Inequalities in lung cancer mortality by the educational level in 10 European populations

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Abstract

Previous studies have shown that due to differences in the progression of the smoking epidemic European countries differ in the direction and size of socioeconomic variations in smoking prevalence. We studied differences in the direction and size of inequalities in lung cancer mortality by the educational level of subjects in 10 European populations during the 1990's. We obtained longitudinal mortality data by cause of death, age, sex and educational level for 4 Northern European populations (England/Wales, Norway, Denmark, Finland), 3 continental European populations (Belgium, Switzerland, Austria), and 3 Southern European populations (Barcelona, Madrid, Turin). Age- and sex-specific mortality rates by educational level were calculated, as well as the age- and sex-specific mortality rate ratios. Patterns of educational inequalities in lung cancer mortality suggest that England/Wales, Norway, Denmark, Finland and Belgium are the farthest advanced in terms of the progression of the smoking epidemic: these populations have consistently higher lung cancer mortality rates among the less educated in all age-groups in men, including the oldest men, and in all age-groups in women up to those aged 60–69 years. Madrid appears to be less advanced, with less educated men in the oldest age-group and less educated women in all age-groups still benefiting from lower lung cancer mortality rates. Switzerland, Austria, Turin and Barcelona occupy intermediate positions. The lung cancer mortality data suggest that inequalities in smoking contribute substantially to the educational differences in total mortality among men in all populations, except Madrid. Among women, these contributions are probably substantial in the Northern European countries and in Belgium, but only small in Switzerland, Austria, Turin and Barcelona, and negative in Madrid. In many European countries, policies and interventions that reduce smoking in less educated groups should be one of the main priorities to tackle socioeconomic inequalities in mortality. In some countries, particularly in Southern Europe, it may not be too late to prevent women in less educated groups from taking up the smoking habit, thereby avoiding large inequalities in mortality in the future in these countries.
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1. Introduction

The habit of smoking usually spreads through populations like an epidemic with four stages. In stage 1, smoking is an exceptional behaviour and mainly a habit of men and people in higher socioeconomic groups. In stage 2, smoking becomes more common. Rates among men peak at 50%–80% and are equal among socioeconomic groups or higher among higher socioeconomic groups. In women, these patterns usually lag 10–20 years behind those of men. Smoking is first adopted by women from higher socioeconomic groups. In stage 3, prevalence rates among men decrease to approximately 40% since many men stop smoking, especially those who are better off. Women reach their peak rate (35%–45%) during this stage, and at the end of this stage their rates also start to decline. In stage 4, prevalence rates keep declining slowly for both men and women, and smoking becomes progressively more a habit of the lower socioeconomic groups. As a result, during the smoking epidemic, there is a reversal from a positive to a negative association between socioeconomic status and smoking [1].

Different countries are in different stages of the smoking epidemic, as shown by international-comparative studies of smoking prevalence rates by age, sex and socioeconomic status [2,3]. A previous study which we conducted, and which used data from surveys undertaken around 1990 in 12 Western European countries, found positive associations between education and smoking (implying a higher smoking prevalence in more educated groups) among men and women of all ages in Portugal, among younger and older women in Spain, and among older women in Italy and France. This suggested that countries in Southern Europe were still in stage 2 (Portugal) or at the beginning of stage 3 (Spain, Italy, France) of the smoking epidemic. On the other hand, we found negative associations between education and smoking among men and women of all ages in Great Britain, Norway, Sweden and the Netherlands. In West Germany, negative associations were found only for men and younger women, while in Finland, negative associations were limited to men. This suggested that countries in Northern Europe were already in stage 4 (Great Britain, Norway, Sweden, the Netherlands) or at the end of stage 3 (West Germany, Finland) [4].

We now report on a study of socioeconomic inequalities in lung cancer mortality in 10 European countries during the 1990's. Socioeconomic variations in lung cancer incidence and mortality have been reported for a number of European countries, including Italy [5], the Netherlands [6,7], Spain [8,9], Sweden [10], Switzerland [11,12], and the United Kingdom [13,14]. However, a systematic analysis of variations between countries in the size and pattern of socioeconomic inequalities in lung cancer mortality has not yet been performed. Such

a systematic analysis may shed further light on, first, the progression of the smoking epidemic and, second, the role smoking plays in socioeconomic inequalities in total mortality.

Lung cancer mortality rates reflect the exposure of populations to smoking over previous decades, and in a sense summarise that exposure and form a useful complement to survey data, which are not as widely available for comparisons between countries. We will therefore use the socioeconomic patterning of lung cancer mortality to make inferences about the stage of the smoking epidemic that countries find themselves in. We will also use the lung cancer mortality rates by socioeconomic group to obtain an indication of differences in the role of smoking in generating socioeconomic inequalities in total mortality in different populations. Smoking accounts for a considerable proportion of premature deaths in developed countries, partly through its effect on lung cancer (for which aetiological fractions are in the order of 90% or more), partly through its effect on other causes of death (for which aetiological fractions are mostly smaller, but absolute numbers of smoking-induced deaths may be larger) [15]. Previous studies have indicated that smoking accounts for a considerable part of the excess mortality in lower socioeconomic groups, at least in some countries [16–18]. However, it is likely that the role of smoking differs between countries that are in a different stage of the smoking epidemic. As Peto and colleagues have shown, one can use lung cancer rates in national populations to indirectly estimate the contribution of smoking to premature mortality in these populations [19,20], and, similarly, lung cancer rates in different socioeconomic groups can be used to indicate the contribution of smoking to socioeconomic variations in total mortality.

Thus, the aims of our study were: (1) to describe socioeconomic inequalities in lung cancer mortality in different European populations; (2) to make inferences about the staging of the smoking epidemic in different European populations; (3) to make inferences about the contribution of smoking to socioeconomic inequalities in total mortality in different European populations.

2. Data and methods

2.1. Data

Table 1 presents a summary description of the data used in this study. We obtained data from seven national, one regional (Madrid) and two city-wide (Turin and Barcelona) registrations of mortality, all collected according to a longitudinal design in which persons enumerated during a census in the (early) 1990's were followed-up for various periods of time. Most studies covered the entire national, regional or local

Table 1
Data sources

Population	Follow-up period	Person-years at risk of total male population	Person-years at risk of total female population	Number of male deaths due to lung cancer	Number of female deaths due to lung cancer
England/Wales	1991–1996	587 136	679 078	1310	673
Norway	1990–1995	3 936 934	4 472 965	5450	2205
Denmark[a]	1991–1995	3 698 337	3 839 716	4854	3160
Finland	1991–1995	4 748 902	5 739 763	7681	1839
Belgium	1991–1995	9 329 715	10 924 258	27 137	4240
Switzerland	1991–1995	4 065 132	4 959 756	6234	1517
Austria	1991–1992	1 500 822	1 874 248	2238	759
Turin	1991–1996	990 986	1 237 383	2341	617
Barcelona	1992–1996	1 705 174	2 176 193	3666	468
Madrid	1996–1997	1 400 662	1 706 276	1984	251

[a] Ages 40–69 years.

populations, but the data for England/Wales come from a representative 1% sample of the national population (i.e. the Longitudinal Study of the Office of National Statistics), while the data for Switzerland cover the German-speaking parts only (approximately 70% of the total). For each population, the data-base used for this analysis included data on numbers of deaths and person-years at risk by sex, five-year age-group (age specified at start of follow-up, and ranging from age 40 years to age 90 years), and level of education.

Level of education was initially coded according to national classification schemes. Using guidelines from the International Standard Classification of Education [21] and the observed population distributions across national educational categories, we reclassified national levels of education into a common two-class scheme that leads to roughly similar population distributions across educational categories. For example, for England/Wales, the distinction is between less-than-A-level ("lower" education (less educated)) and A-level ("higher" education (more educated)). It is important to note that the "absolute" level of education in each of these categories (as measured, for example, in years of education) is not the same across countries, and that direct comparisons between countries of the levels of mortality in e.g. the less educated groups are not advisable. However, this does not present a problem for the analyses reported in this paper because the emphasis here is on international variation in differences in lung cancer mortality across the educational hierarchy. In the analysis, educational differences in lung cancer mortality are summarised by comparing mortality among those with a "lower" level of education (generally attained by between 60 and 80% of the male and 65 and 88% of the female population) to mortality among all those with a "higher" level of education. The exception is Switzerland where the only educational classification that we could apply produced a distribution with 22%

of the male and 47% of the female population in the less educated group.

Lung cancer was defined as code numbers 162, 163 and 165 of the ninth revision of the International Classification of Diseases [22]. Although these code numbers include some other tumours of the respiratory tract, the overwhelming majority will be lung cancer in all countries. The Danish data were coded according to the eighth revision (162, 163) and the tenth revision (C33, 34, 39), the Swiss data were coded according to the eight revision (162, 163).

2.2. Methods of analysis

We started by looking at age-standardised lung cancer mortality rates by population, sex, 10-year age-group and level of education. These rates were standardised by five-year age groups using the direct method and the European standard population of 1995 as the standard [23].

We then applied Poisson regression analysis to calculate mortality rate ratios adjusted for age (in five-year age-groups), using the more educated groups as reference groups. These calculations were performed with the SAS statistical package, version 6.12. This resulted in Rate Ratios with 95% Confidence Intervals (CIs), that were compared with Relative Indices of Inequality (a measure that, unlike the Rate Ratio, adjusts for differences between countries in the size of more and less educated groups) [24]. The latter gave almost exactly the same results in terms of the patterning of lung cancer mortality across the educational groups.

In order to indicate variations between countries in the proportion of total excess mortality in the less educated groups that is due to smoking, we used a modified version of the estimation procedure developed by Peto and colleagues [19,20] (see Appendix). Essentially, our method first estimates the proportion of smokers in
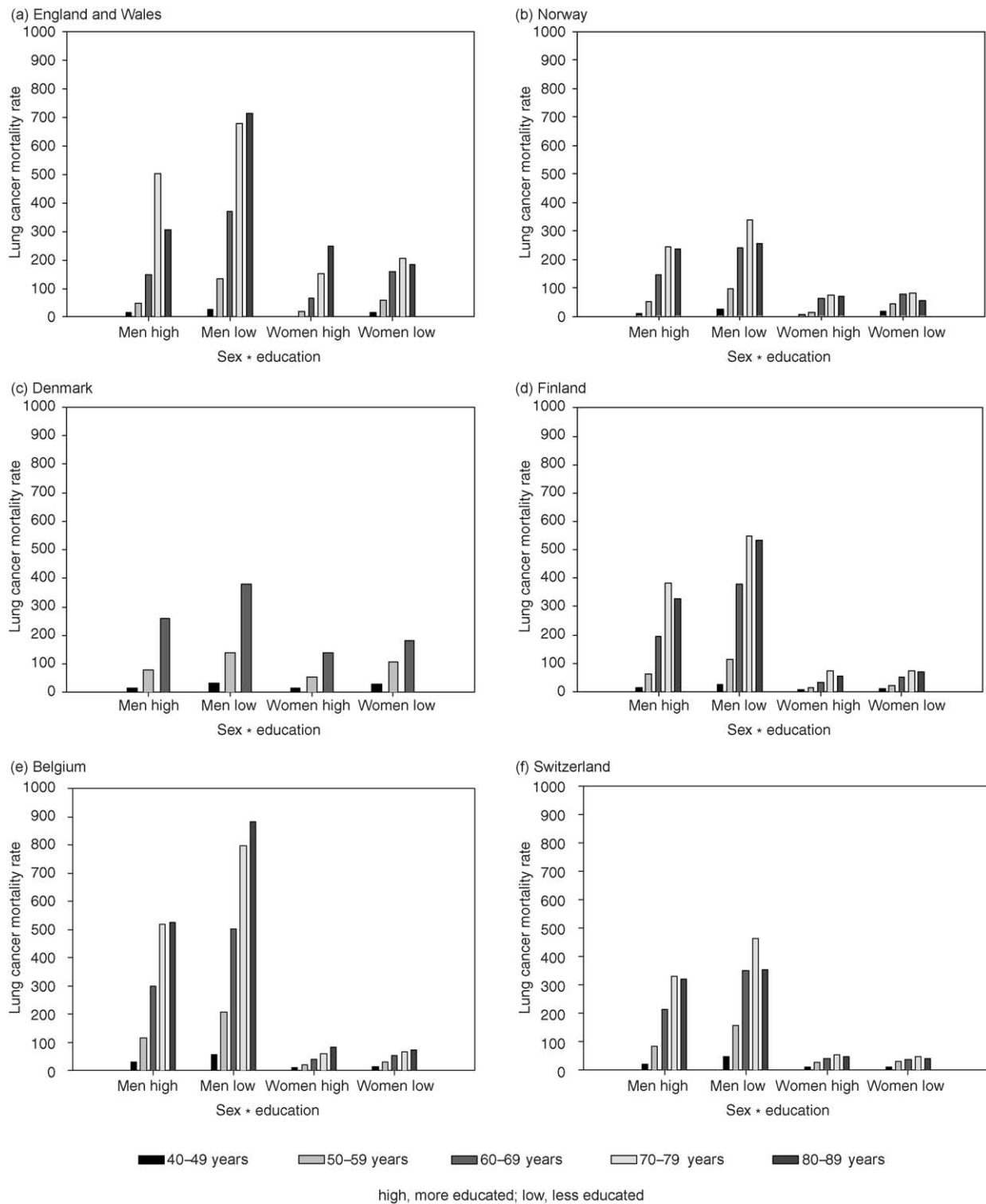
Fig. 1. (a) Lung cancer mortality rates for men and women from England and Wales per 100 000 person years at risk; (b) lung cancer mortality rates for men and women from Norway per 100 000 person years at risk; (c) lung cancer mortality rates for men and women from Denmark per 100 000 person years at risk; (d) lung cancer mortality rates for men and women from Finland per 100 000 person years at risk; (e) lung cancer mortality rates for men and women from Belgium per 100 000 person years at risk; (f) lung cancer mortality rates for men and women from Switzerland per 100 000 person years at risk; (g) lung cancer mortality rates for men and women from Austria per 100 000 person years at risk; (h) lung cancer mortality rates for men and women from Turin (Italy) per 100 000 person years at risk; (i) lung cancer mortality rates for men and women from Barcelona (Spain) per 100 000 person years at risk; (j) lung cancer mortality rates for men and women from Madrid (Spain) per 100 000 person years at risk.
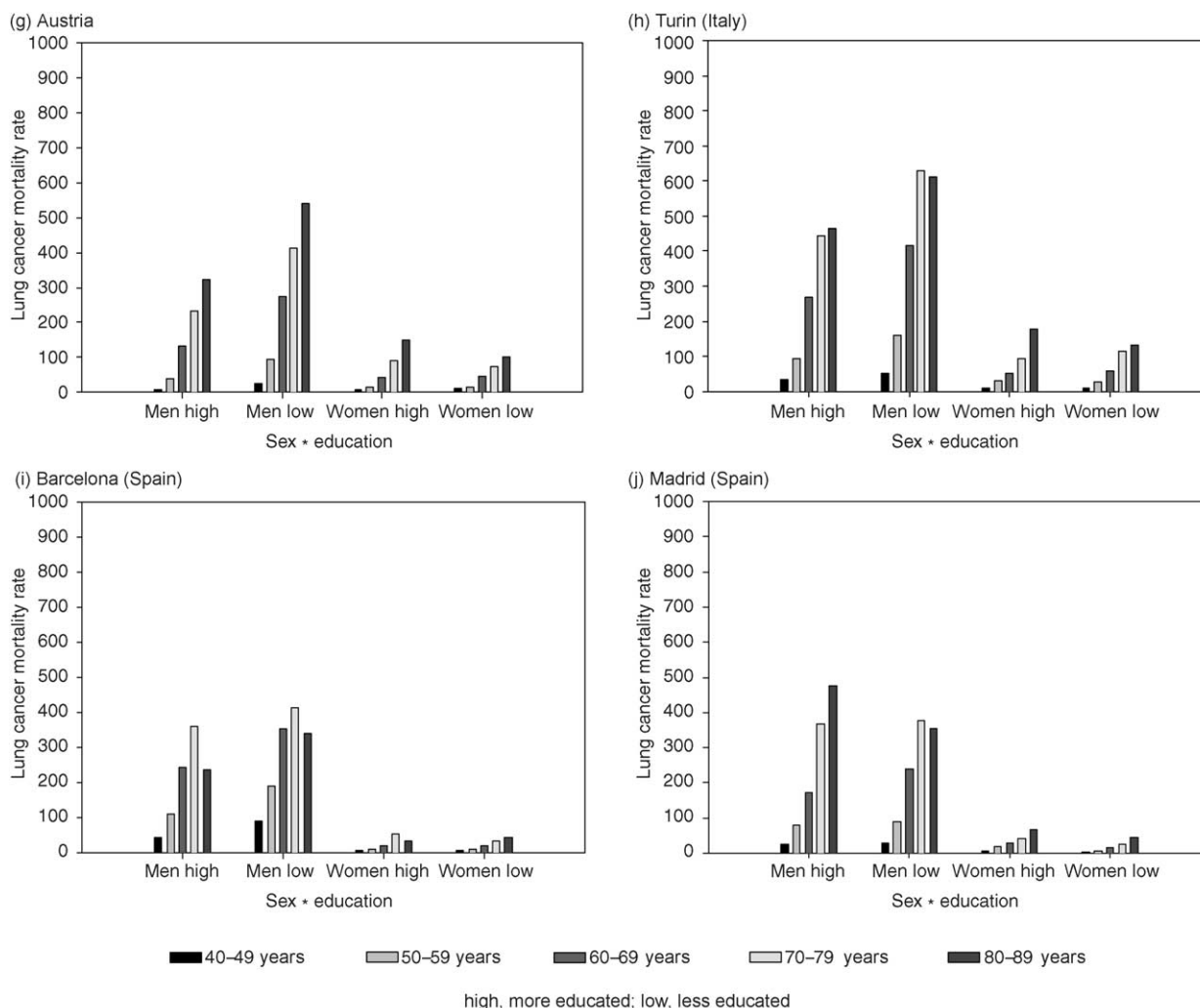
Fig. 1 (*continued*).

each educational group from its lung cancer mortality rate, then calculates the proportion of total deaths due to smoking in each educational group using the general formula for the aetiological fraction, and from this finally calculates the total excess deaths in the less educated groups that are attributable to smoking.

3. Results

Fig. 1 presents an overview of age- and sex-specific lung cancer mortality rates in the ''lower'' and ''higher'' educated groups in the ten populations included in this study. Lung cancer mortality rates generally increased with age, although in many populations the highest mortality rates were not found in the highest age-group(s), suggesting cohort effects with higher mortality rates in the more recently born birth cohorts. Lung cancer mortality rates were higher among men than women, but the size of the difference varied between the countries, e.g. in England/Wales, women's rates were

much closer to the rates of men than in most of the other countries. Lung cancer rates were usually higher among the less educated men and women than among those with higher education.

Table 2 presents a summary measure for the size of relative educational differences in lung cancer mortality, calculated for each ten-year age- and sex group in all ten populations included in this study. Among middle-aged men, inequalities in lung cancer mortality were found in all populations, although the differences were small and 95% CIs included 1.00 in Madrid. Among men, inequalities in lung cancer mortality persisted into old age in most populations, but the size of the differences diminished. Only in Madrid was an indication found that in the older birth cohorts (now aged 80–89 years) smoking has been more prevalent in the more than in the less educated groups: the rate ratio of lung cancer mortality was much smaller than 1 (although the 95% CI included 1). In Barcelona and Turin, inequalities in the lung cancer mortality rate were relatively small in this age-group among men.

Table 2a
Educational rate ratios and 95% Confidence Intervals (CIs) for lung cancer, men, ages 40–89 years

Population	Age group (years)				
	40–49	50–59	60–69	70–79	80–89
England/Wales	1.55 (0.75–3.20)	2.85 (1.68–4.83)	2.48 (1.73–3.55)	1.36 (1.01–1.83)	2.27 (1.11–4.63)
Norway	2.56 (1.79–3.66)	1.96 (1.56–2.47)	1.65 (1.41–1.92)	1.39 (1.17–1.64)	1.09 (0.78–1.54)
Denmark	2.47 (1.97–3.09)	1.80 (1.57–2.07)	1.47 (1.34–1.60)	–	–
Finland	1.79 (1.45–2.20)	1.84 (1.61–2.11)	1.97 (1.78–2.18)	1.44 (1.28–1.60)	1.66 (1.31–2.11)
Belgium	1.97 (1.74–2.22)	1.81 (1.68–1.95)	1.68 (1.59–1.78)	1.54 (1.44–1.65)	1.64 (1.43–1.87)
Switzerland	2.15 (1.69–2.74)	1.83 (1.60–2.10)	1.64 (1.50–1.79)	1.39 (1.28–1.52)	1.11 (0.94–1.30)
Austria	3.20 (1.72–5.97)	2.40 (1.67–3.45)	2.08 (1.68–2.58)	1.73 (1.38–2.16)	1.62 (1.19–2.21)
Turin	1.48 (1.01–2.17)	1.68 (1.30–2.17)	1.56 (1.30–1.87)	1.39 (1.12–1.73)	1.40 (0.93–2.10)
Barcelona	1.97 (1.56–2.47)	1.70 (1.45–2.00)	1.45 (1.29–1.63)	1.14 (1.00–1.30)	1.42 (1.08–1.86)
Madrid	1.26 (0.88–1.80)	1.12 (0.88–1.42)	1.39 (1.14–1.69)	1.03 (0.84–1.25)	0.74 (0.54–1.02)

Table 2b
Educational rate ratios and 95% confidence intervals (CIs) for lung cancer, women, ages 40–89 years

Population	Age group (years)				
	40–49	50–59	60–69	70–79	80–89
England/Wales	3.23 (0.43–24.49)	3.27 (1.20–8.92)	2.41 (1.28–4.55)	1.35 (0.78–2.31)	0.71 (0.36–1.41)
Norway	2.31 (1.42–3.76)	3.52 (2.06–6.00)	1.26 (0.94–1.68)	1.13 (0.79–1.63)	0.80 (0.44–1.47)
Denmark	1.96 (1.57–2.44)	1.95 (1.66–2.30)	1.32 (1.17–1.94)	–	–
Finland	1.42 (1.00–2.01)	1.48 (1.11–1.98)	1.54 (1.23–1.93)	0.98 (0.80–1.21)	1.17 (0.79–1.72)
Belgium	1.31 (1.04–1.65)	1.44 (1.19–1.74)	1.37 (1.16–1.62)	1.11 (0.90–1.37)	0.86 (0.64–1.15)
Switzerland	1.29 (0.93–1.78)	1.12 (0.90–1.39)	0.94 (0.78–1.14)	0.88 (0.72–1.07)	0.85 (0.62–1.17)
Austria	1.77 (0.91–3.41)	1.06 (0.58–1.94)	1.00 (0.71–1.42)	0.81 (0.59–1.12)	0.67 (0.45–0.98)
Turin	1.19 (0.51–2.79)	0.84 (0.49–1.44)	1.07 (0.67–1.71)	1.18 (0.71–1.97)	0.74 (0.41–1.35)
Barcelona	0.89 (0.49–1.64)	0.93 (0.55–1.57)	1.14 (0.73–1.77)	0.63 (0.44–0.90)	1.30 (0.65–2.59)
Madrid	0.55 (0.23–1.34)	0.38 (0.20–0.74)	0.61 (0.32–1.14)	0.62 (0.32–1.21)	0.64 (0.27–1.49)

For women, the pattern was more variable. Among middle-aged women, large relative inequalities (favouring the more educated groups) were found in some populations only (England/Wales, Norway, Denmark), while Madrid had rate ratios of lung cancer mortality that were consistently below 1. At older ages, inequalities were rarely demonstrated, although for women 60–69 years, higher lung cancer mortality rates in the less educated groups were found in England/Wales, Denmark, Finland and Belgium. A reversal from inequalities favouring the less educated groups, to inequalities favouring the more educated groups, as one moved from older age-groups (older birth cohorts) to younger age-groups (more recently born birth cohorts) could be observed in Austria, while many other populations also showed indications of such a pattern.

When all age-groups were combined, lung cancer mortality rates were higher in the less educated groups among men in all ten populations (Table 3). The largest relative differences were found in Austria, the smallest in Madrid. Among women, inequalities favouring the more educated groups were found in five populations only. In Switzerland, Austria, Turin and Barcelona, the rate ratios were close to 1, and 95% CIs included 1.

Among Madrid women, there was a considerable excess mortality from lung cancer in the more educated groups.

Table 3 also shows the relative inequalities in total mortality. The rate ratios are remarkably similar between populations, and are always above 1. Among men, the rate ratios for total mortality ranged between 1.19 in Madrid and 1.45 in Austria, and among women the rate ratios ranged between 1.17 in Madrid and 1.37 in Barcelona.

These patterns of lung cancer and total mortality suggest that the contribution of smoking to the socio-economic inequalities in total mortality differs substantially between countries. This is confirmed by Fig. 2 which presents indirect estimates of the contribution of smoking to excess total mortality in the "lower" educated groups for each of the ten countries. These estimates are based on a modified version of the indirect estimation method developed by Peto and colleagues (see Appendix), and while the absolute levels of these estimates have rather wide margins of uncertainty, they do provide a basis for comparison between countries. Among men, the estimated contribution of smoking to excess total mortality in the "lower" educated group ranged

Table 3
Educational rate ratios and 95% Confidence Intervals (CIs) for lung cancer and total mortality, by sex, in 10 populations

|	Men		Women	
	Lung cancer	All causes	Lung cancer	All causes
England/Wales	1.95 (1.60–2.36)	1.35 (1.29–1.43)	1.71 (1.23–2.38)	1.23 (1.16–1.32)
Norway	1.63 (1.49–1.80)	1.39 (1.36–1.42)	1.58 (1.31–1.90)	1.29 (1.25–1.33)
Denmark[a]	1.65 (1.53–1.77)	1.33 (1.30–1.36)	1.60 (1.47–1.75)	1.29 (1.27–1.33)
Finland	1.75 (1.65–1.86)	1.36 (1.34–1.38)	1.29 (1.14–1.45)	1.25 (1.23–1.28)
Belgium	1.69 (1.63–1.75)	1.36 (1.34–1.37)	1.27 (1.16–1.40)	1.30 (1.28–1.32)
Switzerland	1.53 (1.45–1.61)	1.28 (1.27–1.30)	0.98 (0.88–1.09)	1.22 (1.21–1.24)
Austria	1.97 (1.73–2.23)	1.45 (1.41–1.50)	0.92 (0.76–1.10)	1.33 (1.29–1.38)
Turin	1.52 (1.36–1.70)	1.24 (1.19–1.28)	1.00 (0.78–1.28)	1.19 (1.13–1.25)
Barcelona	1.44 (1.34–1.55)	1.31 (1.28–1.35)	0.88 (0.71–1.10)	1.37 (1.33–1.41)
Madrid	1.13 (1.02–1.26)	1.19 (1.15–1.24)	0.55 (0.40–0.75)	1.17 (1.10–1.24)

[a] Includes ages 40–69 years only.
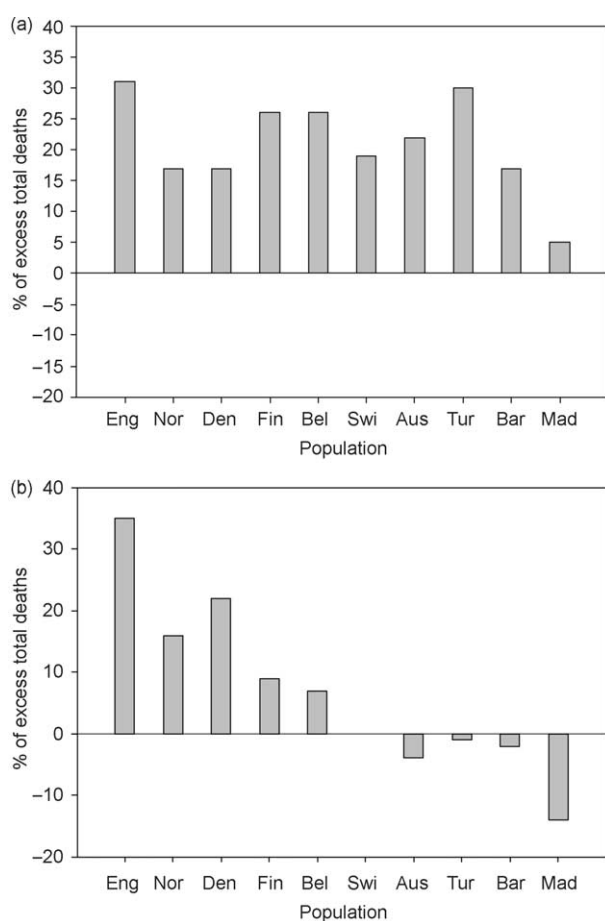
Fig. 2. (a) Percentage of excess total deaths in the less educated groups attributable to smoking among men; (b) percentage of excess total deaths in the less educated groups attributable to smoking among women.

between 5% in Madrid and 30% in England/Wales and Turin. Among women, the proportion of excess total mortality due to smoking ranged between −14% in Madrid (indicating that the effect of inequalities in smoking is to reduce inequalities in total mortality) and 35% in England/Wales.

4. Discussion

4.1. Summary of the main findings

Our results suggest that England/Wales, Norway, Denmark, Finland and Belgium are the farthest advanced in the progression of the smoking epidemic: these populations have consistently higher lung cancer mortality rates among the "lower" educated in all age-groups including the oldest ones in men, and in all age-groups until the age-group of 60–69 years in women. Madrid appears to be less advanced, with "lower" educated men in the oldest age-group and "lower" educated women in all age-groups still benefiting from lower lung cancer mortality rates. Switzerland, Austria, Turin and Barcelona have intermediate positions.

The lung cancer mortality data suggest that in the 1990's inequalities in smoking contributed substantially to the educational differences observed in total mortality among men in all populations, except Madrid. Among women, contributions of smoking to the inequalities in mortality were probably substantial in England/Wales, Norway and Denmark, smaller in Finland and Belgium, but close to zero in Switzerland, Austria, Turin and Barcelona, and negative in Madrid.

4.2. Main limitations and sources of bias

International comparisons of mortality data by cause of death may be subject to bias because of differences between countries in certification and coding of the causes of death. Although certification and coding of lung cancer is more straightforward, than that for many other causes of death [25], we cannot exclude the possibility that some of the differences between populations in the levels of lung cancer mortality as observed in Fig. 1, or as expressed in the estimated contribution of smoking to excess total mortality in the less educated groups, are due to such data problems. It seems unlikely that the recognition of lung cancer as a cause of death

differs between educational groups, because health-care systems provide reasonably equal access to all populations included in this study [26].

Measurement of socioeconomic inequalities in mortality is not straightforward, and comparisons between countries may be subject to bias because of differences in the inclusion of specific population groups, differences in the measurement of education, and differences in the length of follow-up. Despite our efforts at standardisation, some differences are bound to remain because data collection systems and educational systems differ between European countries. This applies to Switzerland in particular, because the educational distribution in this country is rather different from that in the other countries (see Data and methods). Depending on the form of the educational gradient of lung cancer mortality in Switzerland, its Rate Ratios may be biased towards 1 simply because they compare less extreme groups.

Our attempt at quantifying the contribution of smoking to inequalities in total mortality used a modification of a method developed by Peto and colleagues. Despite this simplification, our results are, by and large, compatible with those published by Peto and colleagues in Ref. [19]. For each country, we compared the proportions of total mortality that can be attributed to smoking, as calculated in our analysis, with those published by Peto and colleagues for the same country in 1990, and found the international patterns to be quite similar (data not shown). However, it is important that our estimates of the contribution of smoking to excess total mortality in the "lower" educated groups are based on a number of assumptions, only some of which are shared in the method of Peto and colleagues.

The most crucial assumption relates to the estimation of smoking prevalences from lung cancer mortality rates (see Appendix). Peto's method, like ours, uses the lung cancer rate among smokers and non-smokers in a large cohort study conducted by the American Cancer Society (Cancer Prevention Study (CPS-II) to estimate the (unobserved) proportion of smokers in a population from its (observed) lung cancer mortality rate. This calculation is based on the assumption that the CPS-II smoker and non-smoker lung cancer mortality rates are a valid approximation of the (unobserved) smoking-specific lung cancer mortality rates in the population under study. In our analysis, this assumption not only has to be made for each national population (as in Peto's analysis), but also for each educational group in each country. Our own data suggest that this assumption is violated in some countries, because observed lung cancer mortality rates sometimes are so high (e.g. in less educated men in Belgium—Fig. 1), that CPS-II data suggest a smoking prevalence of higher than 100%. We have, in these cases, arbitrarily fixed the smoking prevalence at 100%, but that only partially solves the

problem that the lung cancer mortality rate among non-smokers probably differs between countries and/or between educational groups due to other factors, e.g. air pollution, occupational exposures or diet [27]. Clearly, the results, as presented in Fig. 2, can only be seen as a crude indication of the variation between countries in the contribution of smoking to inequalities in total mortality.

4.3. Comparison with previous studies

The results of this study correspond well with those of our previous study on the basis of 1990 smoking prevalence data by educational level from national health interview and multipurpose surveys [4]. This previous study suggested that countries in Northern Europe were already in stage 4 or at the end of stage 3 of the smoking epidemic, while countries in Southern Europe were mostly at the beginning of stage 3. This is confirmed by the lung cancer mortality patterns presented here that 'integrate' the exposure of these populations to tobacco smoke over previous decades. The current analysis also adds a few continental-European countries, of which Belgium seems to be roughly in the same stage as countries in Northern Europe, while Switzerland and Austria occupy intermediate positions between the Northern and Southern European countries studied.

It is interesting to compare the results of these studies of educational differences in either smoking or lung cancer mortality with those of studies comparing time-trends (including cohort patterns) of lung cancer mortality between the same set of European countries [28,29]. The main contrast observed is between the United Kingdom, where lung cancer mortality among men and women peaked before all other countries, and Spain, where even among men lung cancer mortality is still rising. The other countries are in between, without a clear advance of Norway, Denmark, Finland and Belgium compared with Switzerland, Austria and Italy, as observed in our analysis.

There have been a number of longitudinal studies on the contribution of smoking to socioeconomic inequalities in either lung cancer incidence or mortality, or to total mortality, linking smoking as reported during a base-line measurement to mortality in the same individuals as measured during a defined follow-up period [6,7,14,17,18,30]. Among men in Northern European populations, higher smoking prevalences in lower socioeconomic groups typically explain between 10 and 20% of the gap in total mortality [14,16–18]—which is not inconsistent with our cruder estimates (Fig. 2). However, more interesting is the fact that several studies have found that smoking can only account for a small part of the higher lung cancer incidence or mortality rates in the lower socioeconomic groups [6,7,30].

Because smoking is estimated to account for between 80 and 90% of all lung cancer cases in the population, one would expect a very high contribution to the observed socioeconomic inequalities in lung cancer as well, but that is not what these studies have found. For example, in two Scottish studies smoking accounted for approximately 55% of the higher lung cancer mortality rate in manual compared with non-manual men [30]. One possible explanation is that this is due to measurement error: smoking in these cohort studies is usually measured on the basis of self-report on a single occasion, and considerable degrees of misclassification, in terms of the intensity of exposure to tobacco smoke over a relevant part of the life-course, may have occurred, thereby diluting the associations with lung cancer. However, another possible explanation is that other risk factors play a more important role than was previously thought, particularly in the lower socioeconomic groups (see above). This is clearly an area for further research, and until individual-level studies confirm the quantitative contribution of smoking, as suggested in Fig. 2, the latter should be seen as a very first approximation only.

4.4. Implications

To the extent that socioeconomic inequalities in lung cancer mortality reflect differences in smoking behaviour, they also point to important entry-points for interventions and policies to tackle inequalities in health. According to a recent review, interventions and policies that have been shown to be effective in reducing smoking in lower socioeconomic groups include raising tobacco taxes, smoking restrictions in work-places and nicotine replacement therapy [31]. Implementing such measures should be a top priority for public health throughout Europe.

The model of the smoking epidemic suggests that socioeconomic inequalities in lung cancer mortality are likely to widen further, particularly among women and in Southern European countries. It may not be too late to prevent the less educated groups from taking up the smoking habit, and effective public health action may thereby avoid larger inequalities in mortality in the future.

Acknowledgements

Appendix. Estimation of the proportion of excess total mortality in the less educated group that is due to smoking

In a first step, we used the lung cancer mortality rates in less and more educated groups to indicate the approximate proportions due to smoking of total mortality in these groups, and, in a second step, we used these proportions to calculate the proportion of total excess mortality in the less educated group that is attributable to smoking.

For the first step, the procedure was as follows. As suggested by Peto and colleagues, the prevalence of smoking can be estimated indirectly from the lung cancer mortality rate, by comparing the lung cancer mortality rate in the population of interest with the lung cancer rate among smokers and non-smokers in a large cohort study conducted by the American Cancer Society (CPS-II), and by fitting the proportions of smokers and non-smokers to the observed lung cancer mortality rate [19,20]. This was done separately for each educational group, ten-year age-group and sex. The assumption here is that the CPS-II smoker and non-smoker lung cancer mortality rates are a valid approximation of the (unobserved) smoking-specific lung cancer mortality rates pertaining to these various populations.

With the proportions of smokers and non-smokers so obtained, the proportion of total mortality in each educational group, ten-year age-group, and sex that is attributable to smoking was calculated. Here, we simplified Peto's procedure which uses information on mortality from a range of other smoking-related causes of death that was not available in our study. Instead, we used the fact that the aetiological fraction (the proportion of all cases of disease or death in a population that can be attributed to a particular determinant) is a function of the proportion of the population that is exposed (i.e. the proportion of smokers that we already obtained) and the relative risk: $EF = p(RR-1)/\{p(RR-1)+1\}$. The relative risk for smoking of total mortality is approximately 2 in many epidemiological studies, including the CPS-II [19,20]. We have assumed that this relative risk applies to all population groups included in this study. Similarly to the original method proposed by Peto and colleagues, we halved these aetiological fractions to remove residual confounding and to obtain conservative estimates of the numbers of deaths attributable to smoking.

In the second step, we used the aetiological fractions for smoking of total mortality (by educational group, ten-year age-group and sex) and the total mortality rate to calculate the absolute rate of mortality that is due to smoking in each educational group and sex (aggregated over age-groups). The difference between more and less educated groups in these rates was then used to calculate

the proportion of the total excess death rate in the less educated groups that is attributable to smoking.

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