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Variations in the relation between education and cause-specific mortality in 19 European populations: A test of the "fundamental causes" theory of social inequalities in health

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ABSTRACT

Link and Phelan have proposed to explain the persistence of health inequalities from the fact that socioeconomic status is a "fundamental cause" which embodies an array of resources that can be used to avoid disease risks no matter what mechanisms are relevant at any given time. To test this theory we compared the magnitude of inequalities in mortality between more and less preventable causes of death in 19 European populations, and assessed whether inequalities in mortality from preventable causes are larger in countries with larger resource inequalities.

We collected and harmonized mortality data by educational level on 19 national and regional populations from 16 European countries in the first decade of the 21st century. We calculated age-adjusted Relative Risks of mortality among men and women aged 30–79 for 24 causes of death, which were classified into four groups: amenable to behavior change, amenable to medical intervention, amenable to injury prevention, and non-preventable.

Although an overwhelming majority of Relative Risks indicate higher mortality risks among the lower educated, the strength of the education–mortality relation is highly variable between causes of death and populations. Inequalities in mortality are generally larger for causes amenable to behavior change, medical intervention and injury prevention than for non-preventable causes. The contrast between preventable and non-preventable causes is large for causes amenable to behavior change, but absent for causes amenable to injury prevention among women. The contrast between preventable and non-preventable causes is larger in Central & Eastern Europe, where resource inequalities are substantial, than in the Nordic countries and continental Europe, where resource inequalities are relatively small, but they are absent or small in Southern Europe, where resource inequalities are also large.

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In conclusion, our results provide some further support for the theory of "fundamental causes". However, the absence of larger inequalities for preventable causes in Southern Europe and for injury mortality among women indicate that further empirical and theoretical analysis is necessary to understand when and why the additional resources that a higher socioeconomic status provides, do and do not protect against prevailing health risks.

1. Introduction

In all countries with available data, mortality rates are higher among those in less advantaged socioeconomic positions (Commission on Social Determinants of Health, 2008). This is not only the case in poor parts of the world but also in high income countries with advanced health care systems and elaborate systems of social security (Mackenbach, 2012; Mackenbach et al., 2008), and these inequalities in mortality have been observed throughout the 20th century, despite massive changes in disease patterns and determinants of disease (Pamuk, 1985).

In order to explain the robustness of the inverse association between socioeconomic status and mortality across time and place, Link and Phelan have proposed that socioeconomic status is a "fundamental cause" of inequalities in mortality. In their view, socioeconomic inequalities in mortality persist over time and place despite changing specific mechanisms because socioeconomic status "embodies an array of resources, such as money, knowledge, prestige, power, and beneficial social connections, that protect health no matter what mechanisms are relevant at any given time" (Phelan et al., 2004, page 265).

According to this theory, a person's socioeconomic status provides him or her with "flexible resources" which can be used "to avoid disease risks or to minimize the consequences of disease once it occurs" regardless of the prevailing circumstances. The association between socioeconomic status and health then "is reproduced over time via the replacement of intervening mechanisms", and as opportunities for avoiding disease expand so health inequalities continue to exist (Link and Phelan, 1995; Phelan et al., 2004; Phelan et al., 2010, various pages).

It is important to note that this explanation of inequalities in mortality does not compete with conventional explanations based on specific determinants, such as the higher prevalence of unfavorable material, psychosocial and behavioral factors in lower socioeconomic groups (Marmot, 2003), but refers to what has been called a "metamechanism": an overarching mechanism that explains how multiple specific mechanisms reproduce a particular relationship in different places and different times (Freese and Lutfey, 2011; Lutfey and Freese, 2005).

In essence, the "fundamental causes" theory implies that health results from purposive action or "health-directed human agency", and that socioeconomic differences in the availability of the means to achieve health goals are the crucial factor on which the fundamental relationship between socioeconomic status and health rests (Phelan and Link, 2005a). If this is correct, then this allows for an empirical test of the theory, because it predicts that socioeconomic status is more strongly associated with mortality from preventable causes than with mortality from less preventable causes.

In one of the few empirical tests of the "fundamental causes" theory, Phelan et al. reasoned that, when relatively little can be done to prevent death from a particular cause, the association between socioeconomic status and mortality should be substantially diminished, and that the strongest associations should be found for preventable causes of death. Using data from the United States National Longitudinal Mortality Study, they compared income- and education-related disparities in mortality between a group of causes with high preventability and a group of causes with low preventability, and found that indeed inequalities in mortality were higher for the first than for the second, implying support for the theory (Phelan et al., 2004).

Other tests of the theory followed a similar reasoning. Phelan and Link compared trends in mortality by socioeconomic status between two groups of diseases: three causes for which the capacity to prevent death has increased significantly (e.g., heart disease) and two causes for which that is not the case (e.g., brain cancer). They found that over time sharp disparities emerged in the United States for the first, but not for the second group (Phelan and Link, 2005b). Educational disparities in the United States also widened over time for mortality from heart disease and lung cancer but not for mortality from non-preventable cancers (Masters et al., 2012). Furthermore, mortality from diseases for which there has been more progress in their prevention or treatment (as indicated by the number of active drug ingredients available to treat a disease, or the rate of decline in mortality from that disease) is more strongly associated with education in the United States than mortality from diseases with less technological progress (Glied and Lleras-Muney, 2008).

In a study focusing not on mortality but more directly on the innovation that reduced mortality, Link et al. found that disparities by education and income arose in the United States during the introduction of the Pap test (for cervical cancer) and mammography (for breast cancer) (Link et al., 1998). In the 1960s and 1970s, knowledge that smoking causes lung cancer travelled unevenly through the United States population, and a sharp gradient favoring the higher educated emerged where none had existed in the 1950s (Link, 2008). Similarly, during the introduction of statins disparities favoring the higher income groups arose in their use, and in cholesterol levels, in the United States (Chang and Lauderdale, 2009).

While these are important studies, they only cover a single country, and it remains unknown whether their results also apply to other high-income countries – as would be necessary under the "fundamental causes" theory. These studies also are limited in their coverage of causes of death – often, only a few conditions are studied, or all preventable causes are lumped together as in Phelan et al.'s study (Phelan et al., 2004), which did not check whether larger inequalities were present for all preventable causes individually, as the theory predicts. The first objective of this paper therefore is to assess the generalizability of previous studies' findings, by comparing inequalities in mortality between 18 preventable and 6 non-preventable conditions for 19 European populations. If the "fundamental causes" theory holds, we expect inequalities in mortality from all preventable causes to be larger than those for non-preventable causes in all these populations.

The broader comparative scope of our study, however, also allows us to add a second objective, which is to assess whether the contrast between preventable and non-preventable causes is larger in countries where social inequalities are larger. If the "fundamental causes" theory holds, one would expect the link between socioeconomic position and mortality from preventable causes to

be stronger in countries with a more unequal distribution of "general resources, like knowledge, money, power, prestige, and social connections" (Link and Phelan, 1995, page 88).

Whereas no data are available to systematically compare inequalities in non-material factors like knowledge and prestige, quantitative data are available to show that European countries differ considerably in their extent of income inequality, rate of poverty and risk of social exclusion, partly as a result of differences in income redistribution through taxes and transfers and of differences in average income (OECD, 2011). The highest proportions of population "at risk of poverty or social exclusion" (a summary measure used by the European Commission that combines income poverty, severe material deprivation, and being out of paid work) are found in some Central & Eastern European countries, e.g. Hungary and Lithuania (>30%). The lowest proportions are found in the Nordic countries and in most continental-European countries, e.g. the Netherlands, France and Switzerland (<20%), with Southern Europe (e.g., Spain and Italy) and the United Kingdom in-between (20–30%) (European Commission, 2013). We therefore expect the link between socioeconomic position and mortality from preventable causes to be strongest in Central & Eastern Europe, and weakest in the Nordic and continental-European countries.

2. Data and methods

Our analysis uses mortality data from 19 European populations for men and women aged 30–79. These populations are those of Finland, Sweden, Norway, Denmark, England and Wales, Netherlands, Belgium, France, Switzerland, Austria, Spain (Barcelona, Basque Country and Madrid), Italy (Turin and Tuscany), Czech Republic, Poland, Hungary, and Estonia. Most data cover complete national populations with the exceptions of England and Wales (1 per cent representative sample of the population), Netherlands (linkage to national labor force survey representing around 2 per cent of the population), France (1 per cent representative sample of the population), Spain (Barcelona, Madrid and Basque Country only) and Italy (Turin and Tuscany only). These data were mostly collected in the framework of a longitudinal mortality follow-up of population censuses carried out around the year 2000. At the moment of writing (2013), most countries did not yet have mortality data by socioeconomic position for the 2010s. Data for Barcelona, Hungary, Czech Republic, Poland and Estonia derive from cross-sectional studies.

Most countries with longitudinal data classified person-years and deaths by age at baseline, and as length of follow-up differed between studies adjustment was necessary. For this we used a procedure based on the proportion of person-years spent outside the correct age interval and the observed increase of the death rate by age. This method was validated with mortality data for three countries that could provide both data classified by age at baseline and age at death (Finland, France, and Sweden), and was found to work satisfactorily (Ostergren et al., 2012). The statistical analyses were restricted to the ages between 30 and 79 years because education gradually loses its discriminatory power as a measure of socioeconomic status among the elderly, and because cause-specific analyses become more difficult due to the increasing number of multiple causes of death at older age. A full overview of data sources is given in Table 1, and more details can be found elsewhere (Eikemo and Mackenbach, 2012).

Socioeconomic status was indicated by highest level of completed education. We focused on educational inequalities in mortality (instead of, e.g., occupational inequalities in mortality) because comparable data on educational attainment are available for both men and women in all European populations under study.

Table 1
Data sources.

	Type of dataset	Period	Geographic coverage	Demographic coverage
Finland	Longitudinal	2001–2007	National	20% of Finns excluded at random
Sweden	Longitudinal	2001–2006	National	Whole population
Norway	Longitudinal	2001–2006	National	Whole population
Denmark	Longitudinal	2001–2005	National	Whole population
England & Wales	Longitudinal	2001–2006	National	1% Sample
Netherlands	Longitudinal	1998–2007	National	Linkage based on the labour force survey
Belgium	Longitudinal	2004–2005	National	Whole population
France	Longitudinal	1999–2005	National	1% Sample, born outside France excluded
Switzerland	Longitudinal	2001–2005	National	Non-Swiss nationals excluded
Austria	Longitudinal	2001–2002	National	Whole population
Barcelona	Repeated cross-sectional	2000–2006	City	Whole population
Basque Country	Longitudinal	2001–2006	Region	Whole population
Madrid	Longitudinal	2001–2003	Region	Whole population
Turin	Longitudinal	2001–2006	City	Whole population
Tuscany	Longitudinal	2001–2005	3 Cities	Whole population
Hungary	Cross-sectional unlinked	1999–2002	National	Whole population
Czech Republic	Cross-sectional unlinked	1999–2003	National	Whole population
Poland	Cross-sectional unlinked	2001–2003	National	Whole population
Estonia	Cross-sectional unlinked	1998–2002	National	Whole population

In addition, education is the most stable measure of socioeconomic position because it is normally completed early in adulthood, which also avoids reverse causation problems (i.e., health outcomes at older ages cannot change a person's level of education) (Daly et al., 2002). Education was classified according to the International Standard Classification of Education (ISCED-97). The categories used in this analysis were 'no, primary or lower secondary education' (ISCED 0,1,2; 'low'), 'upper secondary and post-secondary non-tertiary education' (ISCED 3, 4; 'mid') and 'tertiary education' (ISCED 5, 6; 'high'). We quantified educational inequalities in mortality by calculating Relative Risks (RR) and their 95% Confidence Intervals using Poisson regression analysis, with age in five-year groups as control variable and the 'high' educated as the reference group. Because of the large number of Relative Risks studied, and in order to reduce the risks of multiple testing, we also present results based on 99% Confidence Intervals. In this paper, we present results for the 'low' (versus the 'high') educated; results for the 'mid' educated will be mentioned only briefly and are available upon request.

We were able to study 24 causes of death, which we classified in four groups according to their "preventability". While our selection of "preventable" causes of death generally follows that of Phelan et al. (2004), we explicitly distinguish between conditions amenable to behavior change, conditions amenable to medical intervention, and conditions amenable to injury prevention (Table 2). Our criterion for classifying causes of death as "amenable to behavior change" was that the combined population-attributable fraction (PAF) for smoking, alcohol abuse, overweight, low fruit and vegetable intake, physical inactivity and unsafe sex was >50% in the Global Burden of Disease study 2000 (World Health Organization, 2002). Our criterion for classifying causes of death as "amenable to medical intervention" was that (a)

Table 2
Causes of death selected for the analysis, and their preventability.

	Amenable to				
	Behaviour change	Medical intervention	Injury prevention	Total preventable	Coding
Cancer of buccal cavity, pharynx, and oesophagus	Yes	No	No	Yes	B
Cancer of stomach	No	No	No	No	N
Cancer of colorectum	No	No	No	No	N
Cancer of liver	No	No	No	No	N
Cancer of pancreas	No	No	No	No	N
Cancer larynx	Yes	No	No	Yes	B
Cancer of trachea, bronchus and lung	Yes	No	No	Yes	B
Cancer of breast	No	Yes	No	Yes	M
Cancer of cervix	Yes	Yes	No	Yes	B/M
Cancer of prostate	No	Yes	No	Yes	M
Cancer of kidney and bladder	No	No	No	No	N
Hodgkin's disease and leukemia	No	Yes	No	Yes	M
Diabetes mellitus	Yes	No	No	Yes	B
Hypertensive disease	Yes	Yes	No	Yes	B/M
Ischemic heart disease	Yes	Yes	No	Yes	B/M
Cerebrovascular disease	Yes	Yes	No	Yes	B/M
Pneumonia/influenza	No	Yes	No	Yes	M
Chronic obstructive pulmonary disease	Yes	No	No	Yes	B
Appendicitis, hernia and peptic ulcer	No	Yes	No	Yes	M
Other liver and gall bladder diseases	No	No	No	No	N
Alcohol abuse	Yes	No	No	Yes	B
Road traffic accidents	No[a]	No[a]	Yes	Yes	I
Accidental falls	No[a]	No[a]	Yes	Yes	I
Suicide	No[a]	No[a]	Yes	Yes	I

Alcohol abuse: causes of death related to excessive alcohol consumption, e.g. alcoholic psychosis, liver cirrhosis and alcohol poisoning.
B: amenable to behavior change. M: amenable to medical intervention. I: amenable to injury prevention. N: non-preventable.
For ICD-codes, see web Appendix Table A1.
[a] Although mortality from injuries can also partly be prevented by behaviour change and/or medical intervention, injuries have been classified as a separate group.

relative 5-year survival rates around the year 2000 exceeded 70% in Eurocare (Verdecchia et al., 2007) and/or 80% in the United States Surveillance, Epidemiology and End Results (SEER) program (Ries et al., 2008), and/or (b) effective screening programs are available and had been implemented in European countries around the year 2000 (Mackenbach and McKee, 2013b), and/or (c) they are among the conditions included in most selections of "conditions amenable to medical intervention" (Nolte and McKee, 2004). We also considered deaths due to injuries (road traffic accidents, accidental fall, suicide) as amenable to prevention through various means. These include a wide range of safety measures (e.g., road and vehicle safety, safety at home and in the workplace, limiting access to means of suicide) in addition to behavior change (e.g., reducing alcohol consumption) and medical treatment (e.g., recognition and treatment of depression) (Mann et al., 2005; Peden, 2004; Sethi, 2006, 2010; van der Feltz-Cornelis et al., 2011). Please note that some causes of death are both amenable to behavior change and medical intervention (e.g. cancer of cervix which results from unsafe sex but can also be prevented by screening).

ICD-code numbers are given in web Appendix Table A1. In order to reduce random variation, for each population we decided to only present results for causes of death for which the observed number of deaths in the total population exceeded 100 (males and females assessed separately). A parallel analysis based on all causes of death, regardless of the observed number of deaths, produced very similar results, and led to the same conclusions (results not shown).

3. Results

Table 3 provides a general overview of the results. Total mortality is higher among the low than among the high educated in all populations included in this analysis, with minimum values for the age-adjusted Relative Risk of 1.45 (95%CI:1.39–1.51) among men in the Basque Country, and of 1.15 (1.04–1.26) among women in Turin, and maximum values of 2.93 (2.87–2.98) among men in Hungary, and 2.24 (2.16–2.33) among women in the Czech Republic.

Mortality is also higher among the low than among the high educated for most specific causes of death. The only Relative Risks below 1.00 for which the 95% Confidence Interval did not include 1.00 were for cancer of trachea, bronchus and lung among women in Madrid (RR = 0.61 (95%CI: 0.46–0.82)), and for breast cancer among women in Finland (0.86 (0.78–0.93)), the Basque Country (0.74 (0.64–0.95)) and Hungary (0.86 (0.79–0.94)). All other Relative Risks for which the 95% Confidence Interval did not include 1.00 indicated higher mortality among the low educated. Largely similar results were found when 99% Confidence Intervals were used (Table 3).

The strength of the inverse relationship between education and mortality differs substantially between causes of death, as indicated by the first- and third quartile values for the country-specific Relative Risks presented in Table 3. Although, because of the limitation to causes of death for which the observed number of deaths exceeded 100, not all 19 populations contributed Relative Risks for all causes of death, the interquartile ranges are generally based on substantial numbers of observations. The median values of the country-specific Relative Risks are also presented graphically in Fig. 1.

Among men, cancer of larynx, alcohol-related causes and Chronic Obstructive Pulmonary Disease (COPD) are the causes of death with the highest median Relative Risks. These all exceed a value of 3.0, indicating very large inequalities in mortality from these preventable causes in a majority of countries. Among women, alcohol-related causes, diabetes mellitus, cancer of cervix and COPD are the causes of death with the highest median Relative Risks. These again indicate very large inequalities in mortality from some preventable causes in a majority of countries. It can easily be seen in Fig. 1 that the non-preventable causes of death tend to be among those with lower median Relative Risks.

Table 3
Overview of associations between education and cause-specific mortality, by sex, 19 European populations.

A. Men

	Classification	Observations					Range of values				
		Total	RR < 1.00 (95%)	RR < 1.00 (99%)	RR > 1.00 (95%)	RR > 1.00 (99%)	Minimum	Q1	Q2 (median)	Q3	Maximum
Total mortality	n.a.	19	0	0	19	19	1.45	1.64	1.84	2.20	2.93
Cancer of buccal cavity, pharynx, and oesophagus	B	19	0	0	19	17	1.61	1.94	2.32	3.20	5.72
Cancer of stomach	N	18	0	0	16	14	1.38	1.70	1.95	2.27	3.12
Cancer of colorectum	N	19	0	0	9	7	0.79	1.11	1.23	1.36	2.39
Cancer of liver	N	18	0	0	14	9	1.05	1.32	1.56	1.91	5.28
Cancer of pancreas	N	19	0	0	10	6	0.86	1.14	1.25	1.52	1.97
Cancer of larynx	B	14	0	0	14	14	2.59	2.91	3.96	6.76	12.32
Cancer of trachea, bronchus and lung	B	19	0	0	19	19	1.37	2.08	2.55	2.98	4.27
Cancer of prostate	M	19	0	0	10	6	0.86	1.02	1.21	1.30	1.65
Cancer of kidney and bladder	N	19	0	0	12	11	1.17	1.32	1.46	1.54	2.06
Hodgkin's disease and leukemia	M	15	0	0	6	4	0.92	1.06	1.17	1.44	1.77
Diabetes mellitus	B	18	0	0	14	11	1.13	1.59	2.26	2.61	9.94
Hypertensive disease	B/M	16	0	0	9	9	0.88	1.34	1.73	2.38	3.93
Ischemic heart disease	B/M	19	0	0	19	18	1.16	1.54	1.94	2.16	2.90
Cerebrovascular disease	B/M	19	0	0	19	17	1.34	1.62	1.88	2.15	3.19
Pneumonia/influenza	M	17	0	0	15	14	1.09	2.07	2.47	3.04	5.13
Chronic Obstructive Pulmonary Disease	B	19	0	0	19	17	1.86	2.43	3.39	4.40	8.35
Appendicitis, hernia and peptic ulcer	M	13	0	0	12	10	1.77	2.09	2.43	2.79	5.12
Other liver and gall bladder diseases	N	16	0	0	15	12	1.51	1.80	2.10	2.62	3.16
Alcohol abuse	B	18	0	0	18	16	1.82	2.62	3.78	4.40	7.49
Road traffic accidents	I	15	0	0	14	12	1.14	1.76	2.06	2.47	3.08
Accidental falls	I	19	0	0	12	11	0.61	1.54	1.84	2.38	3.49
Suicide	I	17	0	0	15	15	1.17	1.82	2.08	2.52	6.16

B. Women

	Classification	Observations					Range of values				
		Total	RR < 1.00 (95%)	RR < 1.00 (99%)	RR > 1.00 (95%)	RR > 1.00 (99%)	Minimum	Q1	Q2 (median)	Q3	Maximum
Total	n.a.	19	0	0	19	19	1.15	1.44	1.61	1.84	2.24
Cancer of buccal cavity, pharynx, and oesophagus	B	13	0	0	8	7	0.85	1.44	1.52	2.24	3.03
Cancer of stomach	N	16	0	0	10	7	1.22	1.35	1.83	2.14	4.62
Cancer of colorectum	N	19	0	0	8	6	0.93	1.14	1.28	1.33	1.87
Cancer of liver	N	16	0	0	7	5	0.72	1.09	1.46	1.68	2.19
Cancer of pancreas	N	17	0	0	6	4	0.74	1.07	1.26	1.30	1.62
Cancer of trachea, bronchus and lung	B	19	1	1	12	11	0.61	1.19	1.55	1.97	3.21
Cancer of breast	M	19	3	2	2	1	0.77	0.85	0.97	1.02	1.33
Cancer of cervix	B/M	13	0	0	11	9	1.07	2.22	2.82	3.80	4.57
Cancer of kidney and bladder	N	15	0	0	9	6	0.88	1.17	1.51	1.75	9.79
Hodgkin's disease and leukemia	M	15	0	0	3	1	1.01	1.18	1.29	1.37	3.00
Diabetes mellitus	B	16	0	0	12	11	1.13	2.24	3.19	3.70	9.76
Hypertensive disease	B/M	16	0	0	10	9	0.82	1.53	2.48	3.09	4.90
Ischemic heart disease	B/M	19	0	0	17	14	1.17	1.76	2.41	2.72	3.65
Cerebrovascular disease	B/M	19	0	0	15	11	1.08	1.51	1.90	2.27	2.90
Pneumonia/influenza	M	16	0	0	10	10	0.94	1.50	2.20	2.96	3.96
Chronic obstructive pulmonary disease	B	17	0	0	13	10	1.08	2.29	2.78	3.29	5.70
Appendicitis, hernia and peptic ulcer	M	10	0	0	9	6	1.19	2.02	2.24	2.75	4.49
Other liver and gall bladder diseases	N	16	0	0	14	8	1.44	1.69	2.09	2.40	3.20
Alcohol abuse	B	14	0	0	13	11	1.96	2.41	3.29	3.88	6.74
Road traffic accidents	I	13	0	0	4	3	1.00	1.14	1.26	1.40	1.69
Accidental falls	I	11	0	0	6	4	0.99	1.20	1.55	1.81	2.62
Suicide	I	14	0	0	9	6	0.96	1.26	1.64	2.12	2.90

For classification of coding, see Table 2.
RR < 1.00 or >1.00: 95% or 99% Confidence Interval of Relative Risk does not overlap with 1.00.
Q1: first quartile; Q2: median; Q3: third quartile.

Table 4 presents a systematic comparison of the distribution of Relative Risks between preventable and non-preventable causes of death. The interquartile range of the Relative Risks for all preventable causes (based on 276 and 244 cause- and country-specific observations among men and women, respectively) is 1.61–2.88 among men, and 1.27–2.74 among women, with median values of 2.15 and 1.90, respectively. The interquartile range of the Relative Risks for all non-preventable causes (based on 109 and 99 cause- and country-specific observations) is 1.26–1.91 among men, and 1.20–1.86 among women, with median values of 1.53 and 1.43. This clearly indicates generally larger inequalities for preventable than for non-preventable causes.

Among men, larger inequalities than seen for non-preventable causes are also found for each of the three groups of preventable causes separately: the median Relative Risks for causes of death amenable to behavior change, medical intervention and injury prevention are 2.35, 1.82 and 1.94, respectively. Among women, however, while a larger median Relative Risk is found for causes of

death amenable to behavior change (2.30) and medical intervention (1.90), it is not for causes of death amenable to injury prevention (1.40). As shown by these figures, causes of death amenable to behavior change have the highest median Relative Risks.

This contrast between preventable and non-preventable causes is found in most populations but not in all (Fig. 2). Both among men and among women, the contrast is small or absent in the Southern European populations (Barcelona, Basque Country, Madrid, Turin, Tuscany). On the other hand, the difference in magnitude of mortality inequalities between preventable and non-preventable causes is very large in Central & Eastern Europe (Hungary, Czech Republic, Poland, Estonia).

All results presented so far apply to the low educated, and their Relative Risks of mortality as compared to the high educated. Similar results are found for the mid educated, who generally have mortality risks in-between those of the low and high educated. The number of Relative Risks for which the 95% Confidence Interval did not include 1.00 is correspondingly smaller, but among those the number of Relative Risks larger than 1.00, indicating a higher mortality risk for the mid than for the high educated (406), greatly exceeds the number of Relative Risks smaller than 1.00 (3 only), as it does for the low educated (Table 3). Like the low educated, the mid educated have larger Relative Risks for preventable than for non-preventable causes of mortality. For example, among mid educated men, the median Relative Risks as compared to high educated men are 1.53 for all preventable causes, 1,68 for causes of death amenable to behavior change, 1.46 for causes of death amenable to medical intervention, and 1.50 for causes of death amenable to injury prevention, against a Relative Risk of 1.29 for all non-preventable causes (results not shown).

4. Discussion

4.1. Summary of main findings

Although an overwhelming majority of Relative Risks indicate higher mortality risks among the lower educated, the strength of the education–mortality relation is highly variable both between

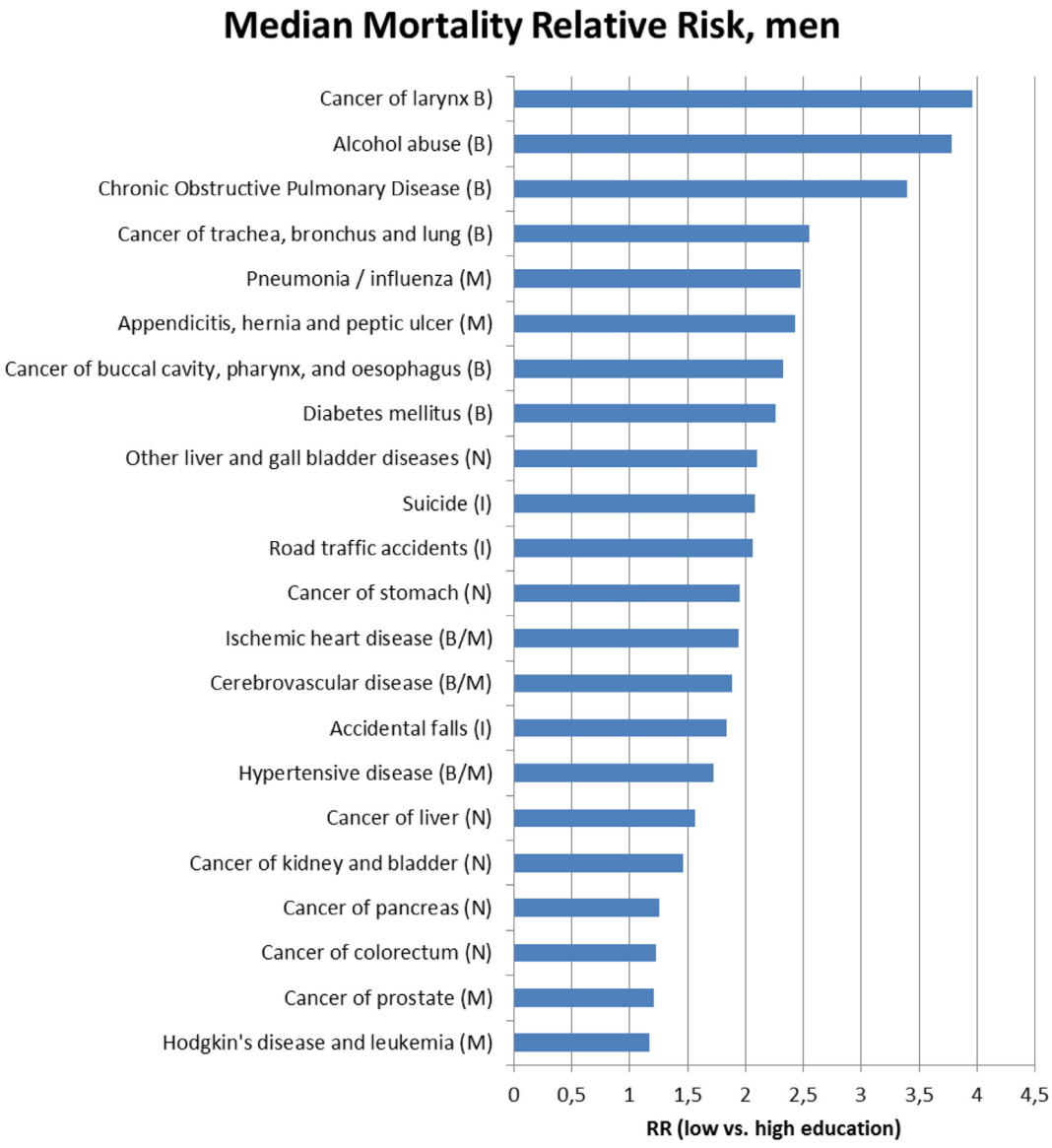


Fig. 1. Median values for the association between education and cause-specific mortality, by sex, 19 European populations.

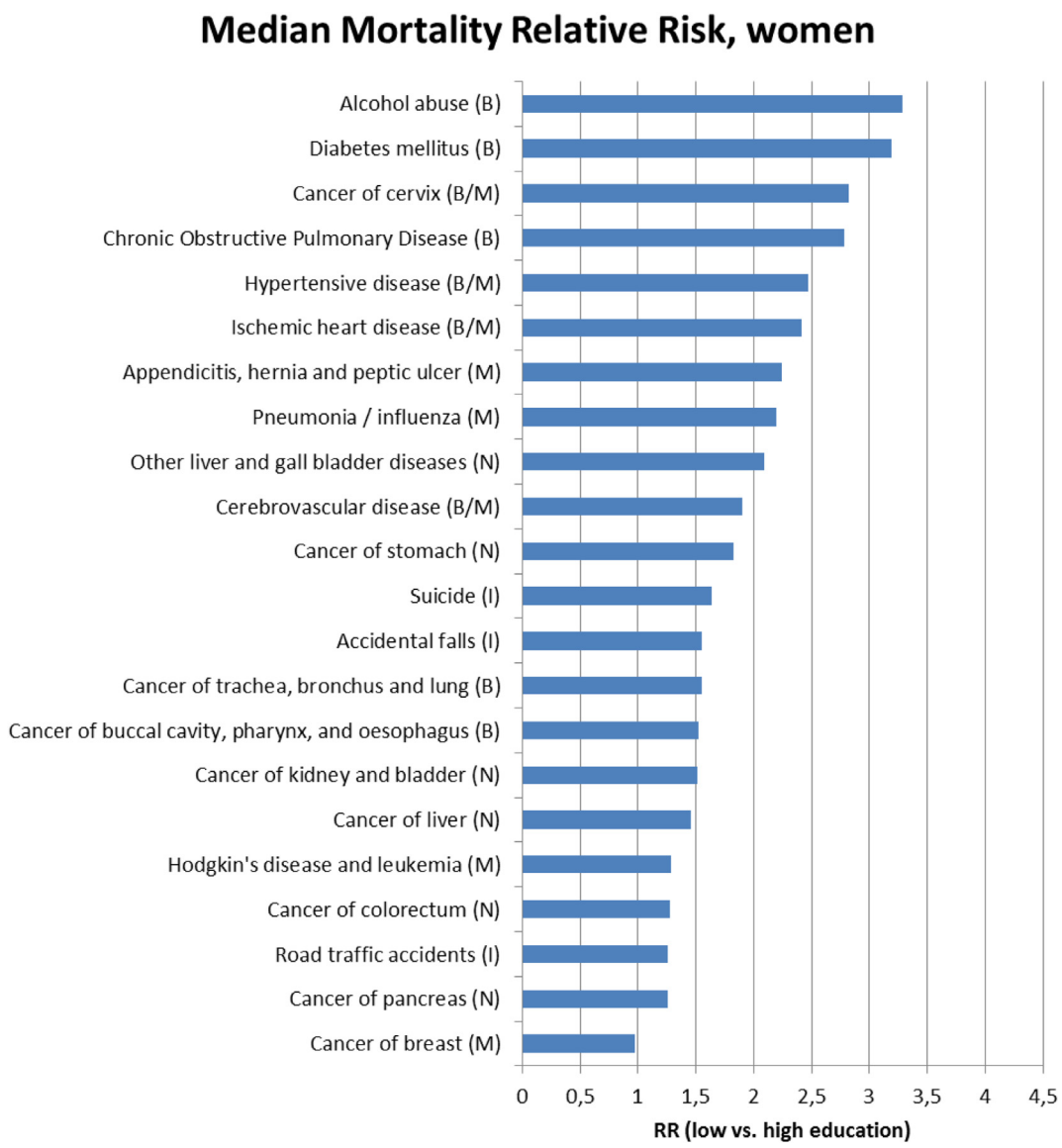


Fig. 1. (*continued*)

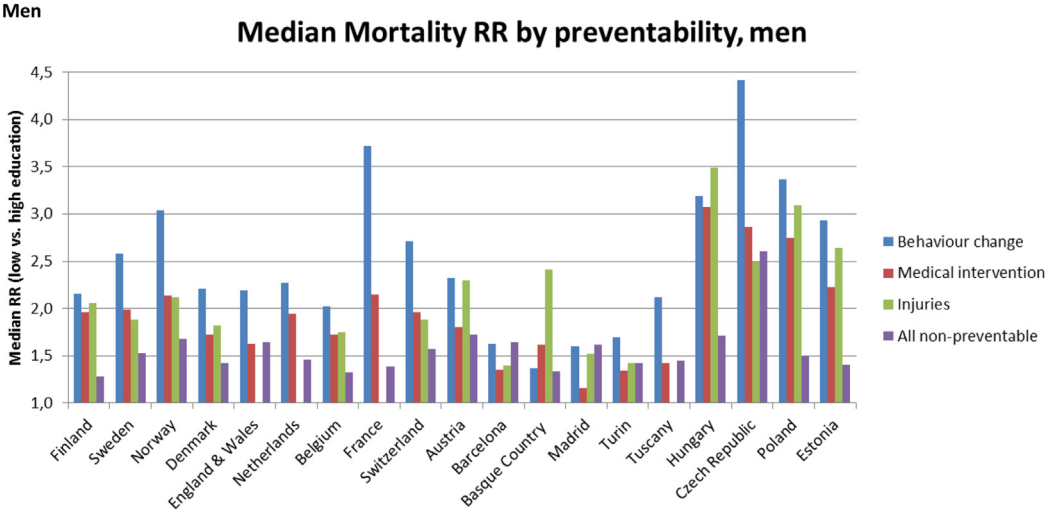
causes of death and populations. Relative inequalities in mortality are generally larger for causes amenable to behavior change, medical intervention and injury prevention than for non-preventable causes. The contrast between preventable and non-preventable causes is particularly large for causes amenable to behavior change, but absent for causes amenable to injury prevention among women. The contrast between preventable and non-preventable causes is larger in Central & Eastern Europe, where resource inequalities are substantial, than in the Nordic countries and continental Europe, where resource inequalities are relatively small, but they are absent or small in Southern Europe, where resource inequalities are also large.

Table 4
Associations between education and cause-specific mortality: comparison between preventable and less preventable conditions, by sex, 19 European populations.

	Men				Women			
	Observations	Q1	Q2 (median)	Q3	Observations	Q1	Q2 (median)	Q3
All causes	385	1.43	1.90	2.62	343	1.25	1.67	2.43
All preventable	276	1.61	2.15	2.88	244	1.27	1.90	2.74
Amenable to behaviour change	161	1.86	2.35	3.19	146	1.57	2.30	3.10
Amenable to medical intervention	118	1.40	1.82	2.34	127	1.20	1.90	2.66
Amenable to injury prevention	51	1.72	1.94	2.51	38	1.18	1.40	1.69
All non-preventable	109	1.26	1.53	1.91	99	1.20	1.43	1.86

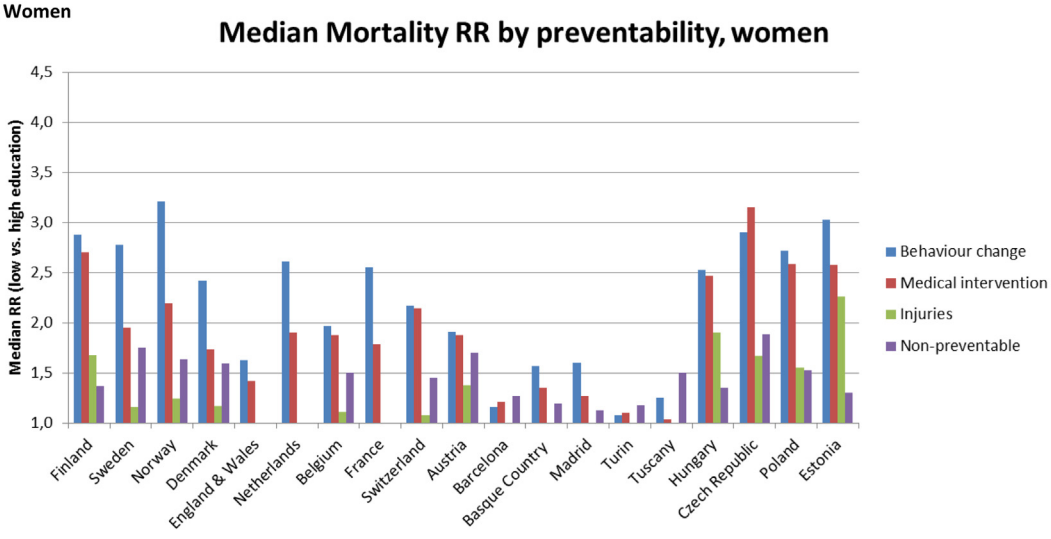
Q1: first quartile; Q2: median; Q3: third quartile.

a. Men



Note: Median Mortality Relative Risk only presented if at least 3 available observations each based on >100 deaths; therefore, median RR's missing for injuries in England & Wales, Belgium, France and Tuscany.

b. Women



Note: Median Mortality Relative Risk only presented if at least 3 available observations each based on >100 deaths; therefore, median RR's missing for injuries in England & Wales, Belgium, France, Barcelona, Basque Country, Madrid, Turin and Tuscany, and for non-preventable causes in England & Wales, Netherlands, and France.

Fig. 2. Associations between education and cause-specific mortality: comparison between preventable and less preventable conditions, by sex and population.

4.2. Limitations

This is probably the most comprehensive analysis of inequalities in cause-specific mortality ever conducted, but its broad international scope inevitably raises issues of data comparability. Despite extensive harmonization efforts, our comparisons between countries may be biased by differences in data collection, for example with regard to study design, population coverage, time-periods covered, and data classification. For example, in Hungary, the Czech Republic, Poland and Estonia mortality data were collected in a cross-sectional unlinked design, which may produce over- or underestimation of mortality inequalities as compared to studies using a longitudinal design (Shkolnikov et al., 2007). It is unlikely, however, that our comparison of preventable and non-preventable causes is biased as a result of these differences in data design, because the latter will affect mortality from both groups of causes in a similar way.

The data for Italy and Spain come from studies conducted in largely urban settings, which are not necessarily representative of the national population in these countries. We have shown previously that the Italian and Spanish populations included in our analysis are characterized by relatively small educational and occupational inequalities in mortality (Mackenbach et al., 1997, 2008). This has been confirmed by studies covering the complete Spanish and Italian national populations (Marinacci et al., 2013; Regidor et al., 2012). We consider it likely, therefore, that our results on preventable and non-preventable can also be generalized to the national populations of these countries.

Our analysis relies on the accuracy of cause-of-death certification and coding, and while this may differ between countries and causes of death, comparisons between groups of preventable and non-preventable causes are unlikely to be seriously affected. Our classification of causes according to their preventability is a potentially larger source of uncertainty. In contrast to Phelan et al.

(2004) we did not primarily rely on expert opinion but used authoritative literature for our classification, but this does of course not rule out misclassifications, because the scientific literature is full of debate about causality of risk factors and effectiveness of interventions (Rothman and Greenland, 2005). This uncertainty is illustrated by the fact that mortality from some non-preventable causes, e.g. stomach cancer, has declined considerably over the past decades in many countries (Karim-Kos et al., 2008), whereas mortality from some preventable causes, e.g. alcohol abuse, has certainly not uniformly declined (Herttua et al., 2008). Without in-depth and country-specific knowledge about the "health-directed human agency" involved in levels and trends of mortality from each of these conditions, a classification according to their "preventability" will have to remain somewhat tentative.

As its title implies, the theory of "fundamental causes" assumes that low socioeconomic status is a causal determinant of health problems. Causality, however, is not the only possible explanation for the association between socioeconomic status and health problems: reverse causation (or health-related selection during social mobility) (Macintyre, 1997) and confounding by factors temporally preceding achievement of socioeconomic position and the occurrence of health problems (such as cognitive ability and personality) (Mackenbach, 2010) are other possible explanations. In our analysis we have used education as the indicator of socioeconomic position, and while education is less sensitive to reverse causation than occupational class or income, confounding may still be an issue. However, quasi-experimental approaches using compulsory schooling reforms have generally supported the claim that at least part of the association between education and mortality is causal (Lleras-Muney, 2005). Nevertheless, despite the fact that we have used longitudinal data wherever available, we cannot claim causality, and in our comparisons between causes of death we have to assume that non-causal mechanisms are equally important across these causes. This seems a plausible assumption, although it is theoretically possible that the association between education and non-preventable conditions is less strongly confounded by third factors like cognitive ability than the association between education and preventable conditions.

A final limitation of our study is that it is cross-sectional in nature, and compares levels of mortality at one point in time. In order to capture the dynamics of mortality change as postulated by the "fundamental causes" theory, one would need to look at differences between preventable and non-preventable causes in mortality trend, like some previous studies have done (Masters et al., 2012; Miech et al., 2011; Phelan and Link, 2005b). We therefore recommend to replicate our analysis with data on time trends in cause-specific mortality by socioeconomic position as soon as trend data become available for these European populations.

4.3. Interpretation

Our study, based on data from a large number of European countries, generally confirms previous findings for the United States that social inequalities in mortality from preventable causes tend to be larger than social inequalities in mortality from non-preventable causes. However, in contrast to previous tests of the "fundamental cause" theory, we were able to make comparisons within the high-preventability group, which included conditions amenable to behavior change, medical intervention, and injury prevention. We show that the contrast between preventable and non-preventable causes is present for all three groups (with the exception of injury prevention among women). Because our analysis treats all causes of death as equally important, and does not lump them together thereby introducing a weighting by number of deaths, we believe that ours is a stronger test of the theory than Phelan et al. (2004).

Causes of death amenable to behavior change showed the largest inequalities in mortality, both among men and among women. In most European countries, inequalities in smoking, excessive alcohol consumption, obesity and other behavioral risk factors are substantial and contribute importantly to the explanation of inequalities in mortality (Eikemo and Mackenbach, 2012; Kulik et al., 2013, 2014; Mackenbach et al., 2008; Makela et al., 1997; Roskam et al., 2010). It is quite likely that these inequalities in health-related behaviors are indeed a reflection of differences between low and high educated people in "an array of resources, such as money, knowledge, prestige, power, and beneficial social connections" (Phelan et al., 2004, page 265). These resources also include collective facilities, such as tobacco control initiatives which have generally been more successful in reducing smoking among the higher than among the lower educated (Schaap et al., 2008). Inequalities in mortality from conditions amenable to medical intervention have also been demonstrated before (Stirbu et al., 2010), and are likely to reflect differences in help-seeking behavior as well as in access to good quality medical care (Mackenbach et al., 2008; Plug et al., 2012).

It is not immediately clear, however, why inequalities in mortality from causes amenable to injury prevention (road traffic accidents, accidental fall, suicide) are larger than inequalities in mortality from non-preventable causes among men, but not among women. This cannot be due to the fact that injury mortality among women is particularly low in most European populations – it is low, but not lower than mortality from various other conditions for which clear social gradients are found, such as cervical cancer, hypertensive disease, and accidental fall (Table 3). A previous study of road traffic injury in Europe also found educational inequalities among men, but not among women (Borrell et al., 2005). Inequalities in road traffic accident mortality are the product of differences in traffic exposure (access to vehicles, kilometers driven, etc.), differences in injury incidence (as a result of both crashes and crash protection), and differences in case fatality (as a result of injury severity and promptness and quality of medical treatment). Perhaps among lower educated women, higher injury incidence and/or higher case fatality are compensated by lower traffic exposure, e.g. because of lower access to motorized transport (Borrell et al., 2005). Further in-depth studies are required to explain these findings, and to determine whether they can be reconciled with the "fundamental causes" theory which predicts that higher educated women are better able to avoid the health risks associated with road traffic.

The "reverse" inequalities in lung and breast cancer mortality among women seen in some European populations also seemingly contradict the "fundamental causes" theory. In the case of lung cancer, we have demonstrated in previous studies that the "anomaly" is due to the fact that women in Southern Europe have taken up smoking relatively recently, and that among them smoking has so far been more common among the higher than among the lower educated, particularly in older generations (Cavelaars et al., 2000). In the case of breast cancer, a similar time-dependent process is likely to be at work, with modern patterns of child-bearing behavior (delayed child bearing, smaller numbers of children, less breast feeding, …) having been adopted by high educated women first (Menvielle et al., 2005).

These exceptions suggest a need to more explicitly consider the introduction of new health risks. Because the core of the "fundamental causes" theory is based on the notion that "as opportunities for avoiding disease expand so health inequalities continue to exist" (Link and Phelan, 1995), it does not explain what happens when new health risks, such as those of motorized transport,

smoking or modern patterns of child-bearing, are introduced. These risks often manifest themselves first among those with a higher income (because new products or behaviors are expensive) or higher education (because information on new products or behaviors reaches them first). Only when the new products or behaviors have diffused towards the lower socioeconomic groups, *and* when the health risks of these products or behaviors have become known and actionable, can "health-directed human agency" and differential access to resources start to produce an inverse association between socioeconomic status and mortality. While these exceptions are likely to be only temporary deviations from the relationships stated by the "fundamental causes" theory, they underline the importance of "diffusion of innovation" as one of the mechanisms involved (Chang and Lauderdale, 2009; Glied and Lleras-Muney, 2008).

Our findings are only partly in accordance with the hypothesis that the link between socioeconomic position and mortality from preventable causes is strongest in countries where social inequalities (measured as inequalities in access to material resources) are largest. On the basis of proportions of population at risk of poverty and social exclusion we expected inequalities in mortality from preventable conditions to be largest in Central & Eastern European countries (which indeed proved to be the case), and smallest in the Nordic and continental-European countries (which appeared not to be the case). Inequalities in mortality from preventable causes are generally smallest in Southern Europe, where despite considerable resource inequalities, inequalities in mortality from preventable causes are rather small. This does not only apply to smoking-related causes of death, but is true also for other causes amenable to behavior change, for causes amenable to medical intervention, and for causes amenable to injury prevention (among men – numbers of deaths among women are too small to provide reliable estimates of inequalities in injury mortality among women in Southern Europe). In order to reconcile these findings with the "fundamental cause" theory, one would have to explain why the resources of a higher educational level do not provide protection against the preventable mortality risks prevailing in these countries, whereas they do in other countries.

This is not because Spain and Italy have more universal, or more universally effective, welfare or public health policies (Mackenbach and McKee, 2013a). Alternatively, one may want to look for "countervailing mechanisms" producing "reverse" gradients favoring the lower educated (Lutfey and Freese, 2005), and determine whether and why these are relatively more important in Spain and Italy than in other European countries. We have previously shown that inequalities in mortality from ischemic heart disease are smaller in Spain and Italy than in other European countries (Mackenbach et al., 2000, 2008), and the available evidence suggests that this is partly due to the fact that while the higher socioeconomic groups in these countries have adopted a modern western diet, the lower socioeconomic groups have continued to adhere to a traditional Mediterranean diet (Kulhanova et al., in press; Mackenbach et al., 2000). This could be an example of a countervailing mechanism produced by "status pursuit": "when maintaining status conflicts with the optimal behaviors for the prevention and control of a disease, this might create some pathways that work against the fundamental relationship, even though the overall balance of mechanisms strongly sustains it" (Lutfey and Freese, 2005, page 1365). The existence of a clear gradient in almost all causes of death, whether preventable or not, also raises open questions that deserve further analysis.

On balance, and despite some exceptions indicating a need for further empirical and theoretical analysis, our results provide support for the "fundamental causes" theory. Our study's strategy, like that of several others (Glied and Lleras-Muney, 2008; Masters et al., 2012; Phelan et al., 2004), capitalizes on one aspect of the theory, i.e. "health-directed human agency", which allows a distinction between causes of death that can be eliminated by purposive action and those that cannot. Apart from the fact that such intentionality is not always required for the elimination of a cause of death (as in the case of stomach cancer, which has declined partly as an unintended side-effect of changes in food conservation, and is socially patterned despite its non-preventability (Howson et al., 1986)), it is not the only aspect of the theory that allows empirical testing. For example, one could directly study whether it is true that when one specific mechanism linking socioeconomic status to mortality is eliminated, its place is taken by another (Miech et al., 2011). Such a "replacement of intervening mechanisms" is suggested by the gradual replacement, over time, of smoking by excessive alcohol consumption as main contributor to inequalities in life expectancy in Finland between 1988 and 2007 (Martikainen et al., 2014), or the replacement of smoking by obesity as main contributor to inequalities in mortality among Scottish women (Hart et al., 2011), or by the different roles of smoking, unhealthy diet, and physical inactivity in a comparison of inequalities in mortality between England and France (Stringhini et al., 2011). At a simpler level, the basic observation on which the theory rests, that of the persistence of health inequalities over time and place, also deserves further scrutiny (Bengtsson and van Poppel, 2011; Kunitz, 2007).

We end with a few words about the policy implications of the "fundamental cause" theory. If it is true that the association between socioeconomic status and health "is reproduced over time via the replacement of intervening mechanisms" (Phelan et al., 2004, page 268), tackling these intervening mechanisms will not necessarily help to reduce inequalities in mortality. Phelan et al. therefore "advocate policies that encourage medical and other health-promoting advances while at the same time breaking or weakening the link between these advances and socioeconomic resources. This can be accomplished either by reducing disparities in socioeconomic resources themselves or by developing interventions that, by their nature, are more equally distributed across SES groups" (Phelan et al., 2010)(page S28). We agree, but note that both are far from easy, as illustrated by the remarkable robustness of inequalities in mortality across time and place.

5. Conclusions

Our results provide some further support for the theory of "fundamental causes". However, the absence of larger inequalities for preventable causes in Southern Europe and for injury mortality among women indicates that further empirical and theoretical analysis is necessary to understand when and why the additional resources that a higher socioeconomic status provides, do and do not protect against prevailing health risks.

Competing interests

The authors declare to have no conflicts of interest.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.socscimed.2014.05.021.

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