at young ages, cardiometabolic diseases predominate within smoking-related mortality, whereas at older ages the most prevalent smoking-related causes contributing to educational gaps in life expectancy were respiratory diseases. Our findings also show that among women the contributions of smoking-related causes are rather small at ages under 60 years and they are negative after age 60 as smoking was more common among higher educated elderly. These inverse educational gradients in smoking-related mortality at ages 60 and over represent a unique feature of smoking in Spain.[14–17] Therefore, our results need to be interpreted in the context of differences in

Table 3 Life expectancy (LE) at age 35, LE excluding smoking-attributable mortality, potential gains in life expectancy (PGLE) by eliminating smoking-related mortality by sex and educational groups, Spain 2016–2019

		LE	LE without smoking	PGLE
Men	**All**	**46.1**	**48.7**	**2.6**
	High	48.3	50.4	2.1
	Medium	46.3	48.9	2.6
	Low	43.0	46.1	3.1
Women	**All**	**51.3**	**51.9**	**0.6**
	High	52.7	53.5	0.9
	Medium	51.6	52.3	0.7
	Low	49.7	50.3	0.6

Figure 2 Age and cause-specific contributions of smoking-related mortality and non-smoking related mortality to educational inequalities in life expectancy at age 35 between high-low educational level groups by sex, Spain 2016–2019.

the smoking epidemic model.[32] [33] In Spain, women started to smoke 30 years later than women in other high-income countries (eg, the UK or the USA) mainly due to contextual factors, that is, political, social and economic transformations including women's participation in the workforce and access to tertiary education did not really accelerate until after the Franco dictatorship (1939–1975). For instance, when a decline in smoking among college students started in the USA around the 1970s, higher educated women in Spain started to smoke. Our findings are consistent with Haeberer *et al*[22] who found that Spanish women aged 55 years and over with high socioeconomic status showed higher smoking-related mortality. As Wensink *et al*[34] point out, the continuous increase in smoking-attributable mortality in older women cohorts remains a cause for serious concern.

Implications and future research
The educational disparity we have found in smoking-related mortality among men represents one example of how smoking can lead to socioeconomic inequalities in health and mortality. This pattern of educational inequality among men can be reduced by increasing the prevalence of never smokers or quitters among less-educated individuals. To do so, tobacco control campaigns should target this specific and vulnerable population by investing more efforts and resources dedicated to find evidence-based smoking cessation interventions and approaches that target this specific population who continue to suffer the most from nicotine dependence. As Potter *et al* have recently reported,[35] intersectionality— or the interaction between multiple sociodemographic

inequality dimensions such as education, social class, sex and race and ethnicity—may be a promising framework for addressing health inequities in smoking cessation among individuals characterised by poor cessation outcomes (ie, individuals with low socioeconomic status or marginalised groups).

Continually monitoring smoking-attributable mortality is vital to keep a country's population healthy. Further research on monitoring smoking-attributable mortality more regularly must be a health priority in Spain since women picked up smoking later. This information can then be used to reinforce the importance of comprehensive tobacco control programmes. Hence, we believe that our findings are informative for Spanish health authorities who develop health policies and tobacco cessation programmes. In addition, given that men and women show different patterns in smoking prevalence and mortality, and that they are in different stages of the smoking epidemic model, sex and educational perspective in tobacco control policies needs to be taken in consideration when designing public health interventions (see also Bilal *et al*[14]).

We are also aware that smoking-attributable mortality is not the only factor that affects life expectancy. There are other behavioural risk factors such as alcohol consumption, diet, physical inactivity, that have an impact on mortality in the Spanish population. Yet, the impact of smoking on life expectancy we estimated (2.6 years for males and 0.6 years for females) is larger as compared with the one from alcohol using multiple causes of death estimates (0.15 years for males and 0.03 years for females).[36]

Future research should therefore also look into the contribution of other behavioural risks factors such as diet or physical inactivity, and particularly on the joint contribution of multiple lifestyles to social inequalities in health and mortality, in line with recent research.[31 37]

Limitations of this study

Certain limitations should be acknowledged when interpreting the results. First of all, we analyse mortality among the population aged 35 and over because smoking-related deaths rarely occur before the age of 35. Likewise, we also assume that the educational attainment of the population analysed is completed as moving up educational categories after age 35 is considered rare (even beyond age 25).[38] Second, estimating smoking-attributable mortality remains a challenge. Smoking per se is not a cause of death within the ICD. Therefore, estimates of smoking-related mortality need to rely on indirect techniques and the results should be interpreted with this caution in mind. We have opted for using PAF techniques that rely on smoking prevalence and RRs to estimate smoking-attributable mortality. The main advantage of these indicators is that they provide cause-specific mortality estimates as compared with other methods that only provide overall smoking-related mortality estimates.[39 40] For instance, Janssen et al[37] estimated a PGLE of 2.4 years among men and 0.3 years among women for Spain in 2014 using the Peto-Lopez method.[39] Their estimates are slightly higher among men and slightly lower among women compared with our more recent estimates for 2016–2019 for the total population (2.6 years among men and 0.6 years among women), but are in line with the expected time trends. Third, as mentioned before, PAFs rely on smoking prevalence. As we have used prevalence of smoking that comes from self-reported survey data, there might be some degree of underestimation. Moreover, the RRs of mortality between smokers and non-smokers were derived from follow-up cohort studies that had been conducted in the USA as Spain lacks this kind of data. We, therefore, had to assume that the RRs in the USA also apply in Spain, although this is a common practice in studies in the field.[22 37 41] Despite the above-mentioned limitations, the consistency of our results with other studies[22 37] seems to validate the accuracy of our overall smoking-attributable mortality estimates.

CONCLUSIONS

Our study demonstrates that smoking remains a major preventable risk factor of premature mortality in Spain, disproportionately affecting life expectancy of low-educated men. This educational disparity in the contribution of smoking to life expectancy among men represents an example of socioeconomic inequalities in health and mortality in Spain, therefore a public health priority. Tobacco control policies remain vital for addressing socioeconomic inequalities in health because educational differences in smoking prevalence are widening.

Particularly the low-educated population should therefore be targeted. Furthermore, the increase in smoking-attributable mortality in older high-educated women remains a cause for serious concern that should be monitored.

ORCID iDs
Bárbara Piñeiro http://orcid.org/0000-0003-4225-3500
Sergi Trias-Llimós http://orcid.org/0000-0002-8052-6736
Jeroen J A Spijker http://orcid.org/0000-0002-3957-9553
Amand Blanes Llorens http://orcid.org/0000-0001-8411-9567
Iñaki Permanyer http://orcid.org/0000-0002-7051-5144

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