Health & Place 47 (2017) 44–53

Contents lists available at ScienceDirect

Health & Place

journal homepage: www.elsevier.com/locate/healthplace

Determinants of the magnitude of socioeconomic inequalities in mortality: A study of 17 European countries

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ARTICLE INFO

Keywords:
International variations
Mortality
Health inequalities
Determinants
Europe

ABSTRACT

The magnitude of socioeconomic inequalities in mortality differs importantly between countries, but these variations have not been satisfactorily explained. We explored the role of behavioral and structural determinants of these variations, by using a dataset covering 17 European countries in the period 1970–2010, and by conducting multilevel multivariate regression analyses. Our results suggest that between-country variations in inequalities in current mortality can partly be understood from variations in inequalities in smoking, excessive alcohol consumption, and poverty. Also, countries with higher national income, higher quality of government, higher social transfers, higher health care expenditure and more self-expression values have smaller inequalities in mortality. Finally, trends in behavioral risk factors, particularly smoking and excessive alcohol consumption, appear to partly explain variations in inequalities in mortality trends. This study shows that analyses of variations in health inequalities between countries can help to identify entry-points for policy.

1. Introduction

Inequalities in mortality and morbidity between people with a higher and lower socioeconomic position, as indicated by educational level, occupational class, or income level, are a persistent challenge for health policy. These inequalities are present within all European countries with available data, as shown in a series of comparative studies funded by the European Commission (Mackenbach et al., 2008). These comparative studies offer a rare 'macroscopic' view of health inequalities which has challenged conventional ideas. For example, the finding that health inequalities within countries are not smaller in European countries with more egalitarian social policies, such as the Nordic countries, suggests that health inequalities are not primarily determined by inequalities in material living conditions (Mackenbach et al., 1997; Dahl et al., 2006).

Most of these studies have focused on inequalities in mortality by level of education. Fig. 1a illustrates the remarkable differences between countries: relative inequalities in mortality are largest in the East (Czech Republic, Lithuania, Hungary, Estonia, and Slovenia), and smallest in the South (Spain and Italy).

This geographical pattern also applies to absolute inequalities in mortality (Web Appendix Fig. A1), because the mortality rates of the higher educated are rather similar between countries, whereas the mortality rates of the lower educated are much higher in some countries than in others (Lundberg et al.; van Raalte et al., 2011).

Another remarkable feature of this geographical pattern is that it is a recent phenomenon. Relative inequalities in mortality have widened considerably in many countries during the last decades, particularly among men, mainly because mortality has declined more strongly among the high than among the low educated (Mackenbach et al., 2015a; de Gelder et al., 2017; Mackenbach et al., 2016). Fig. 1b illustrates that the current geographical pattern of inequalities in

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http://dx.doi.org/10.1016/j.healthplace.2017.07.005
Received 20 November 2016; Received in revised form 24 June 2017; Accepted 18 July 2017

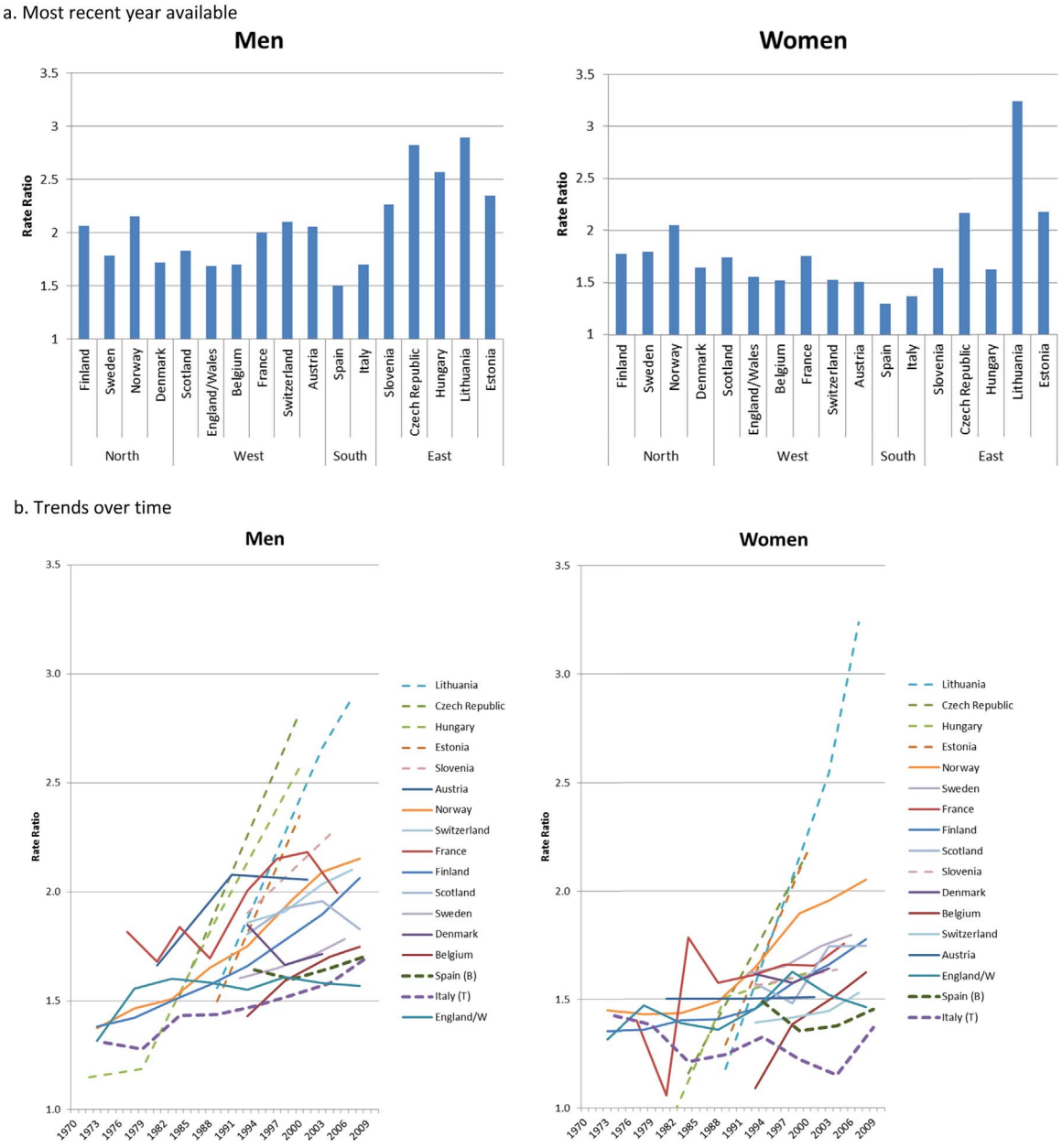

Fig. 1. Relative inequalities in mortality by education. (a) Note: Rate Ratio (RR) of age-standardized mortality among 'low' as compared to 'high' educated (reference category). Most recent year available: most recent of periods covered as given in Web Appendix Table A1. (b) Note: Rate Ratio (RR) of age-standardized mortality among 'low' as compared to 'high' educated (reference category). Broken lines for countries in Eastern and Southern Europe.

mortality is the result of a strong divergence between countries starting in the 1980s. Both among men and women, variation between countries was small in the 1980s, but since then inequalities in mortality have risen much more in some countries than in others, and as a result relative inequalities in mortality are now very large in Eastern Europe, and have remained small in Southern Europe (de Gelder et al., 2017).

The explanation of these between-country patterns is largely unknown. Although there have been many social-epidemiological studies of the contribution of specific determinants to inequalities in mortality at the individual level, between-country variations in the magnitude of health inequalities at the aggregate level have only rarely been studied. Detailed descriptions of between-country variations have been published for ischemic heart disease (Avendano et al., 2006), stroke (Avendano et al., 2004, 2005), lung cancer (Mackenbach et al., 2004; Van der Heyden et al., 2009), breast cancer (Strand et al., 2007), diabetes (Vandenheede et al., 2015; Espelt et al., 2008), tuberculosis (Alvarez et al., 2011; Nagavci et al., 2016), road traffic accidents (Borrell et al., 2005), suicide (Lorant et al., 2005a, 2005b) and homicide (Stickley et al., 2012), but in none of these studies an attempt has been made to relate variations in inequalities of cause-specific mortality to variations in inequalities in determinants of mortality.

Some recent studies by our group have analyzed the impact of inequalities in behavioral risk factors (Eikemo et al., 2014), particularly smoking (Kulhanova et al., 2014a; Cavelaars et al., 2000; Huisman et al., 2005; Kulik et al., 2014; Kulik et al., 2013; Gregoraci et al., 2017), excessive alcohol consumption (Mackenbach et al., 2015b), and obesity (Roskam et al., 2010; Hoffmann, 2015; Hoffmann et al., 2015), but did not directly address why inequalities in mortality are larger in some European countries than in others. Previous studies of between-country variations in the magnitude of inequalities in mortality have also largely ignored the possible role of structural determinants of health inequalities, such as poverty and other economic conditions and social and health care policies. The study reported in this paper

therefore aims to explore which factors might be involved in generating the between-country variations in inequalities in mortality and mortality trends illustrated above, by assessing, within the framework of an ecological analysis, the possible role of a number of behavioral as well as structural determinants.

2. Data and methods

2.1. Data

2.1.1. Mortality

Our analysis used register-based mortality data from 17 European countries: Finland, Sweden, Norway, Denmark ('North'); Scotland, England & Wales, Belgium, France, Switzerland, Austria ('West'); Spain and Italy ('South'); and Slovenia, Czech Republic, Hungary, Lithuania and Estonia ('East'). Many European countries are unable to provide such data, either because no indicators of socioeconomic position are registered or because of barriers in data linkage. An overview of the mortality data sources and some key characteristics of the data are given in Web Appendix Table A1. More information on the mortality data can be found on the project website (www.demetriq.eu) as well as in previous papers based on the same datasets (Mackenbach et al., 2015a, 2016, 2015b).

Most data stemmed from a longitudinal mortality follow-up after a census, in which socioeconomic information of the population-at-risk and of the deceased had been recorded in the census; some countries only had unlinked cross-sectional data in which socioeconomic information on the population-at-risk came from the census, and socioeconomic information on the deceased came from the death certificate. In most countries linkage between the population and death registries was more than 95% complete; for countries where linkage failure exceeded 5% (Madrid, Barcelona and the Basque Country) mortality rates were multiplied by the inverse of the proportion of deaths that were successfully linked in order to adjust for the linkage failure. Data for Spain and Italy came from regional populations, but previous studies have shown that patterns observed in these regional populations correspond well to those seen at the national level (Regidor et al., 2012; Marinacci et al., 2013).

Socioeconomic status was indicated by highest level of completed education. Education was classified according to the International Standard Classification of Education (ISCED-97) (Unesco, 1997). In our analyses we compared those with 'no, primary or lower secondary education' (ISCED 0–2; 'low') to those with 'tertiary education' (ISCED 5–6; 'high'). Persons with missing education were excluded from the analysis. The proportion of population aged 35–79 years with unknown educational level varied between 0% and 11%.

In addition to all-cause mortality we distinguished four large cause-of-death groups (cardiovascular disease, cancer, other diseases and external causes). The analyses were restricted to the ages between 35 and 79 years because education gradually loses its discriminatory power as a measure of socioeconomic status among the elderly (Galobardes et al., 2006). A previous study based on the proportion of deaths coded as due to "symptoms and ill-defined conditions" has found no indications for socioeconomic inequalities in accuracy of cause-of-death classification (Kulhanova et al., 2014b).

2.1.2. Determinants

In order to capture exposure to behavioral risk factors we used survey-reported current smoking and obesity by education, as well as mortality by education from three directly smoking-related causes (lung cancer, aerodigestive cancers, and COPD/asthma, indicating cumulative life-time exposure to smoking, which affects many more causes of death than these three only (Ezzati et al., 2006)) and from four directly alcohol-related causes (liver cirrhosis, alcoholic cardiomyopathy, alcoholic psychosis, dependence and abuse, and accidental poisoning by alcohol, indicating current and cumulative exposure to excessive alcohol consumption, which affects many more causes of death than these four only (Ezzati et al., 2006)). Unfortunately, reliable and comparable survey data on inequalities in alcohol consumption are not available in Europe. We also measured the prevalence of poverty by level of education using the harmonized EU indicator of people "at risk of poverty or social exclusion". Poverty data were only available for the most recent time-period covered by the mortality data. Further details on the survey data are given in Web Appendix Table A1, Fig. A2, and Note A1.

In our dataset, smoking, smoking-related mortality, alcohol-related mortality and poverty are all strongly and positively associated with all-cause mortality in a cross-sectional analysis, and smoking, smoking-related mortality, alcohol-related mortality and obesity are also strongly and positively associated with mortality in the trend analysis, which underpins our use of these individual-level risk factors as potential mediators of the association between education and mortality.

Data on national-contextual determinants were obtained from harmonized international databases, mainly the Quality of Government Dataset (Quality of Government Institute, 2014) and the Comparative Political Data Set (Institut für Politikwissenschaft, 2014). We selected for analysis variables which have previously been shown to be associated with mortality in cross-European studies: national income (world-wide, levels of prosperity continue to be among the most important determinants of mortality, and this is also still true in Europe (Mackenbach and Looman, 2013)), income inequality (although results of studies are not entirely consistent, higher levels of income inequality have often been found to be associated with higher mortality (Pickett and Wilkinson, 2015)), quality of government (higher quality of government goes together with lower mortality, probably because of the greater effectiveness of institutions and programs that help to lower mortality (Mackenbach and McKee, 2013)), social transfers (better social protection through more generous or more inclusive social security programs is associated with lower mortality (Lundberg et al., 2008), and health care expenditure (higher levels of health care expenditure are associated with lower mortality, particularly from conditions amenable to medical intervention (van Baal et al., 2013)). We also selected two measures of national culture, i.e. the "secular-rational" (versus "traditional"), and the "self-expression" (versus "survival") dimension as developed by Inglehart (Inglehart, 1997); higher values on these dimensions indicate more modern cultural values, which are associated with lower mortality in European countries, probably through an effect on individual health-related behaviors such as smoking and excessive alcohol consumption, and/or on collective efforts to improve population health such as tobacco control or traffic safety policies (Mackenbach, 2014). All these variables were independently associated with mortality in our dataset, and we expected higher values of all contextual variables to be associated with smaller inequalities in mortality, except income inequality for which we expected the reverse. Details on the measurement of these contextual variables are given in Web Appendix Note A1.

2.2. Analysis

All mortality rates and smoking and obesity prevalence rates by educational level were directly age-standardized using the European Standard Population (Ahmad et al., 2001).

For the cross-sectional analysis of individual-level determinants we conducted regression analyses of the natural logarithm of the age-standardized mortality rate on education (dummy variable with 1 = 'low' versus 0 = 'high'), controlling for sex (dummy variable with 1 = male and 0 = female) and region (dummy variables representing North, West, South, and East). This was done in a multilevel framework using linear mixed models with random intercepts for 'country'. In order to assess the possible contribution of risk factors to the excess mortality among the low educated, we added the behavioral determinants and

poverty to the regression model and determined the degree of attenuation of the regression coefficient for low education. In order to assess the possible contribution of these risk factors to smaller inequalities in the South and larger inequalities in the East, we added a two-way interaction term between low education and the dummy variable for South and East, respectively, and repeated the same procedure. The number of observations in each of these analyses was 68 (17 countries, 2 sexes, 2 education groups). For presentation purposes, the regression coefficients for low education and for the interaction between low education and region were transformed into Rate Ratios and their 95% Confidence Intervals.

For the trend analysis we conducted a similar series of analyses, now using log transformed age-standardized mortality rates and risk factors by sex, country, education, and calendar-year, and again controlling for sex and region. In order to quantify inequalities in mortality decline we added a two-way interaction term between low education and calendar-year. These analyses were also done in a multilevel framework using linear mixed models with a random intercept for 'country', and in order to take into account the serial autocorrelation in the observed mortality rates we used an autoregressive model of order 1 (AR(1)). The number of observations in each of these analyses was 308 (17 countries, 2 sexes, 2 education groups, variable number of time-periods). For presentation purposes, the regression coefficients for low education and for the interaction terms were transformed into Percent Annual Changes and their 95% Confidence Intervals.

We also did cross-sectional analyses for the national-contextual variables, to assess whether the excess mortality among the low educated, or the slower mortality decline among the low educated, was associated with country characteristics. We therefore conducted multilevel multivariate regression analyses of log transformed age-standardized mortality rates on sex, region, education, adding two-way interaction terms between education and each of the contextual variables separately.

In order to retain sufficiently large numbers of observations, we pooled data for men and women in all our analyses. As Fig. 1a shows, inequalities in mortality are often larger among men than among women, but geographical patterns of inequalities in mortality are similar. A regression analysis for current inequalities in mortality in which we introduced an interaction term between low education and sex confirms that inequalities in all-cause mortality are larger (but not statistically significantly so) among men, mainly because inequalities in mortality from cancer and external causes are larger among men. This can largely be explained by larger inequalities in smoking, smoking-related mortality and alcohol-related mortality among men than among women (results not shown).

Analyses were conducted in SPSS version 22.

3. Results

3.1. Inequalities in current mortality

The results of regression analyses of the contribution of behavioral risk factors and poverty to between-country variations in inequalities in mortality are reported in Table 1a (all-cause mortality) and Web Appendix Table A2 (cause-specific mortality). The first line of Table 1a shows that, on average for all countries, all-cause mortality is 89% higher among the low than the high educated (Rate Ratio (RR) = 1.89; 95% Confidence Interval (CI): 1.75–2.03).

The next lines show that, statistically, smoking and alcohol both make substantial contributions to excess mortality among the low educated, but obesity does not. When we control for all four behavioral risk factors, the Rate Ratio for all-cause mortality declines from 1.89 to 1.44 (95%CI: 1.25–1.67), an attenuation of 62% (100 * (1.89-1.44)/(1.89-1.00)). Poverty, however, is an equally important contributor as the behavioral risk factors taken together: when we control for poverty only, the Rate Ratio for all-cause mortality declines from 1.89 to 1.44 (95%CI: 1.17–1.76), again a reduction of 62%.

The next part of Table 1a shows that the association between education and all-cause mortality is statistically significantly weaker in the South. For all-cause mortality, the estimated mortality Rate Ratio of low education in the South as compared to the effect of low education in all other countries is 0.74, i.e. the relative excess mortality among the low educated in the South is only 74% (95% CI: 60–93%) of that observed among all other countries in the study. This smaller effect of low education in the South can to some extent be attributed to smaller inequalities in smoking and alcohol. By contrast, obesity and poverty play no role in the explanation of smaller inequalities in mortality in the South.

The third part of Table 1a shows that the association between education and all-cause mortality is statistically significantly stronger in the East: for all-cause mortality, the effect of low education in the East is 134% (95% CI: 116–155%) of that observed in all other countries in the study. This larger effect of low education in the East partly disappears when we control for alcohol, suggesting that larger inequalities in excessive alcohol consumption in the East contribute substantially to the larger inequalities in mortality. As shown in Web Appendix Table A2, excessive alcohol consumption appears to play a role in excess mortality in the East from three out of four cause-of-death groups: cancer, other diseases, and external causes.

Table 2 shows the results of regression analyses in which we assessed whether the current effect of low education on all-cause mortality was larger or smaller depending on a number of economic, policy-related or cultural factors. Cause-specific results can be found in Web Appendix Table A3.

Among the seven national-contextual factors tested, five have statistically significant relationships with inequalities in all-cause mortality: inequalities in all-cause mortality are smaller when countries have a higher national income, have higher quality of government, spend a larger portion of their national income on social transfers, spend a larger portion of their national income on health care, and have more modern self-expression values. Because the interaction between low education and national income is stronger than the interaction between low education and the other contextual determinants (as indicated by the result of a *t*-test for the interaction term; results not shown), we illustrate the first in Fig. 2a. At higher levels of national income, inequalities in mortality are smaller, because mortality among the low educated decreases more with increasing income than mortality among the high educated.

These contextual effects are likely to be at least partly mediated by the risk factors mentioned before, particularly by inequalities in poverty and excessive alcohol consumption, as can be seen in Table 2. At higher levels of national income, inequalities in poverty and alcohol-related mortality are smaller, but inequalities in current or cumulative smoking and obesity are not (also illustrated in Fig. 2b–f). Educational inequalities in poverty are also larger when income inequalities are larger, and smaller when a larger portion of national income is redistributed through social transfers, but of these only the level of social transfers is statistically significantly associated with the magnitude of inequalities in mortality.

3.2. Inequalities in trends in mortality

In Table 1b (all-cause mortality) and Web Appendix Table A4 (cause-specific mortality) we present the results of a regression analysis in which inequalities in changes of mortality over time, by country, were related to inequalities in changes in smoking, alcohol and obesity. For poverty, no time-trend data were available.

The first and second lines of Table 1b show that, while all-cause mortality among the high educated on average declined by 2.4% (95% CI: 2.1–2.6%) per year, relative decline was 1.1%-points (95% CI: 0.8–

Table 1
Contribution of behavioral determinants and poverty to inequalities in all-cause mortality.

a. Inequalities in current all-cause mortality

Independent variable	Model	Control variables	All causes RR	95%CI	
Low education	1	Confounders	**1.89**	1.75	2.03
Low education	2	Model 1 + Smoking	**1.52**	1.37	1.69
Low education	3	Model 1 + Smoking-related mortality	**1.60**	1.46	1.74
Low education	4	Model 1 + Alcohol-related mortality	**1.68**	1.56	1.82
Low education	5	Model 1 + Obesity	**2.11**	1.86	2.38
Low education	6	Model 1 + all 4	**1.44**	1.25	1.67
Low education	7	Model 1 + Poverty	**1.44**	1.17	1.76
Low education	8	Model 1 + all 5	1.20	0.99	1.46
Low education * South	9	Confounders	**0.74**	0.60	0.93
Low education * South	10	Model 10 + Smoking	0.88	0.71	1.09
Low education * South	11	Model 10 + Smoking-related mortality	**0.80**	0.66	0.96
Low education * South	12	Model 10 + Alcohol-related mortality	0.83	0.68	1.01
Low education * South	13	Model 10 + Obesity	**0.73**	0.60	0.89
Low education * South	14	Model 10 + all 4	0.88	0.73	1.07
Low education * South	15	Model 10 + Poverty	**0.75**	0.61	0.93
Low education * South	16	Model 10 + all 5	0.87	0.73	1.05
Low education * East	17	Confounders	**1.34**	1.16	1.55
Low education * East	18	Model 17 + Smoking	**1.36**	1.21	1.53
Low education * East	19	Model 17 + Smoking-related mortality	**1.28**	1.13	1.44
Low education * East	20	Model 17 + Alcohol-related mortality	1.16	1.00	1.36
Low education * East	21	Model 17 + Obesity	**1.32**	1.15	1.51
Low education * East	22	Model 17 + all 4	**1.27**	1.11	1.45
Low education * East	23	Model 17 + Poverty	**1.32**	1.07	1.62
Low education * East	24	Model 17 + all 5	**1.22**	1.02	1.46
	Bold	p<0.05			
		excess risk attenuation >25%			
		excess risk attenuation >50%			

Notes: Based on multilevel linear regression analysis of the natural logarithm of age-standardized mortality rate (by country, sex and level of education (low and high)) on education (or education and interaction between education and region), confounders (sex, region (north, south, east, other)) and one of the following: smoking (age-standardized prevalence of survey-reported current smoking), smoking-related mortality (age-standardized mortality from 3 causes directly linked to smoking), alcohol-related mortality (age-standardized mortality from 4 causes directly linked to excessive alcohol consumption), obesity (age-standardized prevalence of survey-reported obesity), or poverty (prevalence of being at risk of poverty). Current = most recent of periods covered as given in Web appendix table A1. Number of observations available per analysis: 68.

(continued on next page)

Table 1 *(continued)*

b. Inequalities in all-cause mortality trends

Independent variable	Model	Control variables	All causes PAC	95% CI	
Year	1	Confounders + Education + Educ*Year	**-2.4%**	-2.6%	-2.1%
Low education * Year	1	Confounders + Year + Education	**1.1%**	0.8%	1.5%
Low education * Year	2	Model 1 + Smoking	**0.8%**	0.5%	1.2%
Low education * Year	3	Model 1 + Smoking-related mortality	**1.1%**	0.7%	1.4%
Low education * Year	4	Model 1 + Alcohol-related mortality	**0.9%**	0.5%	1.2%
Low education * Year	5	Model 1 + Obesity	**1.3%**	0.7%	1.9%
Low education * Year	6	Model 1 + all 4	**0.7%**	0.2%	1.2%
	Bold	p<0.05			
		excess trend attenuation >25%			
		excess trend attenuation >50%			

Notes: PAC = Percent annual change. Based on multilevel linear regression analysis of the natural logarithm of age-standardized mortality rate (by country, sex and level of education (low and high)) on education, year and interaction between education and year, confounders (sex, region (north, south, east, other)) and one of the following: smoking (age-standardized prevalence of survey-reported current smoking), smoking-related mortality (age-standardized mortality from 3 causes directly linked to smoking), alcohol-related mortality (age-standardized mortality from 4 causes directly linked to excessive alcohol consumption), and obesity (age-standardized prevalence of survey-reported obesity). Number of observations available per analysis: 308.

1.5%) less fast among the low educated. This mortality decline disadvantage for the low educated is only partly attributable to less favourable trends among the low educated for behavioral risk factors: when we control for all behavioral risk factors together, the disadvantage for the low educated diminishes from 1.1% to 0.7%, i.e. by 36%.

The main contributors are smoking and alcohol. When smoking alone is added to the model, the disadvantage for the low educated diminishes from 1.1% to 0.8%, and when alcohol alone is added to the model the disadvantage for the low educated diminishes from 1.1% to 0.9%. Web Appendix Table A4 shows that the contribution of smoking to inequalities in trends in mortality is particularly large for cancer and other diseases. The contribution of alcohol to inequalities in trends in mortality is particularly large for cardiovascular diseases, other diseases and external causes.

Table 2
National-contextual determinants of current inequalities in all-cause mortality and mortality determinants: results of regression analysis.

Independent variable:			Dependent variable					
Two-way interaction between low education and	Model	Control variables	All causes B	Poverty B	Smoking B	Smoking-related mortality B	Alcohol-related mortality B	Obesity B
National income (GDP)	1	Confounders + Edu + GDP	**-0.016**	**-0.9**	0.003	-1.7	**-4.3**	0.001
Income inequality (Gini)	2	Confounders + Edu + Gini	0.004	**0.8**	0.001	0.0	1.1	-0.003
Quality of government (QoG)	3	Confounders + Edu + QoG	**-0.663**	**-42.6**	**0.299**	13.6	-126.5	0.097
Social transfers (SoT)	4	Confounders + Edu + SoT	**-0.033**	**-1.5**	-0.004	-2.9	**-5.5**	0.004
Health care expenditure (HCE)	5	Confounders + Edu + HCE	**-0.064**	**-3.0**	-0.009	-5.3	**-15.3**	0.007
Self-expression values (SEV)	6	Confounders + Edu + SEV	**-0.142**	**-10.4**	0.035	-15.0	**-55.4**	0.015
Secular-rational values (SRV)	7	Confounders + Edu + SRV	0.181	**-10.0**	0.087	4.1	12.8	0.003
	Bold	p<0.05						
		Less unfavourable for low educated						
		More unfavourable for low educated						

Notes: Standardized regression coefficients from multilevel linear regression analysis of the natural logarithm of age-standardized mortality rate or prevalence of risk factor (by country, sex and level of education (low and high)) on two-way interaction between contextual determinant and education, controlling for confounders (sex, region (north, south, east, other)) and first-order effects of contextual determinant and education. Current = most recent of periods covered as given in Web appendix table A1. Number of observations available per analysis: 68.

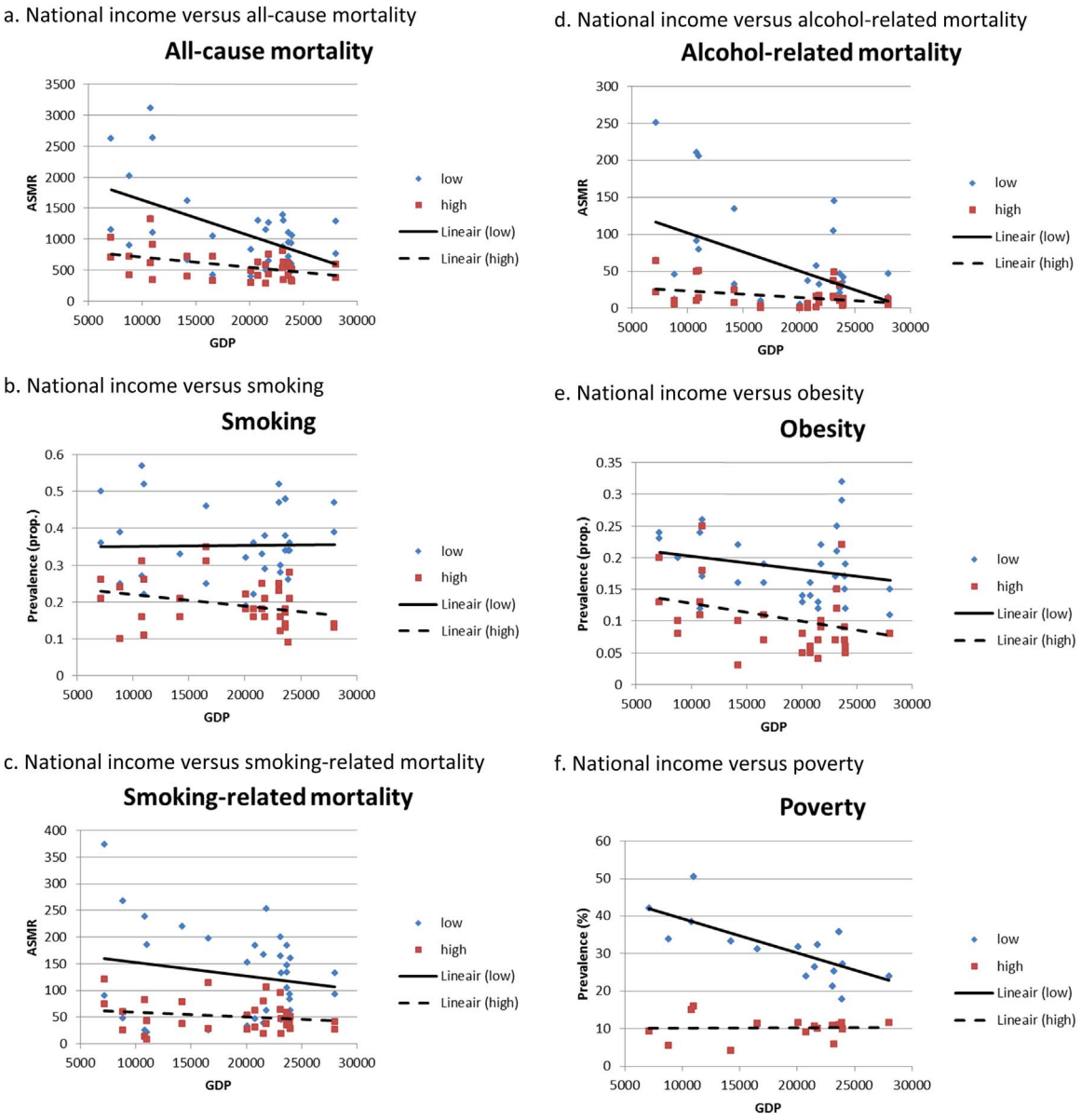

Fig. 2. Association between national income and all-cause mortality, smoking, smoking-related mortality, alcohol-related mortality, obesity and poverty by level of education, most recent year available.

4. Discussion

4.1. Summary of main findings

Our results suggest that between-country variations in inequalities in current mortality can partly be understood from variations in inequalities in smoking, excessive alcohol consumption, and poverty. Also, countries with higher national income, higher quality of government, higher social transfers, higher health care expenditure and more self-expression values have smaller inequalities in mortality. Finally, trends in behavioral risk factors, particularly smoking and excessive alcohol consumption, appear to make a modest contribution to variations in inequalities in mortality trends.

4.2. Strengths and limitations

This is the first study trying to explain, in a multivariate framework, between-country variations in the magnitude of inequalities in mortality or mortality trends, and it exploits a unique collection of data from 17 European countries covering several decades. However, such first attempts come with limitations. For example, our study only deals with educational inequalities in mortality. For mortality by occupational class, somewhat similar geographical patterns are seen, but the correlation between relative inequalities by education and occupational class is a modest 0.52 only (Toch-Marquardt et al., 2014). It will therefore be important to repeat the analyses as reported in this paper with mortality data by occupational class and other dimensions of social stratification.

Although we had access to a large number of national surveys, the availability of data on determinants was limited. We therefore added smoking-related mortality and alcohol-related mortality as indicators of exposure to smoking and excessive alcohol consumption, but these measures are likely to be contaminated by other determinants of mortality (e.g., health care as a determinant of survival from smoking- and alcohol-related conditions). Although trust in our findings is increased by the fact that the role of risk factors in explaining cause-specific results usually is intuitive (Web Appendix Tables A2 and A4), our results should be taken as indicative only. Furthermore, it is quite possible that other determinants, not covered in our analysis, also contribute to the explanation of between-country inequalities in

mortality, e.g. differences in health care access (Stirbu et al., 2010; Plug et al., 2012).

Over the past decades there has been a strong decline in the size of the lower education groups, and the size of these groups also differs between countries. A smaller size may imply a more "extreme" social position, and may also indicate a stronger negative selection in terms of personal characteristics like cognitive ability and personality, which could in itself lead to a wider gap in mortality (Mackenbach, 2010). Although we have not explicitly accounted for this in our analyses, in other comparative work using Relative and Slope Indices of Inequality which make adjustments for differences in the magnitude of education groups, we have found similar patterns of variation of inequalities in mortality between countries and over time (Mackenbach et al., 2016).

Our set of national-contextual variables covered a range of determinants which have in previous work been found to be associated with mortality (for references see Data and methods section). Our main findings relate to national income, quality of government, social transfers, health care expenditure and self-expression values. Because these country characteristics are inter-correlated, and because the number of observations in our analysis does not allow us to further expand our regression models, it is difficult to say which of these variables make(s) an independent contribution.

Although the data we used derived from individual-level data on mortality, behavioral risk factors and poverty, our analyses were essentially ecological in nature. Because we cannot be sure, for example in the analysis of inequalities in mortality versus inequalities in smoking, that excess mortality among the low educated actually occurred among smokers, this raises the possibility of ecological fallacy (Piantadosi et al., 1988). It would be preferable to do analyses on the basis of individual-level data in which risk factors can directly be linked to mortality, but these are only available for a very small number of European countries (Martikainen et al., 2014).

Finally, our analyses ignored lag-times between exposure to determinants and mortality. This implies that we have to assume that current exposure is a proxy for historical exposure. More sophisticated approaches are recommended for replication studies.

All limitations taken together imply that we have to refrain from causal interpretations of the associations found, and that the main value of our analyses is that this is the first ever exploration of these relationships.

4.3. Interpretation

Perhaps unexpectedly, the 'macroscopic' view of health inequalities that this international-comparative study provides, first of all suggests the likely importance of behavioral risk factors for the explanation of inequalities in mortality, particularly smoking and excessive alcohol consumption. At the same time, however, our study also found evidence for the role of more structural determinants, particularly poverty and several national-contextual factors. Our results as presented in Table 2 suggest that the effect of the contextual factors is likely to go, at least in part, through inequalities in poverty and behavioral risk factors such as excessive alcohol consumption, and vice versa: that inequalities in poverty and behavioral risk factors are probably partly determined by these contextual factors.

Previous studies of the role of national-contextual factors in determining the magnitude of health inequalities have related the nature of countries' welfare regimes to educational inequalities in self-reported health, generally with negative results (Beckfield and Krieger, 2009; Eikemo et al., 2008a, 2008b, 2008c). However, there is one interesting exception, which found that, after controlling for national income, European countries with higher welfare spending had smaller inequalities in self-assessed health (Dahl and van der Wel, 2013). In our dataset, we find largely similar results for inequalities in mortality. The higher the level of social transfers in a country, the smaller the educational inequalities in all-cause mortality (Table 2).

Our study strengthens understanding of the larger inequalities in mortality in Eastern Europe. These are a relatively recent phenomenon: in the early 1970s, Hungary had no inequalities in mortality by education at all, whereas in the early 1980s both Hungary and the Czech Republic still had rather small inequalities with Rate Ratios well below those seen in many Western European countries. It is only around the collapse of the Soviet Union, and the accompanying political and economic transformations, that massive inequalities in mortality have arisen (Leinsalu et al., 2009). Even after the year 2000, i.e., after the transition to full democracy, a radical economic transformation, and accession to the European Union of these countries, inequalities in mortality are still very large. Although behavioral risk factors may play an important mediating role in generating larger inequalities in mortality in these countries, our results suggest that contextual factors such as lower national income, less government effectiveness, lower health care expenditures and/or less modern cultural values may also play a role. This is a fertile ground for further study.

It is the Southern European countries which have the smallest inequalities in mortality. In terms of causes of death, smaller inequalities in Southern Europe are a generalized phenomenon, and our results clearly suggest the importance of behavioral risk factors and the unimportance of economic conditions in explaining this phenomenon. As has been noted previously, this probably has a cultural explanation. Smaller inequalities in cardiovascular disease mortality in the South are partly due to the persistence of the Mediterranean diet in lower socioeconomic groups and smaller inequalities in smoking (Kulhanova et al., 2014a; Federico et al., 2013). Also, smaller inequalities in smoking are partly due to more smoking in higher socioeconomic groups than seen in other European countries, as a result of a delayed smoking epidemic (Kulhanova et al., 2014a). Although smaller inequalities in mortality in these countries thus seem to be a historical coincidence rather than the outcome of deliberate policies, the Spanish and Italian examples suggest that large inequalities in total mortality are not inevitable.

4.4. Conclusions

This exploratory study suggests that both behavioral (smoking, alcohol) and structural factors (poverty, and national economic, policy-related and cultural conditions) contribute to between-country variations in the magnitude of socioeconomic inequalities in mortality. More detailed studies of these variations, preferably combining individual- and aggregate-level data, are likely to provide important clues for how to reduce inequalities in mortality.

Funding

Supported by a grant (FP7-CP-FP Grant no. 278511) from the European Commission Research and Innovation Directorate General, as part of the "Developing methodologies to reduce inequalities in the determinants of health" (DEMETRIQ) project. The sponsor had no role in the study design; in the collection, analysis, and interpretation of data; in the writing of the report; and in the decision to submit the article for publication.

Ethics approval

Not required.

Acknowledgements

We thank the Office of National Statistics (Newport (Wales)) for providing data on England & Wales. The help provided by staff of the Longitudinal Studies Centre – Scotland (LSCS) is acknowledged. The LSCS is supported by the ESRC/JISC, the Scottish Funding Council,

the Chief Scientist's Office and the Scottish Government. The authors alone are responsible for the interpretation of the data. Census output is Crown copyright and is reproduced with the permission of the Controller of HMSO and the Queen's Printer for Scotland.

In addition to the authors, the following members of the DEMETRIQ consortium contributed to this study: Austria: Johannes Klotz, Statistics Austria, Vienna; Denmark: Jorn Korsbo Petersen, Statistics Denmark, Copenhagen; Italy: Giuseppe Costa, Department of Clinical Medicine and Biology, University of Turin, Turin; Lithuania: Ramune Kalediene and Remigijus Prochorskas, Lithuanian University of Health Sciences, Kaunas; Norway: Bjørn Heine Strand, Division of Epidemiology, Norwegian Institute of Public Health, Oslo; Scotland: Chris Dibben and Tom Clement, School of Geosciences, University of Edinburgh, Edinburgh; Slovenia: Barbara Artnik, Department of Public Health, Faculty of Medicine, Ljubljana; Spain: Santiago Esnaola, Department of Public Health, Basque Government, Vitoria, and Carme Borrell, Agència de Salut Pública de Barcelona, Barcelona; Sweden: Olle Lundberg, Center for Health Equity Studies, Stockholm. We also thank Joost Oude Groeniger (Department of Public Health, Erasmus MC) for his advice on multilevel analysis.

Appendix A. Supplementary material

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.healthplace.2017.07.005.

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