Educational inequalities in cause-specific mortality in middle-aged and older men and women in eight western European populations

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Summary

Background **Studies of socioeconomic disparities in patterns of cause of death have been limited to single countries, middle-aged people, men, or broad cause of death groups. We assessed contribution of specific causes of death to disparities in mortality between groups with different levels of education, in men and women, middle-aged and old, in eight western European populations.**

Methods **We analysed data from longitudinal mortality studies by cause of death, between Jan 1, 1990, and Dec 31, 1997. Data were included for more than 1 million deaths in 51 million person years of observation.**

Findings **Absolute educational inequalities in total mortality peaked at 2127 deaths per 100 000 person years in men, and at 1588 deaths per 100 000 person years in women aged 75 years and older. In this age-group, rate ratios were greater than 1·00 for total mortality and all specific causes of death, apart form prostate cancer in men and lung cancer in women, showing increased mortality in low versus high eductational groups. In men, cardiovascular diseases accounted for 39% of the difference between low and high eductational groups in total mortality, cancer for 24%, other diseases for 32%, and external causes for 5%. Among women, contributions were 60%, 11%, 30%, and 0%, respectively. The contributions of cerebrovascular disease, other cardiovascular diseases, pneumonia, and COPD strongly increased by age, whereas those of cancer and external causes declined. Although relative inequalities in total mortality were closely similar in all populations, we noted striking differences in the contribution of specific causes to these inequalities.**

Interpretation **Research needs to be broadened to include older populations, other diseases, and populations from different parts of Europe. Effective interventions should be developed and implemented to reduce exposure to cardiovascular risk factors in low-educational groups.**

Introduction

Variations in patterns of cause of death between socioeconomic groups provide valuable clues for the explanation of disparities in health because they point to the specific mechanisms linking low socioeconomic position to ill health. Most studies of socioeconomic variations in patterns of cause of death have been done in only one country,[1–3] and international comparisons have been done before the 1990s[4,5] or in single groups of specific causes of death, such as cardiovascular mortality.[6,7] Some of these international comparative studies yielded important results. Kunst and colleagues[4] showed that during the 1980s the contribution of broad groups of causes of death to inequalities in overall mortality by occupation in middle-aged men varied strongly between northern European and southern European countries.[4]

Here, we use the most recent data for mortality by cause of death for a broad range of male and female populations from various regions in western Europe. We distinguish detailed causes of death and, because the burden of mortality is highest in older people (≥65 years), we include data for older populations. Our aim was to broaden the scope of the evidence base for European public-health policies,[9,10] by assessing the contribution of specific causes of death to differences in mortality by socioeconomic level.

Methods

Data retrieval

Data from longitudinal mortality studies that were based on linkage of vital registries to population censuses were acquired for European populations in Finland, Norway, England and Wales, Belgium, Switzerland, Austria, Turin, Barcelona, and Madrid. All data consisted of total national, regional (Madrid), and urban (Turin and Barcelona) populations, except for England and Wales where the data cover a representative sample of 1% of the English and Welsh populations and for Switzerland where the data cover all Swiss nationals living only in the German speaking parts of the country. Urban and regional data for populations from Italy and Spain were used because national data were not available for these countries. Linkage of mortality data with the census was close to 100% for all populations, with the exception of Madrid where linkage was obtained for 70% of the population. There was no variation by education in the percentage of linkage obtained in this population. We pooled the data from Barcelona and Madrid for analyses

because both are urban populations from Spain. We analysed a total of 1 315 414 deaths in 51 710 855 person years at risk (see webtable 1 at http://image.thelancet.com/extras/03art12304webtable1.pdf).

The underlying cause of death was classified according to WHO guidelines in all populations. Deaths were categorised by the international classification of diseases (ICD)-8, and later ICD-10 in Switzerland, and by ICD-9 in the other populations. We decided to include the four large standard groups of causes of death that together account for all mortality (cardiovascular diseases, neoplasms, other diseases, and external causes), and then within these groups we selected the largest specific causes of death for further analysis. Age was recorded at the start of follow-up. We divided individuals into the following age-groups: 45–59 years, 60–74 years, and 75 years and older.

Socioeconomic groups

Educational level, recorded in the population censuses, was used as an indicator of socioeconomic position. We reclassified national education data into two broad groups, roughly corresponding with the International Standard Classification of Education 0–3 (pre-primary, primary, and lower secondary education, labelled as low); and 4–6 (upper secondary education and post-secondary education, labelled as high). Information about education was missing in less than 4% of the population in all countries. The proportion of low-educated men was between 70% and 84% of the total male population, and that of low-educated women was between 77% and 92% of the total female population (see webtable 2 at http://image.thelancet.com/extras/03art12304webtable2.pdf).

Data analyses

We assessed relative inequalities in mortality by calculating the rate ratio (mortality rate in low-educational groups expressed as a proportion of mortality rate in high-educational groups). These calculations were done with Poisson regression analysis in which we regressed the number of deaths (against an offset of the natural log of the person years at risk) by the level of education separately for each age-group and for sex. We included a categorical variable in the regression models, signifying a 5-year age-group, to control for age. We also calculated absolute rate differences (mortality rate in low-educational groups minus mortality rate in high-educational groups, expressed as deaths per 100 000 person years at risk) in mortality separately for each age-group and for sex. The contribution of a specific cause of death to differences in overall mortality by educational level was determined by expressing the rate difference of that cause as a percentage of the rate difference of total mortality.

Mortality rates were age-standardised according to the direct method, with the pooled population of the European Union (EU) plus Norway of 1995 as the standard, with age-groups of 5 years. Pooled analyses for western Europe were done on a combined dataset that consisted of data for all populations, but in which weights were applied to equalise the sample sizes of the individual countries. Thus those countries with the largest samples received the smallest weights.

Role of the funding source

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Results

Table 1 shows the results of the pooled analyses for men. After weighting to equalise sample sizes between

	45–59 years		60–74 years		⩾75 years		All ages ⩾45 years	
	Rate ratio (95%CI)	Rate difference	Rate ratio (95% CI)	Rate difference	Rate ratio (95% CI)	Rate difference	Rate ratio (95% CI)	Rate difference
Cardiovascular overall	1·51 (1·45–1·57)	97	1·32 (1·29–1·35)	346	1·18 (1·15–1·20)	886	1·27 (1·25–1·29)	315
IHD	1·51 (1·43–1·58)	60	1·32 (1·28–1·36)	193	1·14 (1·10–1·18)	312	1·27 (1·25–1·30)	148
Cerebrovascular	1·56 (1·40–1·74)	15	1·40 (1·32–1·48)	77	1·21 (1·16–1·26)	264	1·30 (1·25–1·34)	78
Other circulatory	1·49 (1·37–1·61)	22	1·27 (1·21–1·33)	76	1·21 (1·16–1·26)	309	1·25 (1·22–1·29)	89
Cancer overall	1·46 (1·40–1·52)	92	1·31 (1·27–1·34)	256	1·15 (1·12–1·18)	326	1·29 (1·26–1·31)	189
Stomach cancer	1·69 (1·43–2·00)	7	1·71 (1·53–1·92)	30	1·64 (1·43–1·88)	71	1·68 (1·55–1·81)	25
Lung cancer	1·89 (1·76–2·03)	49	1·65 (1·58–1·74)	152	1·44 (1·33–1·55)	168	1·66 (1·61–1·72)	106
Colorectal cancer	1·06 (0·95–1·19)	2	1·16 (1·08–1·26)	18	1·14 (1·04–1·24)	45	1·13 (1·08–1·19)	15
Prostate cancer	1·07 (0·87–1·31)	0	0·94 (0·87–1·01)	-9	0·97 (0·91–1·04)	-21	0·96 (0·92–1·01)	-6
Other cancer	1·32 (1·25–1·39)	34	1·19 (1·14–1·23)	65	1·09 (1·03–1·14)	66	1·19 (1·15–1·22)	50
Other diseases overall	1·76 (1·66–1·86)	73	1·54 (1·49–1·60)	234	1·31 (1·27–1·35)	838	1·47 (1·44–1·51)	255
COPD	2·78 (1·27–3·39)	12	2·16 (1·99–2·35)	97	1·77 (1·64–1·91)	335	2·00 (1·89–2·11)	95
Pneumonia	2·31 (1·81–2·94)	6	1·77 (1·57–2·00)	33	1·30 (1·21–1·39)	202	1·45 (1·37–1·54)	47
Other	1·65 (1·56–1·75)	55	1·36 (1·30–1·42)	104	1·21 (1·16–1·25)	300	1·36 (1·32–1·39)	113
External causes	1·50 (1·40–1·60)	29	1·35 (1·25–1·47)	30	1·26 (1·15–1·37)	78	1·37 (1·31–1·43)	37
Total mortality*	1·54 (1·49–1·56)	290	1·36 (1·34–1·38)	867	1·21 (1·19–1·22)	2127	1·32 (1·31–1·33)	796

IHD=ischaemic heart disease; COPD=chronic obstructive pulmonary disease. *Because of rounding, the cause specific rate differences might not exactly add up to the rate difference of total mortality in some cases.

Table 1: **Educational inequalities by cause specific mortality in men in western Europe, by age**

	45–59 years	60–74 years	⩾75 years	All ages ⩾45 years
Cardiovascular	33·5	39·9	41·6	39·5
IHD	20·6	22·3	14·7	18·6
Cerebrovascular	5·1	8·9	12·4	9·7
Other cardiovascular	7·7	8·8	14·5	11·1
Cancer	31·6	29·6	15·3	23·8
Lung cancer	17·1	17·6	7·9	13·3
Other cancer	14·5	12·0	7·4	10·5
Other diseases	25·1	27·0	39·4	32·0
COPD	4·3	11·2	15·8	12·0
Pneumonia	1·9	3·8	9·5	5·9
Other	18·8	12·0	14·1	14·1
External causes	9·9	3·4	3·7	4·7
Total mortality	100	100	100	100

IHD=ischaemic heart disease; COPD=chronic obstructive pulmonary disease.
*Contributions of specific causes of death calculated by expressing differences for causes of death (as in table 1) as a percentage of the rate difference for total mortality (as in table 1). Due to rounding, the percentages of specific causes may in some cases not add up to 100%.

Table 2: **Contribution (%) of specific causes of death to the difference between low and high-educational groups in total mortality in men***

	45–59 years	60–74 years	⩾75 years	All ages ⩾45 years
Cardiovascular	42·5	60·3	62·6	60·1
IHD	20·7	31·6	20·3	24·3
Cerebrovascular	10·7	12·0	18·9	15·8
Other Cardiovascular	11·1	16·7	23·4	19·9
Cancer	21·0	12·7	7·7	10·5
Breast Cancer	−7·8	−4·0	0·6	−1·7
Other Cancer	28·7	16·7	7·1	12·2
Other diseases	36·3	27·2	29·6	29·4
COPD	7·5	5·0	1·8	3·3
Pneumonia	3·7	3·2	7·5	5·7
Other	25·1	19·1	20·3	20·3
External causes	0·1	−0·2	0·2	0·0
Total mortality	100	100	100	100

IHD=ischaemic heart disease; COPD=chronic obstructive pulmonary disease;
*Contributions of specific causes of death calculated by expressing differences for causes of death (as in table 1) as a percentage of the rate difference for total mortality (as in table 3). Due to rounding, the percentages of specific causes may in some cases not add up to 100%.

Table 4: **Contribution (%) of specific causes of death to the difference in total mortality between low and high-educational groups in women***

populations, this dataset consisted of 304 410 deaths in 11 030 032 person years at risk (see also webtable 3 at http://image.thelancet.com/extras/03art12304webtable3.pdf). These results can be interpreted as roughly representing the situation in western Europe as a whole, perhaps with the exception of rural Mediterranean areas. Rate ratios were greater than 1·00 for total mortality and for all specific causes of death (apart from prostate cancer), suggesting increased mortality in the low versus the high-educational groups. In men of all ages (table 1), the highest rate ratios were for COPD, stomach cancer, and lung cancer. Rate differences were highest for ischaemic heart disease, lung cancer, and COPD. Rate ratios usually fall with age, but in most cases remain raised in the highest age-group. In men aged 75 years and older, rate ratios were still remarkably high for stomach cancer, lung cancer, and COPD. Rate differences usually increase strongly with age, suggesting that educational inequalities in mortality in elderly people are of great importance in public health.

In men of all ages, ischaemic heart disease, lung cancer, COPD, other cardiovascular diseases, and cerebrovascular disease made the largest contributions to differences in total mortality by educational group (table 2). The contributions of cerebrovascular disease, other cardiovascular diseases, pneumonia, and COPD rose with age, whereas the contributions of cancers and external causes fell.

Table 3 shows the results of the pooled analyses for women (see also webtable 4 at http://image.thelancet.com/extras/03art12304webtable4.pdf). After weighting to equalise sample sizes between populations, this

	45–59 years		60–74 years		⩾75 years		All ages ⩾45 years	
	Rate ratio (95% CI)	Rate difference	Rate ratio (95% CI)	Rate difference	Rate ratio (95% CI)	Rate difference	Rate ratio (95% CI)	Rate difference
Cardiovascular	1·74 (1·60–1·90)	36	1·56 (1·50–1·63)	243	1·26 (1·23–1·29)	994	1·35 (1·33–1·38)	266
IHD	1·98 (1·71–2·28)	17	1·66 (1·56–1·76)	128	1·26 (1·21–1·31)	322	1·41 (1·36–1·45)	107
Cerebrovascular	1·61 (1·37–1·88)	9	1·43 (1·33–1·54)	48	1·26 (1·21–1·32)	300	1·31 (1·27–1·36)	70
Other circulatory	1·60 (1·38–1·87)	9	1·54 (1·43–1·67)	67	1·27 (1·22–1·32)	372	1·34 (1·29–1·38)	88
Cancer	1·08 (1·03–1·13)	18	1·09 (1·05–1·13)	51	1·10 (1·05–1·14)	122	1·10 (1·07–1·12)	47
Stomach cancer	1·47 (1·12–1·92)	2	1·43 (1·20–1·70)	9	1·69 (1·42–2·00)	46	1·54 (1·38–1·72)	12
Lung cancer	1·50 (1·28–1·75)	10	1·26 (1·13–1·42)	15	0·91 (0·79–1·04)	−7	1·21 (1·12–1·31)	8
Colorectal cancer	1·05 (0·91–1·23)	1	1·07 (0·97–1·19)	6	1·12 (1·01–1·24)	23	1·09 (1·02–1·17)	6
Breast cancer	0·89 (0·81–0·96)	−7	0·84 (0·78–0·91)	−16	1·01 (0·91–1·12)	10	0·89 (0·85–0·94)	−7
Other cancer	1·14 (1·06–1·22)	11	1·14 (1·08–1·19)	38	1·08 (1·03–1·14)	51	1·12 (1·09–1·16)	27
Other diseases	1·70 (1·56–1·86)	31	1·43 (1·35–1·50)	110	1·24 (1·20–1·28)	470	1·34 (1·30–1·37)	130
COPD	2·84 (2·02–4·00)	6	1·52 (1·32–1·76)	20	1·24 (1·10–1·40)	29	1·45 (1·33–1·59)	15
Pneumonia	2·49 (1·65–3·78)	3	1·48 (1·25–1·74)	13	1·26 (1·17–1·35)	119	1·31 (1·23–1·40)	25
Other	1·58 (1·44–1·74)	21	1·40 (1·32–1·49)	77	1·24 (1·19–1·29)	322	1·33 (1·29–1·37)	90
External causes	1·06 (0·94–1·20)	0	0·99 (0·88–1·12)	−1	1·04 (0·94–1·14)	3	1·00 (0·94–1·06)	0
Total mortality*	1·28 (1·23–1·33)	84	1·32 (1·29–1·35)	404	1·22 (1·20–1·24)	1588	1·26 (1·25–1·28)	442

IHD=ischaemic heart disease; COPD=chronic obstructive pulmonary disease; *Due to rounding, the cause specific rate differences may not exactly add up to the rate difference of total mortality in some cases.

Table 3: **Educational inequalities in cause specific mortality in women in western Europe**

	Men		Women	
	Rate ratio (95% CI)	Rate difference	Rate ratio (95% CI)	Rate difference
Finland	1·33 (1·31–1·35)	1005	1·24 (1·22–1·26)	542
Norway	1·36 (1·33–1·39)	947	1·27 (1·24–1·31)	520
England & Wales	1·35 (1·28–1·42)	1052	1·22 (1·14–1·30)	435
Belgium	1·34 (1·33–1·36)	1020	1·29 (1·27–1·31)	577
Austria	1·43 (1·38–1·47)	1007	1·32 (1·28–1·36)	545
Switzerland	1·33 (1·30–1·36)	737	1·27 (1·21–1·33)	401
Turin	1·22 (1·18–1·27)	581	1·20 (1·15–1·26)	378
Barcelona & Madrid	1·24 (1·21–1·27)	540	1·27 (1·22–1·31)	311

Table 5: **Educational inequalities in total mortality by population in men and women aged ⩾45 years**

dataset consisted of 322 122 deaths in 13 725 757 person years at risk. Inequalities in mortality in women were similar to those in men, as indicated by the rate ratio for total mortality. In women of all ages, mortality was higher for most specific causes of death in the low-educational group than in the high-educational group, apart from breast cancer and external causes. Rate ratios were highest for stomach cancer, ischaemic heart disease, and COPD. Absolute inequalities in mortality, as indicated by rate differences, were much smaller in women than in men. Rate differences were highest for ischaemic heart disease, other cardiovascular diseases, and cerebrovascular disease.

In women of all ages, the contributions of specific causes of death to differences in total mortality between low and high educational levels were distinctly different from those in men (table 4). The larger contribution of cardiovascular diseases in women than in men is based on increased shares for each of the three specific causes (ischaemic heart disease, cerebrovascular disease, other cardiovascular disease). Breast cancer contributes negatively because mortality is greater in high-educated women than in low-educated women. The contributions of cerebrovascular disease, other cardiovascular diseases, and pneumonia strongly increase by age in women, and those of cancer and COPD decrease by age.

Table 5 shows that rate ratios for total mortality were substantially different and tended to be reduced in southern European populations. In men, rate differences were largest for England and Wales, followed by Belgium, Austria, and Finland, whereas in women they were largest in Belgium, followed by Austria, Finland, and Norway. Table 6 shows contributions of specific causes of death to mortality by educational level for different populations. In men there are striking differences in the contribution of ischaemic heart disease: this contribution is between 30%

	Finland	Norway	England & Wales	Belgium	Austria	Switzerland	Turin	Barcelona & Madrid
Men								
Cardiovascular	50·0	52·5	47·5	27·6	46·1	42·5	19·7	13·5
IHD	33·3	31·6	37·4	7·1	13·6	17·6	−8·3	2·8
Cerebrovascular	6·3	9·8	5·5	6·8	11·0	6·8	23·2	7·9
Other cardiovascular	10·5	11·1	4·6	13·6	21·5	18·2	4·7	2·7
Cancer	19·7	12·9	27·9	23·8	24·4	25·9	33·8	35·0
Lung cancer	12·3	6·6	13·6	17·2	11·1	12·6	19·9	11·0
Other cancer	7·4	6·3	14·3	6·6	13·3	13·3	13·9	24·1
Other diseases	22·8	30·3	24·9	42·8	23·8	28·1	41·2	49·3
COPD	8·4	8·3	11·1	16·0	5·5	10·3	16·3	17·0
Pneumonia	8·7	8·3	7·4	6·2	2·1	3·4	−0·5	3·5
Other	5·7	13·6	6·5	20·6	16·2	14·4	25·4	28·8
External causes	7·4	4·4	−0·3	5·9	5·8	3·5	5·3	2·2
Total mortality	100	100	100	100	100	100	100	100
Women								
Cardiovascular	69·6	59·5	60·1	52·3	68·8	62·1	49·4	47·1
IHD	41·1	29·8	41·0	14·9	22·2	23·1	1·1	11·6
Cerebrovascular	15·0	12·3	16·3	11·2	21·6	12·5	24·9	13·2
Other cardiovascular	13·6	17·4	2·8	26·1	25·0	26·5	23·4	22·4
Cancer	6·2	12·3	19·0	6·0	7·3	16·5	10·9	10·7
Breast cancer	−2·1	−2·4	0·2	−2·7	−2·0	1·3	−2·8	−2·2
Other cancer	8·3	14·6	18·7	8·7	9·2	15·2	13·7	12·9
Other diseases	24·7	27·0	26·6	40·8	21·9	25·3	34·5	41·4
COPD	1·7	4·7	5·3	4·6	2·2	2·4	2·3	3·1
Pneumonia	11·4	5·6	8·0	4·7	3·6	6·7	1·2	2·7
Other	11·7	16·8	13·3	31·6	16·2	16·3	31·0	35·6
External causes	−0·5	1·2	−5·6	1·0	2·0	−4·0	5·3	1·0
Total mortality	100	100	100	100	100	100	100	100

IHD=ischaemic heart disease; COPD=chronic obstructive pulmonary disease. *Analyses done on separate datasets for each European population. All age-groups over the age of 45, and all causes of death were pooled. Due to rounding, the percentages of specific causes of death may not exactly add up to 100% in some cases.

Table 6: **Contribution (%) of specific causes of death to the difference between low and high-educational groups in total mortality in men and women aged .45 years***

and 40% in northern European populations (Finland, Norway, England and Wales), less than 30% in Switzerland, Belgium, Austria, and Barcelona and Madrid, and a negative percentage in Turin. The smaller share of ischaemic heart disease in the central and southern European populations is compensated by increased shares for other diseases, such as cerebrovascular disease (particularly in Turin), cancers, COPD, and all other diseases.

In women the geographical gradient for the contribution of ischaemic heart disease was closely similar to that in men. However, cardiovascular diseases accounted for half or more of the excess mortality in all populations because of larger contributions of cerebrovascular disease and other cardiovascular diseases in central and southern European populations than in the rest of Europe. Breast cancer makes a negative contribution in all populations, apart from England and Wales and Switzerland; in these countries external causes contributed negatively to excess mortality in low-educational groups.

Discussion

We have shown that differences in mortality by educational level persisted into old age in both men and women in western Europe. Cardiovascular diseases contributed the most to these differences in mortality. In men, the top five specific contributory causes were ischaemic heart disease, lung cancer, COPD, other cardiovascular diseases, and cerebrovascular disease. In women they were ischaemic heart disease, other cardiovascular diseases, cerebrovascular disease, pneumonia, and COPD. Relative inequalities (rate ratios) in mortality decreased with age, whereas absolute inequalities (rate differences) increased strongly. The contribution of specific causes of death to excess mortality in the low educational groups changed substantially with age, with cerebrovascular disease, other cardiovascular diseases, COPD (men only), and pneumonia becoming more important than in younger age-groups. Although relative inequalities in mortality were closely similar in all populations, the pattern of cause of death contributions differed greatly between countries and showed a north-south gradient for ischaemic heart disease in both men and women.

Recently we reported that differences in overall mortality by educational level persist into old age in both men and women in all European populations.[8] This finding indicates that these age-groups should receive due attention in explanatory research. Because different causes of death are important in different age-groups, those that contribute the most to inequalities in overall mortality by educational level can be expected to differ between old and middle-aged populations.

Use of education as an indicator of socioeconomic position has several advantages. First, unlike occupational class, education allows classification of individuals who do not work. Older men and women in many European countries who do not work constitute a large part of the population. Second, level of education is acquired early in life, which makes it unlikely that low socioeconomic position is the result of ill-health (ie, reverse causation).[11] Third, level of education is an individual measure of socioeconomic position. Indicators based on household measures, such as household income, pose difficulties for international comparative studies because of differences between countries in the definition of households. Also, part of the older population does not live in a private household.

Education as a socioeconomic indicator also has several disadvantages. Individuals usually achieve their final level of education early in adult life, thus their educational level might not accurately indicate their current socioeconomic position. Grundy and Holt[12] have suggested pairing level of education with a measure related to deprivation, such as housing tenure, for studies of socioeconomic inequalities in health including those in older people.[12] Because education might predominantly be associated with a cultural or behavioural pathway linking low socioeconomic position to ill-health and housing tenure to a material and psychosocial pathway, such a combination could provide a more comprehensive picture of variations in socioeconomic position. Information on housing tenure was not available for some of the populations, and thus we could not construct such a combined indicator. We do not think, however, that another socioeconomic indicator would lead to different results in terms of patterns of cause of death. Kunst and co-workers'[4] analysis covered partly the same populations as our study, and although they used occupational class as their socioeconomic indicator their results were similar to ours for middle-aged men.[4]

The distribution of education over the populations was skewed, with large groups of low-educated and small groups of high-educated people. Use of these groups as reference categories could have led to an overestimation of educational inequalities in mortality. However, our study is not just a matter of assessment of educational level, but is indicative of the real situation of educational attainment in older populations in Europe—ie, few received an education beyond secondary level. Additionally, because the low-educated group is heterogeneous in terms of educational level and in a wide range of other socioeconomic variables, the inequalities in mortality that we report are probably underestimated. We aimed for comparability between populations in terms of educational distribution, and thus had to sacrifice more detailed information. Nonetheless we succeeded in establishing an educational variable that showed significant inequalities in mortality.

Reliability of cause of death classification might decrease with age because the number of competing causes of death increases, making it more difficult for

certifying doctors and coders to establish the underlying cause of death.[13,14] Pneumonia usually occurs in older people with other underlying chronic conditions, such as cardiovascular diseases and COPD,[15,16] and deaths ascribed to pneumonia could be misclassified. The contribution of this cause to mortality differences therefore needs further investigation.

The degree of misclassification is not only dependent on age, but also can differ between countries because of differences in access to medical care and in certification and coding practices. Within western Europe, cross-country differences in classification of cause of death have been documented for several disorders.[17–20] Ischaemic heart disease, for which we noted pronounced cross-country variations in contribution to excess mortality in low educational groups, is one of the causes that is sensitive to misclassification. If doctors in central and southern European countries were to diagnose or certify ischaemic heart disease less often than doctors in northern European countries, this discrepancy would result in a geographical gradient of the contribution of ischaemic heart disease similar to the one we identified. However, the pattern that arose is consistent with international studies on variations between education and classic cardiovascular risk factors, such as smoking,[21,22] diet,[21,23,24] and obesity,[21] showing that inequalities in these risk factors are smaller, and sometimes even have negative values, in southern than in northern Europe. For example, a study of educational differences in smoking in different European countries around 1990 showed increased smoking rates in low-educated groups in north Europe, and absence of inequalities or raised smoking rates in the high-educated groups in south Europe.[22] This finding suggests that misclassification of causes of death cannot fully explain this striking north-south gradient. We used data from the 1990s, which are the most recent available for international comparisons. Compilation of a more recent dataset will have to await completion of follow-up after the censuses held in 2001.

The scope of our study is substantially broader than that of Kunst and colleagues,[4] because we included old men and middle-aged and old women. Moreover, our data cover the first-half of the 1990s and refer to a partly different set of countries—data on socioeconomic inequalities in mortality in Belgium and Austria, included in our study, have almost never been reported in international publications. We noted a pronounced role for cardiovascular diseases, other than ischaemic heart disease, especially cerebrovascular disease and other cardiovascular diseases, mainly because these causes are much more important for socioeconomic mortality differences in women and in elderly people than in middle-aged men. Exactly the opposite applies to external causes, whose role seems to be much smaller in our study than in that of Kunst and co-workers. Other new findings relate to COPD, which now stands out as one of the main contributors, but was not included as a separate cause of death in their study. However, our findings (which included a large part of the adult population) accorded with those of Kunst and colleagues, showing a north-south gradient in the contribution of ischaemic heart disease, which proved to be related to patterns of cardiovascular risk factors.[6] In our study, Belgium and Austria fit into this gradient by occupying intermediate positions between northern and southern European countries.

Although ischaemic heart disease is clearly one of the most important contributors to differences in mortality between socioeconomic groups, our results also emphasise the role of cerebrovascular disease and other cardiovascular diseases. An association between stroke mortality and socioeconomic status has been reported before,[25–28] but the size of the contribution to excess total mortality has not previously been documented so clearly. Further analyses showed that heart failure is the most important component of other cardiovascular diseases. Most explanatory studies of socioeconomic differences in mortality have been done in ischaemic heart disease.[29–32] Much less is known about the reasons for the differences in cerebrovascular disease[26,27,33–35] or heart failure, although the reasons are probably not the same as for ischaemic heart disease. Socioeconomic differences in prevalence, detection, and treatment of hypertension could play a part,[36] as could adverse socioeconomic circumstances during childhood.[37,38] The large relative inequalities in stomach cancer and COPD that we found are strongly associated with childhood socioeconomic circumstances.[37,39] Further explanations of the inequalities in these causes of death should best be studied over a population's lifetime, and should look at disadvantages and their consequences across the life span.[37] Such explanatory studies could allow useful comparisons between countries because generations have gone through different socioeconomic trajectories in different European countries.

The rise in the contribution of cardiovascular diseases with increasing age was mirrored by a decrease in the contribution of cancer. The diminished share of lung cancer in the older age-groups accounted for a large part of this decrease. In the oldest age-group, low-educated and high-educated men and women have historically been exposed to smoking to much the same extent, whereas the low educated in younger cohorts have been more exposed than the high educational groups.[22,40] In future cohorts, lung cancer will probably play an increasingly important part in socioeconomic inequalities in mortality as smoking in Europe becomes more concentrated in low socioeconomic groups.[41] In men, COPD was another cause that accounted for a substantial part of the differences in mortality. Barcelona and Madrid and Turin showed some of the largest contributions of COPD, and the contribution of lung cancer was also large in these populations. These

results indicate a strong effect of smoking in these populations. However, data for smoking prevalence show that the smoking epidemic is far less advanced in Spain and Italy than in northern European countries.[22,40,42,43] This discrepancy could possibly be explained by the fact that our data are for Barcelona, Madrid, and Turin and that the smoking epidemic is probably more advanced in these urbanised areas than in the rest of Spain and Italy.

Educational inequalities in mortality are ubiquitous throughout western Europe. Rate ratios are largely similar for all countries, which lends support to the importance of upstream determinants (ie, societal processes) for socioeconomic inequalities in mortality. Social stratification, and the resulting differences in access to resources, such as knowledge, wealth, and prestige, produces inequalities in life chances within populations, irrespective of their prevailing health risks and epidemiological characteristics. At the same time, however, similar rate ratios for total mortality often hide important differences between countries in patterns of cause of death. More specific explanations of health inequalities, in terms of the determinants that mediate the effect of low socioeconomic position on mortality, are probably different between populations. Thus results of explanatory research cannot be assumed to be generalisable from one population to the other, and all countries should to some extent invest in such studies. This is not to say that countries cannot learn from each other, but they do all need to build up their own evidence base for public-health policy.

Reduction of cardiovascular disease mortality in the low-educational groups should clearly be an important public-health priority throughout western Europe. There is an urgent need to develop and implement effective interventions and policies to reduce exposure to cardiovascular risk factors, including smoking, in low-educational groups. Very few have been developed, let alone implemented, so far.[44] International exchange of experiences with interventions reaching the lower socioeconomic groups might be of benefit to all European countries. The EU could have a key role in stimulating and facilitating such international collaboration.

Contributors

M Huisman did the statistical analyses and drafted the paper; A Kunst coordinated the study and contributed to the preparation of the paper; M Bopp collected the Swiss data and commented on the draft of the paper; J-K Borgan collected the Norwegian data and commented on the draft of the paper; C Borrell collected the data from Barcelona and commented on the draft of the paper; G Costa collected the data from Turin and commented on the draft of the paper; P Deboosere collected the Belgian data and commented on the draft of the paper; S Gadeyne collected the Belgian data and commented on the draft of the paper; M Glickman collected the English and Welsh data and commented on the draft of the paper; C Marinacci collected the data from Turin; C Minder collected the Swiss data and commented on the draft of the paper; E Regidor collected the data from Madrid and commented on the draft of the paper; T Valkonen collected the Finnish data and commented on the draft of the paper; and J Mackenbach designed the study protocol and edited the draft of the paper.

Conflict of interest statement

We declare that we have no conflict of interest.

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References

1 Wong M, Shapiro MF, Boscardin WJ, Ettner SL. Contribution of major diseases to disparities in mortality. *N Engl J Med* 2002; **347:** 1585–92.
2 Steenland K, Henley J, Thun M. All-cause and cause-specific death rates by educational status for two million people in two American cancer society cohorts, 1959–1996. *Am J Epidemiol* 2002; **156:** 11–21.
3 Martelin T. Differential mortality at older ages. Helsinki: University of Helsinki, 1994.
4 Kunst AE, Groenhof F, Mackenbach JP, EU Working Group on Socioeconomic Inequalities in Health. Occupational class and cause specific mortality in middle aged men in 11 European countries: comparison of population based studies. *BMJ* 1998; **316:** 1636–42.
5 Mackenbach J, Kunst AE, Groenhof F, et al. Socioeconomic Inequalities in mortality among women and among men: an international study. *Am J Public Health* 1999; **89:** 1800–06.
6 Mackenbach JP, Cavelaars AEJM, Kunst AE, Groenhof F, EU Working Group on Socioeconomic Inequalities in Health. Socioeconomic inequalities in cardiovascular disease mortality; an international study. *Eur Heart J* 2000; **21:** 1141–51.
7 Mackenbach J, Bos V, Andersen O, et al. Widening socioeconomic inequalities in mortality in six western European populations. *Int J Epidemiol* 2003; **32:** 830–37.
8 Huisman M, Kunst AE, Andersen O, et al. Socio-economic inequalities in mortality among the elderly in eleven European populations. *J Epidemiol Community Health* 2004; **58:** 468–75.
9 Mackenbach J, Bakker M, for the European Network on Interventions and Policies to Reduce Inequalities in Health. Tackling socioeconomic inequalities in health: analysis of European experiences. *Lancet* 2003; **362:** 1409–14.
10 McKee M, Jacobson B. Public health in Europe. *Lancet* 2000; **356:** 665–70.
11 Valkonen T. The widening differentials in adult mortality by socio-economic status and their causes. In: Chamie J, Cliguet R, eds. Health and mortality: issues of global concern. Proceedings of the symposium on health and mortality, Brussels, Nov 19–22, 1997. Leuven: Population Division, Department of Economic and Social Affairs, United Nations Secretariat and Population and Family Study Centre, Flemish Scientific Institute, 1999.
12 Grundy E, Holt G. The socioeconomic status of older adults: how should we measure it in studies of health inequalities? *J Epidemiol Community Health* 2001; **55:** 895–904.
13 Mackenbach J, Kunst AE, Lautenbach H, Oei YB, Bijlsma F. Competing causes of death: a death certificate study. *J Clin Epidemiol* 1997; **50:** 1069–77.
14 Lahti R, Pentillä A. Cause-of-death query in validation of death certification by expert panel; effects on mortality statistics in Finland. *Forensic Sci Int* 2003; **131:** 113–24.
15 Koivula I, Sten M, Makela P. Risk factors for pneumonia in the elderly. *Am J Med* 1994; **96:** 313–20.
16 Marik PE, Kaplan D. Aspiration pneumonia and dysphagia in the elderly. *Chest* 2003; **124:** 328–36.
17 Kelson M, Farebrother M. The effect of inaccuracies in death certification and coding practices in the European Economic Community (EEC) on international cancer mortality statistics. *Int J Epidemiol* 1987; **16:** 411–14.
18 Balkau B, Jougla E, Papoz L, EURODIAB Subarea C Study Group. European study of the certification and coding of causes of death of six clinical case histories of diabetic patients. *Int J Epidemiol* 1993; **22:** 116–26.
19 Langlois JA, Smith GS, Baker SP, Langley JD. International comparisons of injury mortality in the elderly: issues and

differences between New Zealand and the United States. *Int J Epidemiol* 1995; **24:** 136–43.
20 Lozano R, Murray CJL, Lopez AD, Satoh T. Miscoding and misclassification of ischaemic heart disease mortality. Geneva: WHO, 2001.
21 Cavelaars AEJM, Kunst AE, Mackenbach JP. Socio-economic differences in risk factors for morbidity and mortality in the European Community: an international comparison. *J Health Psychol* 1997; **2:** 353–72.
22 Cavelaars AEJM, Kunst AE, Geurts JJM, et al. Educational differences in smoking: international comparison. *BMJ* 2000; **320:** 1102–07.
23 Roos G, Johansson L, Kasmel A, Klumbiené J, Prättälä R. Disparities in vegetable and fruit consumption: European cases from the north to the south. *Public Health Nutr* 2000; **4:** 35–43.
24 Trichopoulou A, Naska A, Costacou T, on behalf of the DAFNE III Group. Disparities in food habits across Europe. *Proc Nutr Soc* 2002; **61:** 553–58.
25 Kunst AE, Del Rios M, Groenhof F, Mackenbach JP. Socioeconomic inequalities in stroke mortality among middle-aged men: an international overview. *Stroke* 1998; **29:** 2285–91.
26 Van Rossum CTM, Van de Mheen H, Breteler MMB, Grobbee DE, Mackenbach JP. Socioeconomic differences in stroke among Dutch elderly women: the Rotterdam study. *Stroke* 1999; **30:** 357–62.
27 Jakovljevic D, Sarti C, Sivenius J, et al. Socioeconomic status and ischemic stroke: the FINMONICA stroke register. *Stroke* 2001; **32:** 1492–98.
28 Avendano M, Kunst AE, Huisman M, et al. Educational level and stroke mortality: a comparison of 10 European populations during the 1990s. *Stroke* 2004; **35:** 432–37.
29 Suadicani P, Hein H, Gyntelberg F. Are social inequalities as associated with the risk of ischaemic heart disease a result of psychosocial working conditions? *Atherosclerosis* 1993; **101:** 165–75.
30 Pekkanen J, Tuomilehto J, Uutela A, Vartiainen E, Nissinen A. Social class, health behaviour, and mortality among men and women in eastern Finland. *BMJ* 1995; **311:** 589–93.
31 Vartiainen E, Pekkanen J, Koskinen S, Jousilahti P, Salomaa V, Puska P. Do changes in cardiovascular risk factors explain the increasing socioeconomic difference in mortality from ischaemic heart disease in Finland? *J Epidemiol Community Health* 1998; **52:** 416–19.
32 Wamala S, Mittleman MA, Schenck-Gustafsson K, Orth-Gomer K. Potential explanations for the educational gradient in coronary heart disease: a population-based case-control study of Swedish women. *Am J Public Health* 1999; **89:** 315–21.
33 Hart C, Hole D, Davey Smith G. The contribution of risk factors to stroke differentials, by socioeconomic position in adulthood: the Renfrew/Paisley Study. *Am J Public Health* 2000; **90:** 1788–91.
34 Kilander L, Berglund L, Boberg M, Vessby B, Lithell H. Education, lifestyle factors and mortality from cardiovascular disease and cancer: a 25-year follow-up of Swedish 50-year-old men. *Int J Epidemiol* 2001; **30:** 1119–26.
35 Kapral MK, Wang H, Mamdani M, Tu JV, Boden-Albala B, Sacco RL. Effect of socioeconomic status on treatment and mortality after stroke. *Stroke* 2002; **33:** 268–75.
36 De Gaudemaris R, Lang T, Chatellier G, et al. Socioeconomic inequalities in hypertension prevalence and care: the IHPAF study. *Hypertension* 2002; **39:** 1119–25.
37 Davey Smith G, Hart C, Blane D, Hole D. Adverse socioeconomic conditions in childhood and cause specific adult mortality: prospective observational study. *BMJ* 1998; **316:** 1631–35.
38 Hart C, Hole DJ, Davey Smith G. Influence of socioeconomic circumstances in early and later life on stroke risk among men in a Scottish cohort study. *Stroke* 2000; **31:** 2093–97.
39 Prescott E, Vestbo J. Socioeconomic status and chronic obstructive pulmonary disease. *Thorax* 1999; **54:** 737–41.
40 Graham H. Smoking prevalence among women in the European Community 1950–1990. *Soc Sci Med* 1996; **43:** 243–54.
41 Graham H, Der G. Influences on women's smoking status: the contribution of socioeconomic status in adolescence and adulthood. *Eur J Public Health* 1999; **9:** 137–41.
42 La Vecchia C. Smoking in Italy, 1949–1983. *Prev Med* 1986; **15:** 274–81.
43 Fernandez E, Schiaffino A, Borras JM, Shafey O, Villabi JR, La Vecchia C. Prevalence of cigarette smoking by birth cohort among males and females in Spain, 1910–1990. *Eur J Cancer Prev* 2003; **12:** 57–62.
44 Mackenbach J, Bakker M, eds. Reducing inequalities in health; a European perspective. London: Routledge, 2002.