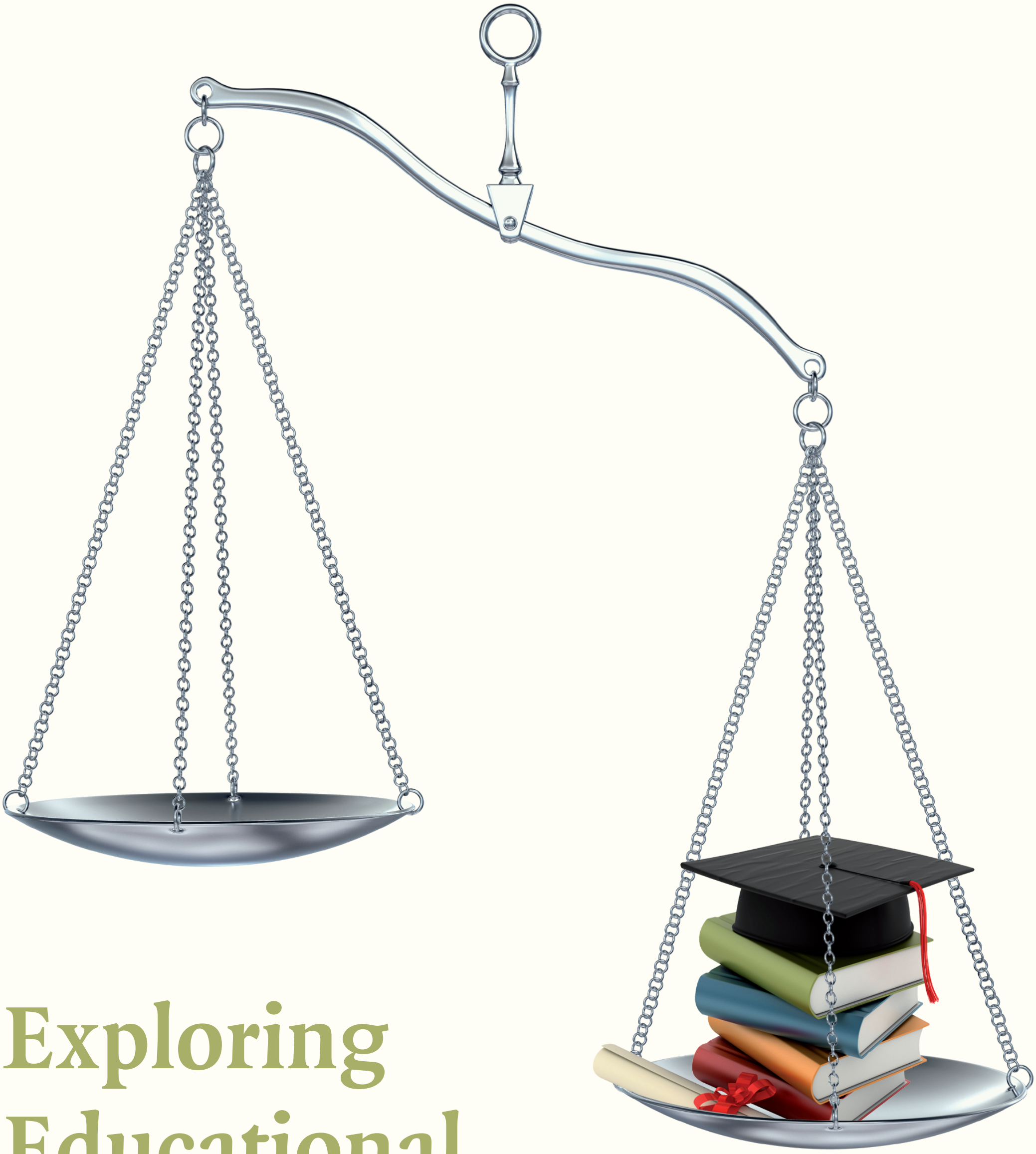

Exploring Educational Inequalities in Mortality in Europe

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I

General introduction

SOCIOECONOMIC INEQUALITIES IN HEALTH

Regardless of how health and socioeconomic position are measured, the general pattern of better health among individuals with higher socioeconomic position is consistently found in all populations and in all time-periods for which systematic data are available. The historical literature shows that socioeconomic inequalities in health are not a recent phenomenon. The first scientific evidence on social variations in morbidity and mortality dates from the 17th century when John Graunt, based on mortality from plague in London, published his book "Natural and political observations mentioned in a following index, and made upon the bills of mortality" [1]. Due to the lack of data, socioeconomic inequalities in health were not a public policy issue until the 19th century. Major contributions to this field were made in the 19th century by the French medical doctor Louis-René Villermé (1782–1863) [2], the German medical doctor Rudolph Virchow (1821–1902) [3] and the British lawyer Sir Edwin Chadwick (1800–1890) [4]. Villermé and Virchow concluded that death was not only biologically determined but was closely related to social circumstances and they identified social class and work conditions as crucial determinants of health and disease [5]. Chadwick contributed to the solution of the high death rates in disadvantaged sections of the population by proposing a sanitary reform in Great Britain. The work of all three men increased public awareness of socioeconomic inequalities in health and led to improved housing, water supply, sanitation, nutrition, access to immunization and work conditions in Europe.

The interest in socioeconomic inequalities in health in Europe started again after the Black report was published in England in 1980 [6]. This report pointed out the widening health gap between those with lower and those with higher socioeconomic position despite major improvements in physical environment, work conditions and health care and the rise of the welfare state during the 20th century. Both the Black report and the subsequent Acheson report published in 1998 [7] initiated large efforts in data collection in Europe, which facilitated a wide range of descriptive and explanatory studies of socioeconomic inequalities in health.

Nowadays, socioeconomic inequalities in health are reported in all European countries, but with substantial variations in their magnitude [8-13] and with a trend towards widening inequalities over time [14-17]. The widening of socioeconomic inequalities in mortality is mostly due to a different speed of mortality decline between lower and higher socioeconomic groups, with a faster decline among those with higher socioeconomic position [14]. However, not only people with higher socioeconomic position live longer than their counterparts with lower socioeconomic position, but due to their lower rates of morbidity, they also spend more years in good health. In Europe, the difference in life expectancy at birth between people from lower and higher socioeconomic groups (e.g., manual versus professional occupations, or primary versus tertiary education) is on average about 5 years, when the difference in healthy life expectancy is more than 10 years [18]. In terms of cause-specific mortality, three European 'regimes' of socioeconomic inequalities in mortality can be distinguished: a North-Western regime characterized by large socioeconomic inequalities in mortality from cardiovascular diseases and cancer; a Southern regime characterized by small socioeconomic inequalities in mortality from cardiovascular diseases and cancer; and an Eastern regime characterized by huge socioeconomic inequalities in mortality from cardiovascular diseases, cancer and injury [10, 13, 19-21].

Due to the persistence of socioeconomic inequalities in health and their widening over time, these inequalities constitute one of the major challenges for public health in developed countries [22]. Reducing socioeconomic inequalities in health should be a priority not only because such inequalities are unfair but also because their burden has huge economic consequences. Socioeconomic inequalities in health have been shown to raise the total costs of healthcare and social security, and to reduce the labour productivity and the Gross Domestic Product (GDP) [23].

EDUCATION AS AN INDICATOR OF SOCIOECONOMIC POSITION

Indicators of socioeconomic position provide information about an individual's access to social and economic resources. Education, occupational class and income belong to the most traditional and most frequently used indicators. Although these indicators correlate with each other, they are not identical and therefore not interchangeable [24-26] because each of these indicators measures different dimensions of the socioeconomic position, and indicates different mechanisms through which socioeconomic position is related to health.

Education has several advantages over the other indicators of socioeconomic position. It is comparatively easier to measure, has a high response rate, and therefore has less missing values than e.g. income, which is a more sensitive variable. Education is relevant for men and women regardless of their employment status, in contrast to occupation which is difficult to ascertain for unemployed, students, housewives, retired people and people in unpaid, illegal or voluntary jobs. Education captures the transition from parental socioeconomic position to own socioeconomic position in adulthood and sometimes even serves as a marker of early life circumstances. Education is a strong determinant of future employment and income as it shapes work opportunities and earnings possibilities [27]. Educational attainment is usually completed in early adulthood; therefore, contrary to other socioeconomic indicators such as occupation or income, reverse causality (ill-health leading to low socioeconomic position, instead of vice versa) is unlikely to happen, except for major mental disorders [25, 28-31]. In addition, education avoids the problem of health-related social mobility later in life. Finally, the measurement of education can relatively easily be harmonized across European countries. For this reason, education is frequently used in European comparisons.

Despite the advantages of using educational attainment as indicator of socioeconomic position, education also has some drawbacks. Education does not capture changes in adult socioeconomic circumstances [32]. Further, the meaning of educational level varies for different birth cohorts [33]. The majority of elderly people in Europe left school at the minimum age with no academic qualifications. Therefore differentiation of the older population according to educational attainment is very limited [29]. Another difficulty with this indicator of socioeconomic position relates to migrants who obtained their education outside the country of residence under a different educational system, which makes comparisons with the native population difficult. Education can be measured as the number of years of completed education (continuous variable) or by assessing the achieved educational level (categorical variable), but this information tells us little about the quality of the acquired education and its social and economic value [30, 33]. For instance, a college degree obtained from a prestigious university may have different value as compared with the same degree granted from a less prestigious institution. Finally, educational attainment may have a different social meaning and different consequences for occupational opportunities and earning possibilities in different time periods and in countries with different levels of economic development [30].

EDUCATION AND HEALTH

The link between education and health has been demonstrated for different health outcomes, such as self-reported health, physical functioning, morbidity, disability and mortality [34, 35]. The main explanations of educational inequalities in health can be arranged under the selection perspective, the causation perspective, the life-course perspective, the human capital theory and the theory of fundamental causes.

The selection perspective

The social selection theory claims that health status determines social position instead of vice versa, e.g. because ill individuals underperform in school and do not achieve a high level of education due to their health problems [36-38]. While this may to some extent be true, it has been shown that health-related selection has negligible impact on educational inequalities in health [39] and more generally cannot explain socioeconomic inequalities in health [40, 41]. Health-related selection may be more pronounced for income or occupational class than for education, which is achieved relatively early in life when the prevalence of health problems is still low. Apart from 'direct' selection into lower or higher education dependent on the presence or absence of health problems, 'indirect' selection may also play a role when individuals are selected into lower or higher education dependent on personal characteristics that also influence their later life health, such as cognitive ability and personality [42, 43].

The causation perspective

Education may protect health via several pathways. Apart from biological factors, such as genetics, age and sex, the main factors explaining the education-health relationship fall into categories of material circumstances, psychosocial circumstances, health behaviour and health care utilization [35].

Material circumstances that play a role in generating educational inequalities in health include financial resources, housing and working conditions and the neighbourhood environment. Education shapes employment and financial opportunities. Higher educated people are less likely to be unemployed, are more likely to work full-time and have more fulfilling jobs than their lower educated counterparts. The better employment opportunities of higher educated people are directly linked to their higher income, which allows them to afford living in a clean and safe neighbourhood and in high-quality housing, to buy healthy food, and to access better health care or expensive above-standard medical treatments [30, 34, 35]. Because of these financial resources the high educated experience less economic hardship. The employment opportunities do not only improve financial resources of higher educated individuals but also increases the chances for an occupation with better working conditions avoiding high environmental and physical risks, for instance exposure to noise, chemicals, radiation, heat, dust, unsafe conditions, cold or stress [30, 35]. In addition, they are able to better cope with stressful situations due to the skills and information acquired via education.

Psychosocial circumstances that play a role in generating worse health among the lower educated include negative life events, stressful living conditions, less adequate coping styles, smaller social networks and less social support. Education increases the sense of personal control, mastery, communication skills and analytical skills, which help to gather and interpret information and to solve problems. The ability to solve problems increases an individual's self-confidence and perception of high control over one's life [35]. Higher educated people also have bigger social networks assuring higher levels of social support. These psychosocial resources may have an important effect on their health through enhancing health behaviour or through physiological mechanisms. People with high personal control are more likely to quit smoking [44, 45] or reduce their alcohol consumption [46]. Social support decreases depression, anxiety, and other mental problems and may increase the likelihood of practicing protective health behaviour [47-49]. The experience of stressful events may affect biological functions and may, via suppression of the immune system, lead to a wide range of diseases [50-53].

Behavioural factors, such as smoking, excessive alcohol consumption, lack of physical activity and/or poor diet, play an important role in generating educational inequalities in health. In general, people with a higher education have less harmful behaviour than people with a lower education.

Smoking is a major determinant of morbidity and mortality in developed countries. Several studies have demonstrated that the prevalence of smoking is related to education [54-56]. It has been shown that educational variations in smoking prevalence differ in European countries depending on the progression of the smoking epidemic [57] and the role of smoking in educational inequalities in health likely differs between countries that are at a different stage of the smoking epidemic [58]. During the smoking epidemic there is a reversal from a positive to a negative association between education and smoking [59]. In a more advanced stage of the smoking epidemic, relatively more individuals with lower education smoke, while people with higher education smoke more in earlier stages. This epidemic is further advanced in northern European countries than in southern European countries [60], which may explain the north-south gradient in smoking-related causes of death. Women lag behind men in the smoking epidemic progression [61], which may explain the gender differences in smoking prevalence and in educational inequalities in smoking-related causes of death. Smoking accounts for a considerable proportion of premature deaths, especially due to lung and aero-digestive cancers and chronic obstructive pulmonary disease [58, 60]. The literature suggests that there are educational differences in smoking prevalence, smoking consumption, smoking initiation and smoking cessation. Lower educated people are significantly more likely to smoke and to consume more cigarettes per day. They have higher initiation ratios and lower quit ratios than their higher educated counterparts [62].

Alcohol consumption and its impact on educational inequalities in mortality differ between men and women, and vary across European populations. In general, lower educated people have worse health and higher alcohol related mortality than higher educated people. This phenomenon is very likely connected with the amount of alcohol consumed which differs by education. Higher educated individuals are more frequently moderate drinkers, while lower educated people are either abstainers or heavy drinkers [63-65]. Both abstinence and excessive alcohol consumption have been associated with higher risk of dying compared with moderate alcohol consumption [66]. Whereas moderate alcohol consumption has been observed to have beneficial effect on mortality from ischaemic heart disease [67, 68] and some infectious diseases [69, 70], excessive alcohol consumption is associated with an increased risk of suicide, homicide, accidental injury, stroke, liver cirrhosis and upper respiratory and digestive cancers [68, 71]. In Europe, there are large differences between populations in the consumption patterns and in the distribution of causes of death. While daily wine consumption during meal is more common in southern Europe, beer consumption and binge drinking are more widespread in the Nordic countries, United Kingdom or Switzerland [71]. The results suggest that high levels of daily consumption influences inequalities in mortality in part through causes of death related to chronic intoxication such as specific cancers or liver cirrhosis whereas binge drinking is mainly associated with inequalities in violent deaths. The heavy drinking habits in the North of Europe very likely contribute to the educational inequalities in poisoning, traffic accidents and suicide.

International literature suggests that the association between education and diet may partly explain the educational inequalities in mortality. The dietary patterns are worse for lower educated people. The lower educated individuals consume less fruit, vegetables and fish but eat more frequently fried food, meat, pasta, potatoes or table sugar [72, 73]. These unhealthy eating habits are very likely responsible for the lower intake of iron, calcium, vitamin A and vitamin D among lower educated people [72]. Healthier diet is associated with a reduction of the risk of chronic diseases. For instance, increased fruit and vegetable consumption is associated with reduced risk of coronary heart disease [74] and stroke [75].

In most European populations, the lower educated people have a higher prevalence of overweight and obesity than their high educated counterparts, which is probably due to an unhealthy diet and a consequent high energy intake and to a low physical activity among the lower educated [76]. The inequalities in overweight and obesity have been found to be largest among women in southern Europe [77]. Obesity is detrimental throughout the life span, any time from childhood to old age, and is associated with an increased risk of several diseases, such as diabetes mellitus, cardiovascular diseases, such as hypertension, dyslipidemia, ischaemic heart disease, and some cancers, such as cancer of female breast, colon, kidney, endometrium and oesophagus [78, 79].

A beneficial effect of regular physical activity on health has been repeatedly demonstrated based on moderate leisure time physical activity, sports activity and bicycling as transportation [80]. Literature evidence indicates that a moderate level of leisure time physical activity and occupational physical activity are associated with a reduction in all-cause and cardiovascular disease mortality for both men and women [81] and that sedentary living is responsible for about one third of deaths due to coronary heart disease, colon cancer, and diabetes mellitus [82]. Lower educated people has been found to exercise less than their higher educated counterparts [83]. There are important quantitative and qualitative differences in physical activity among population groups. Men in lower socioeconomic position spend more time each week walking and doing household chores, whereas men in higher socioeconomic position tend to be more active in leisure time physical activity. Among women, lower socioeconomic position is associated with less time spent each week in all physical activities, from leisure time physical activity over job related physical activity to household physical activity, than higher socioeconomic position [84]. Physical activity is also associated with improved psychological well-being which is important for the prevention and management of certain diseases, such as diabetes mellitus, osteoporosis, osteoarthritis, hypertension, obesity, colon cancer, breast cancer and depression [85].

Organization of the health care system may play an important role in generating educational inequalities in mortality and health. The access to and utilization of health care services contribute to mortality inequalities across educational groups [86]. The scientific evidence shows that the lower educated people are more intensive users of the health care system, however they are less likely to receive preventive medical care, e.g. annual physical exams, vaccination or screening [33, 35, 87]. Regarding the inequalities in health services utilization, the lower educated individuals are more likely to visit general practitioner (GP) but less likely to use services of medical specialists than their high educated counterparts [88]. Lower educated patients are more passive in communication with their GP, they spend less time with their GP and get less information about the health risks or are not able to fully understand the health message that their GP wants to transfer than those with higher education [89]. Educational differences have been reported in the influenza vaccination, screening attendance, diseases treatments and/or survival time after diagnosis. In several European countries, lower educated individuals are less likely to receive influenza vaccine compared with higher educated people [90, 91]. Cancer screening attendance is found to be greater among the higher educated for colorectal, breast or cervical cancer [92-95]. The beliefs and expectations across educational groups towards screening play an important role in differential participation on the screening programmes. Higher stress and lower social support are reported to be an important explanation why lower educated people tend to evaluate screening as more frightening and less beneficial [94]. The lower educated people are less aware of health risks or treatment options and are generally more ill upon admission to hospital than their higher educated counterparts. Their cancer is detected at later stage resulting likely in worse opportunities for treatment [96] and in a shorter survival time [97]. The association between education and survival time is not only observed for cancer [98-100] but also for other diseases, such as stroke [101] and acute myocardial infarction [102, 103]. Further, less educated people are less likely to receive any treatment, surgery and chemotherapy for lung cancer [104].

The life-course perspective

The life-course perspective combines different explanations of the relation between risk factors and health outcomes [105]. The life-course perspective has been defined as "the study of long-term effects on chronic disease risk of physical and social exposures during gestation, childhood, adolescence, young adulthood and later adult life" [106]. At least three general pathways have been proposed. First, the critical period model implies that a specific exposure will impact health only if it takes place during a specific period. The Barker's hypothesis is a well-known example of the role of prenatal and early life circumstances on health in later life. Retarded growth in foetal life and infancy was found to be associated not only with infant mortality, but also with chronic diseases, such as ischaemic heart disease, hypertension or diabetes mellitus, in adulthood [107, 108]. Second, the accumulation model suggests that physical and social exposures gradually accumulate to worsen health. Third, the social mobility model suggests that downward and upward intergenerational or intragenerational mobility affects health. The latter is related to the selection perspective already presented. Low educated people are more likely to be exposed to adverse life-course circumstances, whatever the model considered.

Childhood socioeconomic circumstances influence both educational attainment and health. The socioeconomic background of the parents and the material conditions during childhood may therefore play an important role in the final health outcome over the life course. Higher educated parents secure future advantages for their children by encouraging them to obtain a high level of education [109, 110]. Some health behaviours such as diet and physical activity are strongly associated with childhood living conditions and may track over the life course. Perhaps the most striking aspect of these findings is that adult behaviour, such as smoking or alcohol consumption, and psychosocial orientations, such as depression and hopelessness, are patterned by childhood socioeconomic circumstances [111]. Children with lower socioeconomic backgrounds are more likely to be of low birth weight, to have poorer diets, to be exposed to passive smoking and infectious agents and to have fewer educational opportunities [31]. Deprivation in childhood influences the risk of mortality from coronary heart disease, stroke and respiratory diseases in adulthood [112]. Poor socioeconomic circumstances during childhood are particularly important in determining a higher risk of stomach cancer [112, 113] probably through exposure to infection with Helicobacter pylori.

The human capital theory

Another perspective on the explanation of the impact of education on health is provided by the human capital theory [34, 114]. According to this theory, education influences health via cognitive and non-cognitive psychological resources. Although both cognitive (verbal, reading, writing abilities, mathematics, science, music and art) and non-cognitive (personality, conscientiousness and sense of mastery) factors may be genetically given, they are enhanced through schooling. Education is a learning process that stimulates cognitive development [115] and schooling therefore improves general intelligence as measured by IQ. Previous studies reported that lower intelligence is a risk factor for many mental disorders, e.g., schizophrenia, mood, neurotic or personality disorders [116], and that higher IQ is associated with lower all-cause mortality [117, 118]. Although children enter schools with different level of intelligence, which itself is an important determinant of mortality [118], formal education enhances cognitive skills, such as learning, reasoning and problem solving skills [119, 120]. These cognitive skills promote risk assessment and decision making abilities related to health outcomes [109, 114, 115, 121]. They are useful in preventing chronic diseases or accidental injuries [122] and in reducing risk of Alzheimer's disease and dementia [123].

The theory of fundamental causes

Despite substantial successes in reducing risk factors for diseases during the past two centuries, socioeconomic inequalities in mortality and health have persisted over time. The theory of "fundamental causes" proposes that these inequalities persist because of the persistence of the differences in social and economic resources possessed by socio-economic groups. According to this theory, a higher socioeconomic position involves access to key 'flexible' resources, such as money, power, prestige, knowledge, and beneficial social support and social network, which allow people in higher socioeconomic positions to better take advantage of health-related changes, e.g., new diseases, new risk factors, new treatments or knowledge about them in the population. These key resources are portable from one situation to another. Therefore, people who possess the most resources (very likely the high socioeconomic groups) are best able to avoid future risks and diseases, and/or minimize the consequences of these health-related changes [124, 125].

When the effect of one risk factor declines, the effect of another one emerges. For instance, as the bacteria, viruses or parasites causing infectious diseases, such as e.g., tuberculosis, cholera or smallpox, were eliminated, epidemics of these infectious diseases in the 19th century were eradicated. However, new health risks emerged in the 20th century, e.g., smoking, excessive alcohol consumption, lack of physical exercise or poor diet in fast foods, which increased the frequency of chronic diseases, such as cardiovascular diseases, cancer or diabetes mellitus. These risks for chronic diseases are now, similarly as those for the infectious diseases previously, more concentrated in lower socioeconomic groups, probably because they have less resources to deal with these new health threats as they had when dealing with the old health threats [126].

WHO COMMISSION CONCEPTUAL FRAMEWORK

The WHO commission on health determinants proposed a framework for describing determinants of health inequalities [127]. This framework combines most of the explanations of socioeconomic inequalities in health mentioned above and shows that all of them are complementary.

Figure 1 visually summarizes the determinants, processes and pathways generating socioeconomic inequalities in health. The socioeconomic and political context produces unequal socioeconomic positions and social classes. As a result, the population is stratified according to economic status, power and prestige, characterized by income, educa-

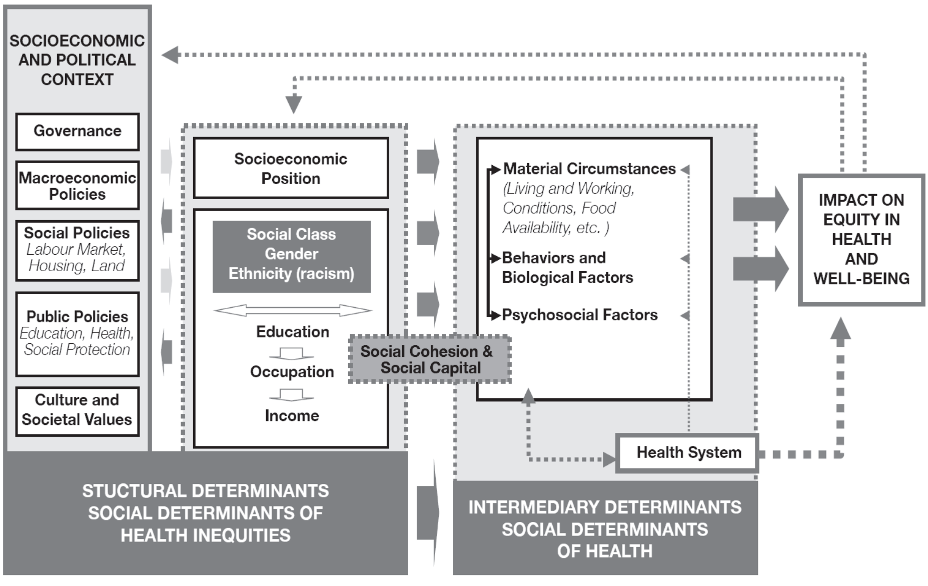

Figure 1 Final form of the framework on social determinants in health
Source: World Health Organization [127]

tion, occupational class, gender and ethnicity. These structural determinants of health inequalities influence health and well-being through intermediary determinants, such as material, psychosocial, behavioural and biological factors and the workings of the health system. These intermediary determinants correspond with the causal pathways described in the previous section. As shown by Figure 1, a person's socioeconomic position can also be influenced by his or her health status, which illustrates the selection perspective also mentioned above in the text. People in poor health are less likely to move up and more likely to move down the social ladder than healthy people, not only due to physical impairments but also because of stigma and discrimination in society.

This framework shows, on the one hand, that health inequalities are generated by intermediary factors, and, on the other hand, that these specific factors are only the consequence of more structural factors in society. In order to effectively reduce socioeconomic inequalities in health, interventions to reduce exposure to specific intermediary factors may not be enough, and more complex modifications may be necessary, especially at the level of structural determinants.

RESEARCH QUESTIONS

The research underlying this thesis aims to explore educational inequalities in all-cause and cause-specific mortality from an international, European perspective. Specifically, we validate the quality of cause of death data, we estimate educational inequalities in all-cause and cause-specific mortality, we assess the effect of the educational structure on mortality trends and we quantify the potential impact of selected lifestyle risk factors on the reduction of educational inequalities in mortality.

The following research questions are addressed:

- Are there differences in the reliability of cause-of-death statistics by education in Europe?
- What is the magnitude of educational inequalities in all-cause and cause-specific mortality in Europe in a comparative perspective and has it changed over time?
- What is the potential for reducing educational inequalities in mortality in Europe?

METHODS AND DATA SOURCES

Data

This thesis was based on data collected in the framework of two large European projects – Eurothine and EURO-GBD-SE – both funded by the Public Health programme of the DG SANCO of the European Commission. Further, we also used individual mortality data from two data sources: a dataset obtained with the linkage between the Dutch Labour Force Survey and death records in the Netherlands, and the GLOBE study.

1) The Eurothine project [128] "Tackling health inequalities in Europe" aimed to describe health inequalities in Europe and to enhance the evidence base for policies to reduce inequalities in health. Its main objectives included:
   · the development and collection of health inequalities indicators,
   · the provision of bench-marking data on inequalities in mortality, morbidity and health determinants,
   · the assessment of evidence on the effectiveness of policies and interventions to make recommendations on policy strategies for reducing health inequalities in a large range of different European countries.

   Two large sets of mortality and morbidity data were collected and harmonized across European countries within the framework of the Eurothine project. The mortality data is a collection of datasets with information on cause-specific mortality by socioeconomic status (education, occupational class, housing tenure) among people aged 30 and older in 16 European populations (Finland, Sweden, Norway, Denmark, Belgium, Switzerland, Turin (Italy), Barcelona (Spain), Basque Country (Spain), Madrid (Spain), Slovenia, Hungary, Czech Republic, Poland, Lithuania and Estonia). Mortality data were collected between 1990 and 2003 and come from longitudinal, cross-sectional linked and cross-sectional unlinked datasets covering national, regional or urban populations. The morbidity data is a collection of datasets with information on health status, lifestyle risk factors, and health care utilization by socioeconomic status (education, occupational class, income, and housing tenure). These datasets are based on recent National Health Surveys conducted among people aged 16 and older in the period between 1994 and 2004 in 19 European countries (Finland, Sweden, Norway, Denmark, England, Ireland, Netherlands, Belgium, Germany, France, Italy, Spain, Portugal, Hungary, Czech Republic, Slovakia, Lithuania, Latvia and Estonia). These mortality and morbidity datasets were used in chapters 3, 5 and 6.

2) The EURO-GBD-SE project [129] is an international collaborative project that aimed:
   · to provide updated estimates of the magnitude of socioeconomic inequalities in health in Europe,

- to estimate the contribution of selected risk factors to the explanation of the socioeconomic health inequalities,
- to estimate the extent to which socioeconomic inequalities in health in Europe can be reduced by policies and interventions on socioeconomic determinants as well as on specific risk factors.

Two large sets of mortality and morbidity data were collected and harmonized across European countries within the framework of the EURO-GBD-SE project. The mortality data is a collection of datasets with information on cause-specific mortality by socioeconomic status (education and occupational class) among people aged 30 and older in 21 European populations (Finland, Sweden, Norway, Denmark, England and Wales, Scotland, Netherlands, Belgium, France, Switzerland, Austria, Barcelona (Spain), Basque Country (Spain), Madrid (Spain), Turin (Italy), Tuscany (Italy), Hungary, Czech Republic, Poland, Lithuania and Estonia). Mortality data were collected between 1998 and 2007 and come from longitudinal, repeated cross-sectional and cross-sectional unlinked datasets covering national, regional or urban populations. For four countries (Hungary, Czech Republic, Poland and Estonia), these datasets are those collected within the Eurothine project. The morbidity data is a collection of datasets with information on health status, lifestyle risk factors, and health care utilization by socioeconomic status (education, occupational class, income, and housing tenure). These datasets are based on recent National Health Surveys conducted among people aged 16 and older in the period between 1994 and 2004 in 18 European populations (Finland, Sweden, Norway, Denmark, England, Scotland, Netherlands, Belgium, France, Switzerland, Spain, Basque Country, Italy, Hungary, Czech Republic, Poland, Lithuania, and Estonia). For most countries, these datasets were those collected in the framework of the Eurothine project. Within the framework of the EURO-GBD-SE project, data were specifically collected for Scotland, Switzerland, the Basque Country and Poland. In addition, we included smoking and BMI prevalence for Austria, using data from the European Community Household Panel, wave 7. We used these datasets in chapters 2, 5, 7 and 8.

3) The Dutch Labour Force Survey (LFS) is a household survey carried out by Statistics Netherlands since 1987. Its representative sample of the Dutch population is drawn from the administrations of Dutch municipalities. The target population consists of persons aged 15 years and older excluding people living in institutions. The information is gathered by face-to-face or phone interviews. The response rate is about 60%. The Dutch LFS was available for the years 1998 to 2002. We restricted the population to people aged 30+. The dataset was then linked with the national death records also collected by Statistics Netherlands, using a unique individual identification number. Mortality follow-up was available for the period 1998–2007. The final linked dataset

provides individual cause-specific mortality data by sex, age group and socioeconomic status (education and occupational class). We used these data with individual information on mortality by socioeconomic status in chapter 4. These data were also used to create the mortality dataset for the Netherlands included in the EURO-GBD-SE project.

4) The GLOBE study (Health and Living Conditions of the Population of Eindhoven and surroundings) [130] is a prospective cohort study which aims at explaining socioeconomic inequalities in health in the Netherlands. The study started in 1991 with a baseline postal survey and two additional sub-samples of respondents including measures of socioeconomic status, health and possible explanatory factors. Follow-up involved repeated postal surveys and interviews, and routinely collected data on hospital admission, cancer incidence and cause-specific mortality. The GLOBE study was used in chapter 6.

Methods

In this thesis, we used a wide number of measures to assess educational inequalities in all-cause and cause-specific mortality. In order to monitor health inequalities and evaluate policy interventions, it is important to estimate both relative and absolute inequalities. It may be that relative differences in mortality increase while absolute differences in mortality decrease, e.g., if the frequency of deaths declines [131]. All analyses were conducted separately for men and women and performed using the statistical software STATA.

Educational attainment was classified according to the International Standard Classification of Education (ISCED) and split into three categories in most chapters, except chapter 4. These three educational categories were: less than secondary education (ISCED 0, 1, 2; 'low'), secondary education (ISCED 3, 4; 'mid') and tertiary education (ISCED 5, 6; 'high'). In chapter 4, we used a more detailed classification based on the following four categories: primary education (ISCED 0, 1), lower secondary education (ISCED 2), upper secondary education (ISCED 3, 4) and tertiary education (ISCED 5, 6).

The magnitude of relative inequalities in mortality was calculated using relative risk (RR), relative index of inequality (RII) and hazard ratio (HR). The RR describes the risk of dying in one group compared with another group. We calculated the RR by means of Poisson regression using tertiary educated as a reference category. The RII is a regression-based measure that takes into account the educational distribution of the population [132]. The calculation of the RII is based on a ranked variable for education, which specifies for each educational group the mean proportion of the population with a lower level of education. This rank places each individual within an educational hierarchy ranging from zero (highest education) to one (lowest education), indicating someone's relative position in the distribution. The RII assesses the association between mortality and this rank and therefore expresses inequality in the whole socioeconomic continuum. A large score on the RII implies large inequalities in mortality across education. It can be interpreted as the average risk of dying among those with the lowest educational level as compared to those with the highest educational level. As it takes into account the size and relative position of each group, the RII is well adapted to compare populations with different educational distributions. The RII was calculated with Poisson regression and adjusted for 5-year age groups. The HR is a measure of the relative risk over time in circumstances where we are interested not only in the total number of events, but in their timing as well. It measures how often a particular event happens in one group compare to how often it happens in another group, over time. It represents the instantaneous risk over the study time period. The HRs were calculated using Cox proportional hazards models [133]:

$$h(t)=h_0(t)\exp\left(\sum_{k=1}^{p}\beta_k x_k\right)$$

where $h(t)$ is the expected hazard at time t, $h_0(t)$ is the baseline hazard, β_k is the regression coefficient of the explanatory variable x_k and p is the total number of explanatory variables. The reference category was tertiary educated men and women. For all three measures, 95% confidence intervals (CI) were obtained from the regression models.

The absolute level of inequalities in mortality between different educational categories was measured using age-standardized mortality rate (ASMR), rate difference (RD) and slope index of inequality (SII). The ASMR was calculated by education, standardized with the direct method using the European Standard Population as standard [134]. In order to calculate 95% CI for the ASMR, we first estimated standard errors using the Keyfitz's formula [135]:

$$se=\frac{ASMR}{\sqrt{N}}$$

where se is the standard error, $ASMR$ is the age-standardized mortality rate and N is the number of deaths. Having standard errors, we computed the 95% CI as follows:

$$95\%CI = ASMR \pm 1.96 * se$$

The RD was computed as the difference in ASMR between tertiary educated individuals and the other educational groups. The SII quantifies the average absolute difference in mortality rates between the lowest and the highest ends of the educational scale [136], and is derived from the relative index of inequality and the age-standardized overall mortality rate according to the following formula [13]:

$$SII=2*ASMR*\frac{(RII-1)}{(RII+1)}$$

Additionally, we computed partial life expectancy between ages 30 and 79 years by education [137]. First, we constructed abridged life tables by educational level for the exact ages between 30 and 79 years according to the standard life table technique [138]. Then, using functions of the life tables we calculated the partial life expectancy using the following formula:

$$_{i}e_{x}=\frac{T_{x}-T_{x+i}}{l_{x}}$$

where $_{i}e_{x}$ is the partial life expectancy between exact ages x and $x+i$, T_x and T_{x+i} are the numbers of person-years lived after exact ages x and $x+i$, and l_x is the number of person-years surviving to the exact age x.

All measures of inequalities presented in this thesis, except the partial life expectancy, were used to estimate inequalities in both all-cause and cause-specific mortality. The contribution of specific causes of death to educational differences in all-cause mortality was computed by two methods. First, we estimated the contribution of cause-specific RD to all-cause RD. Second, we applied the method of life expectancy decomposition in order to obtain age- and cause-of-death-specific contributions (in years) to the difference in partial life expectancy between the lowest and the highest educational level [139].

Finally, after estimating the relative and absolute inequalities in mortality we used a newly developed modelling tool to quantify the potential for reducing these inequalities in all-cause and cause-specific mortality in Europe. This newly developed modelling tool was implemented in the framework of the EURO-GBD-SE project. It is an Excel-based application built on the principles of the Population Impact Fraction (PIF) and the Population Attributable Fraction (PAF) [140]. The PAF is defined as the proportion of disease cases or deaths over a specified time period which would be prevented if the exposure to a specific risk factor were eliminated [141-143]. We use the term PAF not only for the elimination of the exposure to a specific risk factor but also in a situation where the prevalence of a risk factor is merely modified. In the literature, the latter is also described as the PIF. The PAF was computed using following formula:

$$PAF = \frac{\sum_{i=1}^{n} P_i RR_i - \sum_{i=1}^{n} P_i' RR_i}{\sum_{i=1}^{n} P_i RR_i}$$

with n the number of exposure categories (of the risk factor), P_i the proportion of the population currently in the ith exposure category, P'_i the proportion of the population in the ith exposure category in the scenario where the exposure to the risk factor is modified, and RR_i the relative risk of mortality for the ith exposure category.

The original methodology was adapted to estimate the impact of a counterfactual distribution of specific risk factors on the overall level of mortality and on educational differences in mortality. The latter was achieved by stratifying the PAF calculations by education. The value of the PAF combines: 1) the degree of social stratification in the risk factor prevalence and its changes brought about by the scenario and 2) the impact of the risk factor on mortality. Using bootstrap [144] in the statistical program R, we calculated 95% CI around the PAF values. We estimated the potential reduction in relative and absolute inequalities in mortality with the implementation of the counterfactual scenario. The potential reduction in relative inequalities in mortality was expressed as a percentage change in excess mortality (RR-1) before and after the implementation of the counterfactual scenario. The potential reduction in absolute inequalities in mortality was expressed as a number of deaths per 100,000 person-years and calculated as the difference in rate difference before and after the implementation of the counterfactual scenario.

STRUCTURE OF THIS THESIS

This thesis is divided in nine chapters. Chapter 1 provides a general introduction into the topic of this thesis, it describes the aims and specific research questions addressed in this thesis and it introduces the data and methods used in this thesis. Further to the general introduction, this thesis is divided into three sections.

The first section includes one chapter represented by chapter 2, which aims at investigating the quality of cause-specific mortality data. In chapter 2, we investigate the educational structure of ill-defined causes of death and its impact on educational inequalities in well-defined causes of death.

In the second section consisting of three chapters, we focus on educational inequalities in mortality in the different European countries. In particular, in chapter 3 we quantify the magnitude of educational inequalities in all-cause and cause-specific mortality in nine European countries with special emphasis on the small inequalities observed in southern European populations. Chapter 4 describes the magnitude of educational inequalities in mortality in the Netherlands taking advantage of individual data. In chapter 5, we analyse trends in educational inequalities in mortality between the 1990s and the 2000s in 13 European countries in order to compare the development of mortality inequalities across Europe.

After the description of the magnitude of and the trends in educational inequalities in mortality, the third section comprises three chapters, which aim at examining and quantifying the potential for reduction in educational inequalities in mortality. Chapter 6 describes the method and the developed methodological tool used to estimate the inequality reduction. Here, we focus on a limited number of countries, causes of death and risk factors as this chapter serves as an illustration of the method applied in chapters 7 and 8. In chapter 7, we assess the impact of on-going improvements in the educational structure of the population on mortality in Europe. Finally, chapter 8 quantifies the potential effects of the modification of the distribution of selected lifestyle risk factors (smoking, BMI, and physical activity) across educational groups on the reduction of educational inequalities in ischaemic heart disease mortality in Europe.

This thesis ends with a general discussion (chapter 9) of the findings. We more specifically address possible methodological limitations and results' implications for public health policy. We end with an overview of opportunities and recommendations for tackling socioeconomic inequalities in mortality.

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Part I

Data quality

2

Socioeconomic differences in the use of ill-defined causes of death in 16 European countries

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Submitted

ABSTRACT

Background

Cause-of-death data linked to information on socioeconomic position form one of the most important sources of information about health inequalities in many countries. The proportion of deaths from ill-defined conditions is one of the indicators of the quality of cause-of-death data. We investigated educational differences in the use of ill-defined causes of death in official mortality statistics.

Methods

Using age-standardized mortality rates from 16 European countries, we calculated the proportion of all deaths in each educational group that were classified as due to "Symptoms, signs and ill-defined conditions". We tested if this proportion differed across educational groups using Chi-square tests.

Results

The proportion of ill-defined causes of death was lower than 6.5% among men and 4.5% among women in all European countries, without any clear geographical pattern. This proportion statistically significantly differed by educational groups in several countries with in most cases a higher proportion among less than secondary educated people compared with tertiary educated people.

Conclusions

We found evidence for educational differences in the distribution of ill-defined causes of death. However, the differences between educational groups were small suggesting that socioeconomic inequalities in cause-specific mortality in Europe are not likely to be biased.

BACKGROUND

Cause-of-death statistics are an important source of information for epidemiological research and policy decisions. Their reliability is essential, not only for assessing trends and variations in average population health, but also for assessing the magnitude of inequalities in health between population groups. Indeed, many studies of health inequalities make extensive use of cause-specific mortality data [1-4], and it is therefore important to ensure that there are no differences between socioeconomic groups in the quality of cause-of-death information.

The proportion of deaths from ill-defined conditions is one of the commonly used indicators for the quality of cause-of-death data [5-8]. Deaths should be classified as due to ill-defined conditions only in a few cases when the real cause of death cannot be determined. However, in practice, deaths may also be classified as ill-defined when the certifying physician has insufficient knowledge of the disease(s) causing death, and/or has not completed the death certificate properly. It is likely that ill-defined causes of death hide important pathologies, and a high proportion of ill-defined causes of death may therefore lead to an underestimation of the mortality rates from well-defined causes of death, such as ischaemic heart disease (IHD), suicide or injuries [8-11]. On the other hand, a very low proportion of ill-defined conditions does not necessarily imply a high quality of cause-of-death information, because it does not exclude other forms of misclassification such as a tendency to over-report one specific cause of death (e.g., cardiovascular disease) at the expense of another [12].

Previous studies have shown that deaths from ill-defined conditions are more common in ethnic minorities [9], among old people living alone and in very marginal population groups, such as homeless people [13, 14]. To the best of our knowledge, no study has investigated whether the proportion of ill-defined causes of death differs between socioeconomic groups. Such inequalities may occur, for example, if lower socioeconomic groups have less access to good quality health care [15, 16] and, as a consequence, die under circumstances in which their diagnosis is less well-established than is normally the case for patients with a higher socioeconomic position.

The aim of the present study was to examine whether there are educational differences in the proportion of ill-defined causes of death among men and women in 16 European populations.

METHODS

We analysed mortality data from 16 European populations as collected and harmonized in the EURO-GBD-SE project [17]. Data come from longitudinal (Finland, Sweden, Norway, Denmark, England and Wales, Netherlands, Belgium, France, Switzerland, Austria, the Basque Country, Madrid, Turin, Tuscany), repeated cross-sectional (Barcelona) or cross-sectional unlinked (Hungary, Czech Republic, Poland, Estonia) studies in national, regional or urban populations in the time period between 1998 and 2007 (Table A1 in appendix). We combined all Spanish and all Italian datasets to ensure adequate number of deaths.

Completed education was categorized into three groups according to the International Standard Classification of Education (ISCED): less than secondary education (ISCED 0, 1, 2; 'low'), secondary education (ISCED 3, 4; 'mid') and tertiary education (ISCED 5, 6; 'high'). The share of individuals with unknown education was in most populations below 2.3% except in France (6.0%) and Switzerland (6.1%). These individuals were excluded from the analyses. Ill-defined causes of death were defined as codes 780–799 ("Symptoms, signs and ill-defined conditions") or R00–R99 ("Symptoms, signs and abnormal clinical and laboratory findings, not elsewhere classified"), according to respectively the 9th or 10th revision of the International Classification of Diseases. Examples of specific entities within this chapter are 'sudden death', 'senility' or 'old age'.

Analyses were conducted by country, sex and education for the age range 30–79. The proportion of ill-defined causes of death was computed as the share of the age-standardized mortality rate (ASMR) for ill-defined conditions on the all-cause ASMR. We used direct standardization with European Standard Population as standard [18]. We performed Chi-square tests of independence to assess if the proportion of ill-defined causes of death differed by educational group [19]. All tests were performed at the 5% significance level.

RESULTS

The proportion of ill-defined causes of death varied across European countries, but without any clear geographical pattern (Figure 1). The proportion ranged from 0.1% in Hungary to 6.2% in Poland among men, and from 0.05% in Hungary to 4.3% in the Netherlands among women. For both men and women, proportions of ill-defined causes of death lower than 1% were found in Finland, England and Wales, Scotland, Austria, Italy, Hungary, Czech Republic and Lithuania. Proportions of ill-defined causes of death higher than 3% were observed in Norway, Denmark, Netherlands, France, Switzerland and Poland.

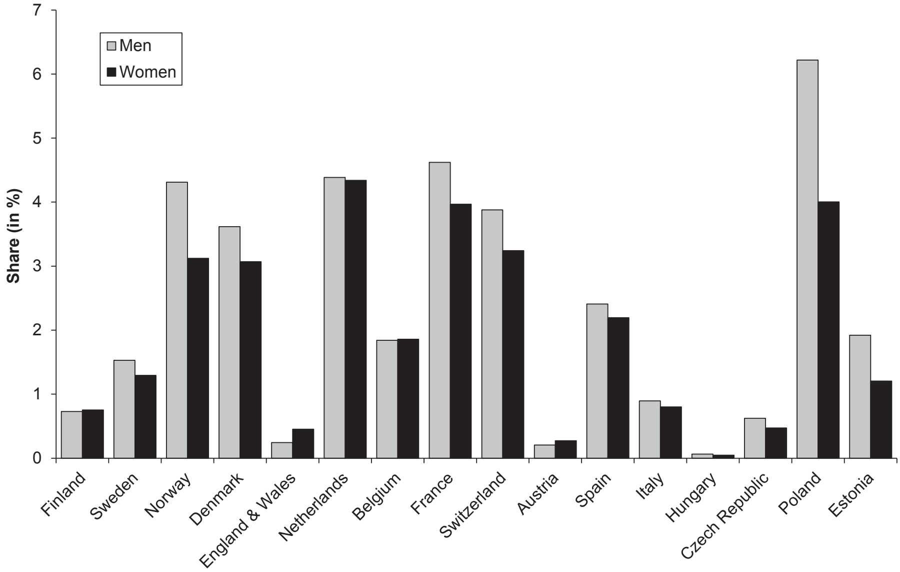

Figure 1 Share of ASMR from ill-defined conditions on all-cause ASMR (in %) by country and sex, 30–79 years

The distribution of ill-defined causes of death differed by educational level in Denmark, England and Wales, Belgium, Switzerland, Italy, Hungary, Czech Republic, Poland and Estonia among men, and in Switzerland and Poland among women with the tendency of a higher proportion among low educated individuals (Table 1). Absolute differences between the low and high educated are, however, small: generally less than one percentage point, with exception of Polish men among whom the difference is 2.9%-points.

DISCUSSION

This study had a broad geographical scope and included countries with different educational systems and different cause-of-death certifying and coding practices. Although we put much effort in harmonizing the data, there are some methodological issues that should be addressed.

First, foreigners and people born outside mainland were excluded from the Swiss and French dataset, respectively. If cause-of-death certification is more incomplete among foreigners [20], this will have led to an underestimation of the proportion of ill-defined causes of death in these countries. Spain and Italy were represented by cities or regions. If cause-of-death information is more complete in these urban areas [7], this will again

Table 1 Number of deaths from ill-defined conditions (D) and share of ASMR from ill-defined conditions on all-cause ASMR (in %) by country, sex and educational level, 30–79 years

Country	Men							Women						
	Low education		Mid education		High education		P-value[a]	Low education		Mid education		High education		P-value[a]
	D	%	D	%	D	%		D	%	D	%	D	%	
Finland	308	0.7	221	0.8	108	0.8	0.822	161	0.8	99	0.8	82	1.2	0.071
Sweden	879	1.6	733	1.6	224	1.6	0.779	669	1.3	371	1.3	123	1.4	0.655
Norway	808	4.2	983	4.4	285	4.8	0.211	553	2.9	454	3.3	101	3.6	0.058
Denmark	1,530	3.9	944	3.4	282	3.2	0.000	1,273	3.1	405	3.1	157	3.0	0.928
England & Wales	16	0.4	*	0.1	0	0.0	0.000	21	0.4	*	0.1	*	1.0	0.071
Netherlands	120	4.0	102	4.6	55	5.1	0.218	107	4.1	47	4.9	14	3.7	0.597
Belgium	767	2.0	156	1.7	107	1.6	0.038	545	1.9	91	1.8	58	1.8	0.820
France	202	4.5	118	4.7	36	6.9	0.121	123	4.1	37	4.2	11	5.0	0.835
Switzerland	528	3.5	1,074	3.8	498	5.0	0.000	566	3.1	538	3.3	114	5.2	0.000
Austria	21	0.3	24	0.2	*	0.1	0.571	42	0.3	16	0.3	*	0.2	0.789
Spain	1,463	2.5	292	2.4	268	2.5	0.753	863	2.3	99	2.2	75	2.0	0.427
Italy	99	0.8	28	0.8	28	1.9	0.017	77	0.8	18	0.9	*	0.4	0.198
Hungary	100	0.1	35	0.1	*	0.0	0.000	51	0.1	10	0.0	*	0.0	0.096
Czech Republic	1,036	0.7	159	0.5	69	0.6	0.012	540	0.5	83	0.4	27	0.8	0.109
Poland	13,532	7.8	13,461	5.7	1,113	4.9	0.000	7,210	4.7	3,476	3.7	387	4.0	0.000
Estonia	350	2.1	306	1.9	44	1.4	0.017	199	1.2	104	1.1	11	0.7	0.208

[a] Chi-square test for the difference across educational groups in the share of ASMR from ill-defined conditions on all-cause ASMR

* D <= 5; Although we cannot present numbers smaller than 5 in the table, we did use them in the analysis.

have led to an underestimation of the proportion of ill-defined causes of death in these countries. Whether this may also have had an impact on our results for educational inequalities is, however, difficult to assess.

Second, people with unknown education were excluded from the analyses. The share of ill-defined causes of death was higher among people with unknown education compared with those with primary education. However, due to the small percentage of unknown education in the mortality datasets, our conclusions do not change when combining unknown education with primary education (results not shown).

Third, some datasets had a cross-sectional unlinked design, whereas other consisted of census-linked mortality follow-up studies. It has been shown that mortality inequalities based on unlinked datasets are likely to suffer from the numerator-denominator bias [13, 21] observed when information on education comes from death certificates for the deceased (the numerator) and from census for the population (the denominator) [22]. Education misreporting has been found larger for deaths from ill-defined conditions [21]. This could spuriously produce inequalities in mortality from ill-defined conditions in countries with cross-sectional unlinked designs. Although all four countries showed statistically significant results, only Poland had an exceptionally high proportion of ill-defined causes of death, which has been reported previously [7, 23].

As mentioned in the introduction, ill-defined causes of death may hide important well-defined causes of death. Autopsy may play an important role in order to identify the correct well-defined cause of death. It has been reported in Barcelona that after forensic tests only 28% of ill-defined causes of death remained ill-defined, the rest being redistributed in other specific causes of death, mainly diseases of circulatory system and to a lesser extent suicide [24]. The percentage of autopsies varies considerably between European countries. In the 2000s, this percentage was less than 10% in Norway, Denmark, Netherlands and Switzerland, about 15% in Sweden, and 30% or more in Finland, Austria, Hungary, Czech Republic, Lithuania and Estonia, and not available in Belgium France, UK, Spain, Italy and Poland [23]. As our findings suggest, the lower the percentage of autopsies the higher the proportion of ill-defined causes of death. Except Poland, for which we do not have information about the autopsy rate, Norway, Denmark, Netherlands and Switzerland are countries with the lowest autopsy rate in Europe but with one of the highest percentages of ill-defined causes of death.

The literature suggests that IHD [25, 26] or suicide [11, 27] may be misclassified as ill-defined causes of death. IHD could be misclassified because deaths from myocardial infarctions may occur suddenly, and when due to cardiac arrhythmia are not detectable even with autopsy. Suicide could be misclassified due to religious taboos, cultural norms and social stigma or due to lack of evidence [28].

To estimate to what extent any misclassification of IHD (ICD-9: 410–414; ICD-10: I20–I25) or suicide (ICD-9: E950–E959; ICD-10: X60–X84, Y87.0) as ill-defined condition may affect socioeconomic inequalities in IHD (respectively suicide) mortality, we conducted a sensitivity analysis by adding 50% (resp. 20%) of deaths from ill-defined conditions to IHD deaths (resp. suicide deaths) in each educational group. We assessed relative inequalities as relative risks using Poisson regression. After this redistribution, relative inequalities in IHD and suicide mortality changed considerably only among men in Poland (Tables A2 and A3 in appendix). In order to estimate the change in the ranking between European countries after this redistribution, we calculated the Spearman correlation coefficient and found that the redistribution of the ill-defined causes of deaths did not change the rank order for relative inequalities in IHD mortality (rho: both men and women = 0.956) and suicide mortality (rho: men = 0.982; women = 0.970) among the countries under investigation.

We found educational differences in the proportion of ill-defined causes of death in several European countries. However the percentage difference was not large enough to impact educational inequalities in well-defined causes of death after a redistribution of ill-defined causes of death. Although there may be other forms of misclassification, our results suggest that findings from previous studies documenting socioeconomic inequalities in cause-specific mortality in Europe are not likely to be biased by differences in the quality of cause-of-death information.

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APPENDIX

Table A1 Mortality data sources

Population	Type of dataset	Period	Geographic coverage	Demographic coverage
Finland	longitudinal	2001–2007	national	20% of Finns are 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% of the population
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% of the population, born outside France mainland 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	Florence, Leghorn, Prato	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

Table A2 Relative risks (RR) by educational level of ischaemic heart disease (IHD) mortality before and after a 50%-redistribution of ill-defined causes of death by country, men and women, 30–79 years

		MEN				WOMEN			
		IHD		IHD after redistribution		IHD		IHD after redistribution	
Country	Edu	RR	95%-CI	RR	95%-CI	RR	95%-CI	RR	95%-CI
Finland	low	2.16	(2.07–2.25)	2.15	(2.06–2.24)	2.66	(2.43–2.92)	2.57	(2.36–2.81)
	mid	1.67	(1.59–1.76)	1.67	(1.59–1.75)	1.82	(1.64–2.01)	1.76	(1.59–1.94)
	high	1		1		1		1	
Sweden	low	2.10	(2.01–2.19)	2.08	(1.99–2.17)	2.78	(2.56–3.02)	2.68	(2.48–2.89)
	mid	1.57	(1.50–1.65)	1.56	(1.50–1.63)	1.95	(1.79–2.12)	1.89	(1.74–2.05)
	high	1		1		1		1	
Norway	low	2.49	(2.30–2.68)	2.41	(2.24–2.58)	3.05	(2.60–3.57)	2.75	(2.39–3.16)
	mid	1.70	(1.57–1.83)	1.66	(1.54–1.78)	1.79	(1.53–2.11)	1.68	(1.46–1.94)
	high	1		1		1		1	
Denmark	low	1.90	(1.78–2.03)	1.94	(1.82–2.06)	2.32	(2.05–2.63)	2.21	(1.98–2.47)
	mid	1.54	(1.43–1.65)	1.55	(1.45–1.65)	1.54	(1.34–1.76)	1.50	(1.33–1.69)
	high	1		1		1		1	
England & Wales	low	1.63	(1.39–1.91)	1.64	(1.40–1.93)	2.62	(1.93–3.56)	2.52	(1.87–3.40)
	mid	1.26	(1.05–1.51)	1.26	(1.05–1.51)	1.55	(1.08–2.22)	1.48	(1.04–2.10)
	high	1		1		1		1	
Netherlands	low	2.11	(1.72–2.59)	1.97	(1.63–2.37)	2.81	(1.72–4.61)	2.51	(1.65–3.82)
	mid	1.54	(1.24–1.90)	1.45	(1.20–1.76)	1.66	(0.98–2.82)	1.60	(1.02–2.51)
	high	1		1		1		1	
Belgium	low	1.82	(1.69–1.97)	1.85	(1.72–1.99)	2.23	(1.90–2.63)	2.16	(1.86–2.51)
	mid	1.36	(1.23–1.49)	1.37	(1.25–1.50)	1.49	(1.24–1.81)	1.47	(1.23–1.75)
	high	1		1		1		1	
France	low	2.15	(1.58–2.93)	2.00	(1.54–2.60)	3.65	(1.60–8.31)	2.69	(1.47–4.91)
	mid	1.65	(1.20–2.28)	1.54	(1.17–2.02)	1.66	(0.68–4.01)	1.49	(0.78–2.84)
	high	1		1		1		1	
Switzerland	low	1.94	(1.82–2.08)	1.88	(1.76–1.99)	2.21	(1.84–2.65)	1.82	(1.56–2.13)
	mid	1.42	(1.33–1.50)	1.38	(1.30–1.46)	1.42	(1.18–1.71)	1.22	(1.04–1.42)
	high	1		1		1		1	
Austria	low	1.62	(1.46–1.80)	1.63	(1.47–1.80)	1.88	(1.47–2.41)	1.88	(1.47–2.41)
	mid	1.49	(1.35–1.64)	1.49	(1.35–1.65)	1.35	(1.05–1.74)	1.36	(1.06–1.74)
	high	1		1		1		1	
Spain	low	1.24	(1.16–1.32)	1.26	(1.19–1.34)	1.55	(1.31–1.83)	1.56	(1.35–1.82)
	mid	1.11	(1.02–1.21)	1.11	(1.03–1.20)	1.19	(0.96–1.48)	1.23	(1.02–1.49)
	high	1		1		1		1	

Table A2 Relative risks (RR) by educational level of ischaemic heart disease (IHD) mortality before and after a 50%-redistribution of ill-defined causes of death by country, men and women, 30-79 years (continued)

		MEN				WOMEN			
		IHD		IHD after redistribution		IHD		IHD after redistribution	
Country	Edu	RR	95%-CI	RR	95%-CI	RR	95%-CI	RR	95%-CI
Italy	low	1.38	(1.19–1.59)	1.33	(1.16–1.53)	1.20	(0.91–1.58)	1.24	(0.95–1.63)
	mid	1.08	(0.91–1.28)	1.04	(0.88–1.23)	0.82	(0.59–1.14)	0.87	(0.63–1.20)
	high	1		1		1		1	
Hungary	low	2.46	(2.38–2.56)	2.47	(2.38–2.56)	2.41	(2.23–2.60)	2.41	(2.24–2.60)
	mid	1.25	(1.20–1.31)	1.25	(1.20–1.31)	1.22	(1.13–1.33)	1.22	(1.13–1.33)
	high	1		1		1		1	
Czech Republic	low	2.90	(2.78–3.02)	2.90	(2.78–3.03)	3.26	(2.91–3.65)	3.17	(2.84–3.55)
	mid	1.56	(1.49–1.64)	1.56	(1.49–1.63)	1.86	(1.66–2.10)	1.82	(1.62–2.04)
	high	1		1		1		1	
Poland	low	1.98	(1.92–2.05)	2.21	(2.15–2.28)	2.49	(2.32–2.66)	2.46	(2.32–2.62)
	mid	1.91	(1.85–1.97)	1.96	(1.90–2.02)	1.97	(1.84–2.11)	1.92	(1.80–2.04)
	high	1		1		1		1	
Estonia	low	2.31	(2.14–2.49)	2.34	(2.17–2.52)	2.50	(2.24–2.80)	2.53	(2.26–2.83)
	mid	1.92	(1.77–2.07)	1.93	(1.79–2.09)	1.86	(1.66–2.09)	1.88	(1.68–2.11)
	high	1		1		1		1	

Table A3 Relative risks (RR) by educational level of suicide mortality before and after a 20%-redistribution of ill-defined causes of death by country, men and women, 30–79 years

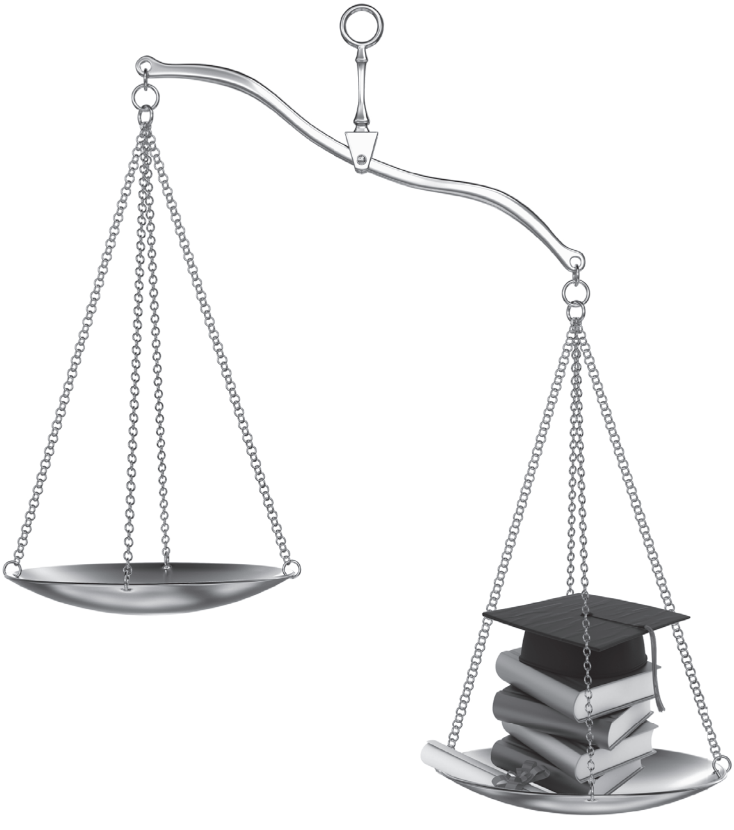
		MEN				WOMEN			
		Suicide		Suicide after redistribution		Suicide		Suicide after redistribution	
Country	Edu	RR	95%-CI	RR	95%-CI	RR	95%-CI	RR	95%-CI
Finland	low	2.08	(1.88–2.31)	2.07	(1.88–2.29)	1.68	(1.42–1.98)	1.64	(1.40–1.93)
	mid	1.76	(1.60–1.95)	1.75	(1.59–1.94)	1.40	(1.20–1.63)	1.37	(1.18–1.60)
	high	1		1		1		1	
Sweden	low	1.88	(1.70–2.09)	1.85	(1.68–2.05)	1.33	(1.15–1.55)	1.35	(1.17–1.56)
	mid	1.45	(1.31–1.60)	1.43	(1.30–1.58)	1.18	(1.04–1.35)	1.18	(1.04–1.34)
	high	1		1		1		1	
Norway	low	2.15	(1.79–2.59)	2.07	(1.77–2.42)	1.24	(0.95–1.62)	1.32	(1.05–1.66)
	mid	1.60	(1.37–1.87)	1.55	(1.35–1.78)	1.15	(0.93–1.43)	1.17	(0.96–1.42)
	high	1		1		1		1	
Denmark	low	1.82	(1.59–2.09)	1.92	(1.69–2.17)	1.17	(0.96–1.42)	1.29	(1.08–1.52)
	mid	1.49	(1.30–1.71)	1.51	(1.33–1.72)	0.97	(0.79–1.20)	1.05	(0.87–1.26)
	high	1		1		1		1	
England & Wales	low	2.08	(1.08–4.00)	2.19	(1.14–4.19)	0.97	(0.37–2.53)	0.93	(0.38–2.25)
	mid	1.34	(0.65–2.76)	1.35	(0.66–2.77)	0.48	(0.13–1.59)	0.41	(0.12–1.36)
	high	1		1		1		1	
Netherlands	low	1.17	(0.75–1.84)	1.21	(0.82–1.76)	0.91	(0.46–1.77)	1.08	(0.60–1.92)
	mid	0.76	(0.47–1.21)	0.85	(0.57–1.25)	1.04	(0.54–2.01)	1.11	(0.62–2.00)
	high	1		1		1		1	
Belgium	low	1.75	(1.55–1.97)	1.78	(1.59–2.00)	0.96	(0.81–1.14)	1.00	(0.85–1.18)
	mid	1.43	(1.25–1.63)	1.43	(1.26–1.63)	0.91	(0.75–1.10)	0.93	(0.77–1.12)
	high	1		1		1		1	
France	low	3.24	(2.03–5.15)	2.80	(1.87–4.19)	2.35	(1.18–4.70)	2.16	(1.16–4.05)
	mid	2.46	(1.55–3.89)	2.15	(1.44–3.21)	1.43	(0.70–2.92)	1.42	(0.74–2.71)
	high	1		1		1		1	
Switzerland	low	1.67	(1.48–1.89)	1.63	(1.45–1.82)	1.08	(0.88–1.33)	1.03	(0.85–1.25)
	mid	1.40	(1.27–1.54)	1.35	(1.24–1.48)	1.10	(0.91–1.33)	1.02	(0.86–1.22)
	high	1		1		1		1	
Austria	low	2.30	(1.78–2.97)	2.31	(1.79–2.97)	1.38	(0.89–2.15)	1.38	(0.89–2.14)
	mid	1.78	(1.40–2.26)	1.78	(1.41–2.26)	0.95	(0.61–1.47)	0.95	(0.62–1.48)
	high	1		1		1		1	
Spain	low	2.05	(1.71–2.47)	1.91	(1.63–2.23)	1.50	(1.13–2.00)	1.53	(1.18–1.97)
	mid	1.39	(1.12–1.72)	1.32	(1.10–1.59)	1.55	(1.13–2.13)	1.52	(1.14–2.03)
	high	1		1		1		1	

Table A3 Relative risks (RR) by educational level of suicide mortality before and after a 20%-redistribution of ill-defined causes of death by country, men and women, 30–79 years (continued)

		MEN				WOMEN			
		Suicide		Suicide after redistribution		Suicide		Suicide after redistribution	
Country	Edu	RR	95%-CI	RR	95%-CI	RR	95%-CI	RR	95%-CI
Italy	low	1.40	(0.91–2.17)	1.26	(0.85–1.87)	0.83	(0.45–1.50)	0.91	(0.51–1.62)
	mid	1.42	(0.89–2.27)	1.25	(0.82–1.92)	0.92	(0.48–1.75)	1.00	(0.54–1.85)
	high	1		1		1		1	
Hungary	low	6.16	(5.48–6.93)	6.17	(5.49–6.94)	2.90	(2.38–3.54)	2.90	(2.38–3.54)
	mid	2.63	(2.34–2.97)	2.64	(2.34–2.97)	1.73	(1.41–2.12)	1.73	(1.41–2.12)
	high	1		1		1		1	
Czech Republic	low	2.49	(2.23–2.79)	2.52	(2.26–2.81)	1.67	(1.29–2.16)	1.64	(1.28–2.10)
	mid	1.23	(1.08–1.39)	1.23	(1.08–1.39)	1.36	(1.04–1.78)	1.31	(1.01–1.70)
	high	1		1		1		1	
Poland	low	5.80	(2.23–6.44)	5.20	(4.78–5.65)	2.37	(1.97–2.85)	2.39	(2.07–2.76)
	mid	2.98	(2.69–3.30)	2.77	(2.55–3.01)	1.65	(1.38–1.97)	1.66	(1.44–1.91)
	high	1		1		1		1	
Estonia	low	3.14	(2.52–3.91)	3.17	(2.57–3.91)	2.26	(1.50–3.40)	2.40	(1.64–3.54)
	mid	2.25	(1.82–2.79)	2.27	(1.85–2.79)	1.56	(1.07–2.27)	1.64	(1.15–2.36)
	high	1		1		1		1	

Part II

Educational inequalities in mortality



3

Why does Spain have smaller inequalities in mortality? An exploration of potential explanations

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ABSTRACT

Background

While educational inequalities in mortality are substantial in most European countries, they are relatively small in Spain. A better understanding of the causes of these smaller inequalities in Spain may help to develop policies to reduce inequalities in mortality elsewhere. The aim of the present study was therefore to identify the specific causes of death and determinants contributing to these smaller inequalities.

Methods

Data on mortality by education were obtained from longitudinal mortality studies in three Spanish populations (Barcelona, Madrid, the Basque Country), and six other Western European populations. Data on determinants by education were obtained from health interview surveys.

Results

The Spanish populations have considerably smaller absolute inequalities in mortality than other Western European populations. This is due mainly to smaller inequalities in mortality from cardiovascular diseases (men) and cancer (women). Inequalities in mortality from most other causes are not smaller in Spain than elsewhere. Spain also has smaller inequalities in smoking and sedentary lifestyle and this is due to more smoking and physical inactivity in higher educated groups.

Conclusion

Overall, the situation with regard to health inequalities does not appear to be more favourable in Spain than in other Western European populations. Smaller inequalities in mortality from cardiovascular diseases and cancer in Spain are likely to be related to its later socioeconomic modernization. Although these smaller inequalities in mortality seem to be a historical coincidence rather than the outcome of deliberate policies, the Spanish example does suggest that large inequalities in total mortality are not inevitable.

INTRODUCTION

Mortality differentials among different socioeconomic groups belong to the most consistent findings in public health, but the magnitude of these inequalities differs substantially between countries. A recent study of inequalities in health in 22 European countries in the 1990s showed that some southern European populations have relatively small educational inequalities in mortality [1]. Smaller inequalities in mortality in Spain and Italy were also found in a previous study [2], but have never been satisfactorily explained. We therefore conducted an in-depth study of potential explanations for smaller inequalities in mortality in Spain.

Spain is a young democracy, with an underdeveloped welfare state, important income inequalities, and a universal national health service [3]. Evidence on socioeconomic differentials in mortality based on individual data is relatively scarce, due to the poor quality of socioeconomic information included in death certificates, and to restrictive legislation with regard to linkage of the death register with census information [4, 5]. International literature focused mainly on the city of Barcelona or the region of Madrid [5-9]. One factor standing out from the more detailed analyses that have been performed is smoking: inequalities in smoking are smaller in Spain and Italy than in other Western European countries, particularly among women, and this is likely to contribute to smaller inequalities in ischaemic heart disease [10, 11] and lung cancer [12]. Studies which tried to explain the comparatively small inequalities in mortality in Spain are non-existent, and a comprehensive explanation is lacking so far.

The present study was based on evidence from three Spanish populations (the city of Barcelona, the region of Madrid, and the Basque Country), which were compared to six other Western European populations (Finland, Sweden, Norway, Denmark, Belgium, and Turin (Italy)). Our analysis aimed at identifying the specific causes of death and some of the specific determinants which contributed to smaller inequalities in total mortality in the three Spanish populations.

METHODS

Study population

Mortality data were obtained from longitudinal mortality studies based on linkage of death registries to population censuses and consisted of deaths and exposure counts by sex, 5-year age groups, cause of death and level of education (Table 1). The data covered national (Finland, Sweden, Norway, Denmark, Belgium), regional (Madrid, the Basque

Table 1 Data sources of mortality and determinants, 30–74 years

	Mortality data				Morbidity data		
Country	Type of study	Follow-up period	Number of persons at risk	Number of deaths	Survey	Years	Number of respondents
Finland	National, longitudinal census-linked mortality study	1990–2000	25,874,201	270,130	Finbalt Health Monitor	1994, 1998, 2000, 2002, 2004	15,207
Sweden	National, longitudinal census-linked mortality study	1991–2000	43,042,216	393,038	Swedish Survey of Living Conditions	2000–2001	7,999
Norway	National, longitudinal census-linked mortality study	1990–2000	19,956,768	213,022	Norwegian Survey of Living Conditions	2002	4,834
Denmark	National, longitudinal census-linked mortality study	1996–2000	13,926,921	136,065	Danish Health and Morbidity Survey	2000	11,739
Belgium	National, longitudinal census-linked mortality study	1991–1995	24,861,015	283,349	Health Interview Survey	1997–2001	13,114
Italy	Urban, longitudinal census-linked mortality study for the city of Turin	1991–2001	4,873,109	50,621	Health and health Care Utilization Multipurpose Family Survey, Aspects of Daily Living	1999–2000 2000	116,600
Spain	Urban, longitudinal census-linked mortality study for the city of Barcelona	1992–2001	8,151,810	77,101	National Health Survey	2001	13,926
	Regional, longitudinal, census-linked mortality study for the region of Madrid	1996–1997	3,663,333	22,585			
	Regional, longitudinal census linked mortality study for the Basque Country	1996–2001	6,098,485	41,704	Health Survey of the Basque Country	2002	8,920

Country) and urban (Barcelona and Turin) populations. The linkage between census data and death registries was achieved for almost 100% in all populations except in Barcelona, Madrid, and the Basque Country where the linkage was obtained for only 94.5%, 70%, and 94.1% of the population, respectively. To correct for the underestimation of deaths we weighted the number of deaths in the three Spanish populations with a correction factor. The correction factors were 1/0.945 for Barcelona, 1/0.7 for Madrid and 1/0.941 for the Basque Country. Data on determinants of mortality by socioeconomic position came from nationally representative health or multipurpose surveys with a cross-sectional design (Table 1).

Measures

The causes of death were classified according to the 9th and 10th revision of the International Classification of Diseases (ICD). We analysed a few large groups of causes (cardiovascular diseases (CVD), cancer, infectious diseases, respiratory diseases, alcohol-related causes, external causes and all other causes), as well as a few specific causes of death (ischaemic heart disease (IHD), cerebrovascular disease, stomach cancer, lung cancer, breast cancer, and pneumonia) (see Table A1 in appendix for ICD-codes).

Data on determinants included smoking, obesity, sedentary lifestyle, and health services utilization. Smoking status was measured as self-reported current tobacco smoking. Obesity was measured on the basis of self-reported height and weight, and defined as a body mass index >29 and <70. Sedentary lifestyle was measured either by asking the best described respondents´ leisure time activities or the frequency of respondents´ physical exercises or activities. The measurement of health services utilization was based on visits to a general practitioner, to specialists, and to any physician. All analyses of health services utilization were adjusted for self-assessed health.

Educational level declared at the census and during the interview surveys was used as a measure of socioeconomic status and classified according to the International Standard Classification of Education (ISCED) using three categories: low (primary and lower secondary education), middle (upper secondary education) and high (post-secondary or tertiary education). Persons with missing information on educational level (generally <5%) were excluded from the analysis.

Statistical analysis

Analyses were conducted separately for men and women aged 30–74 years at baseline (i.e., at the time of census). The follow-up time was 10 years for most countries except Belgium, Denmark, Basque Country (5 years) and Madrid (1.5 years). To obtain comparable ages at death, analyses were conducted on slightly older age groups at baseline for countries with shorter follow-up period (35–79 years for Madrid, and 30–79 years for Belgium and the Basque Country). In Denmark, no information on socioeconomic status was available for subject aged over 75 years. Further information on this adjustment procedure can be found elsewhere [13].

Mortality rates by educational attainment were age-standardized with the direct method using the European Standard Population. The contribution of a specific cause of death to inequalities in all-cause mortality between low and high educated people was determined as the share of the rate difference for each cause of death out of the rate difference for total mortality. The magnitude of mortality inequalities according to educational level was summarized by relative (relative index of inequality, RII) [14] as well as absolute (slope index of inequality, SII) measures of inequality [1] using Poisson regression due to count data.

Prevalence rates of determinants by educational level were also age-standardized, and inequalities in determinant prevalence were summarized by RIIs. As the prevalence of the determinants was relatively high (>10%), we used log-binomial regression.

RESULTS

Mortality analyses

All populations included in the analysis show a graded relationship between education and mortality, but the absolute gap in mortality between the lowest and highest educated is smaller in the three Spanish populations (Figure A1 in appendix). Average mortality rates are also lower in Spain than in other Western European populations, both among men (with the exception of Barcelona) and particularly among women, where mortality in the lowest educated group is lower compared with the highest educated group in all other Western European populations.

Table 2 shows relative inequalities in total and cause-specific mortality. Among men, relative inequalities in total mortality in all Spanish regions tend to be smaller than those in most other populations, although the differences are neither entirely consistent nor substantial. Among women, relative inequalities in total mortality in the three Spanish regions are substantially smaller than those in all other populations, with the exception of Turin, which has similarly small RIIs.

Among men, relative inequalities in CVD mortality in the three Spanish regions are smaller than those in all other populations, but inequalities in mortality from other causes of death are similar in magnitude, or even larger than those elsewhere. Among women, relative inequalities in mortality from cancer are smaller in the three Spanish regions, but inequalities in mortality from other causes are not consistently smaller than those in other populations.

Moreover, reverse pattern was observed for lung cancer among women in the three Spanish populations and Turin, and for breast cancer among women in all populations except Turin and the Basque Country. The large inequalities in mortality from infectious diseases in Spain are predominantly due to AIDS mortality. More detailed data on cause-specific mortality by educational level can be found in appendix (Tables A2, A3 and A4).

Figure 1 quantifies the contribution of specific causes of death to the difference in age-standardized mortality rates between low and high educated men and women. It shows that the smaller absolute inequalities in mortality in the three Spanish populations are partly due to smaller absolute inequalities in CVD mortality. These are negligible in Spain, but substantial in most other populations. Among men, these smaller contributions of CVD are due to both lower average rates of mortality, and smaller relative inequalities in mortality (Table 2). Among women, these smaller contributions of CVD are mainly due to lower average rates of mortality, and not to smaller relative inequalities in mortal-

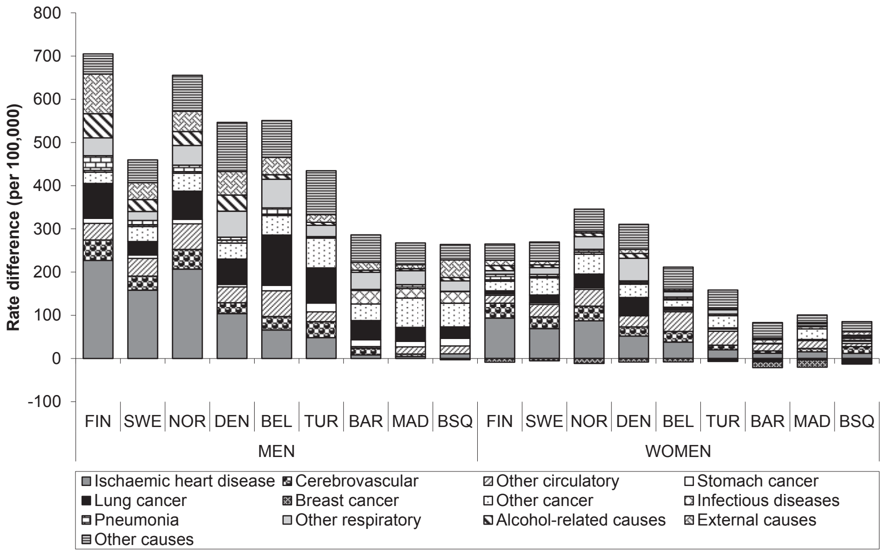

Figure 1 Contribution of causes of death to the difference in age-standardized mortality rates between low and high educated men and women, 30–74 years

Legend: FIN = Finland, SWE = Sweden, NOR = Norway, DEN = Denmark, BEL = Belgium, TUR = Turin, BAR = Barcelona, MAD = Madrid, BSQ = Basque

Table 2 Relative index of inequality (RII) for selected causes of death by educational level, and corresponding 95% confidence intervals (CI), nine European populations, 30–74 years

	Finland		Sweden		Norway		Denmark		Belgium		Turin		Barcelona		Madrid		Basque Country	
Cause of death	RII	95%-CI	RII	95%-CI	RII	95%-CI	RII	95%-CI	RII	95%-CI	RII	95%-CI	RII	95%-CI	RII	95%-CI	RII	95%-CI
MEN																		
Cardiovascular diseases	2.17	(2.10-2.25)	1.99	(1.94-2.04)	2.12	(2.05-2.19)	1.81	(1.72-1.90)	1.77	(1.70-1.85)	1.51	(1.37-1.67)	1.29	(1.19-1.39)	1.20	(1.03-1.39)	1.25	(1.11-1.41)
Ischaemic heart disease	2.26	(2.17-2.36)	2.16	(2.09-2.23)	2.26	(2.17-2.36)	2.01	(1.88-2.16)	1.75	(1.64-1.86)	1.54	(1.31-1.80)	1.21	(1.08-1.36)	1.03	(0.83-1.28)	1.19	(1.00-1.43)
Cerebrovascular disease	1.91	(1.76-2.06)	1.73	(1.63-1.84)	1.82	(1.68-1.97)	1.59	(1.42-1.78)	1.71	(1.55-1.89)	1.85	(1.49-2.30)	1.65	(1.39-1.96)	1.20	(0.85-1.68)	1.09	(0.85-1.39)
Other circulatory diseases	2.11	(1.93-2.31)	1.75	(1.66-1.85)	1.97	(1.83-2.12)	1.59	(1.45-1.75)	1.83	(1.70-1.97)	1.31	(1.11-1.55)	1.18	(1.03-1.36)	1.43	(1.12-1.82)	1.46	(1.18-1.81)
Cancer	1.68	(1.61-1.75)	1.32	(1.28-1.36)	1.46	(1.40-1.52)	1.32	(1.26-1.39)	1.81	(1.74-1.88)	1.86	(1.70-2.05)	1.55	(1.45-1.65)	1.52	(1.35-1.72)	1.57	(1.42-1.73)
Stomach cancer	2.25	(1.89-2.69)	1.83	(1.61-2.09)	1.90	(1.62-2.22)	2.06	(1.56-2.72)	3.20	(2.57-3.97)	4.47	(2.80-7.16)	4.07	(2.91-5.69)	2.35	(1.44-3.85)	3.98	(2.58-6.14)
Lung cancer	3.35	(3.07-3.65)	1.82	(1.70-1.94)	2.51	(2.31-2.73)	1.82	(1.66-1.99)	3.13	(2.92-3.36)	2.50	(2.12-2.96)	1.78	(1.58-2.01)	1.53	(1.22-1.90)	1.60	(1.33-1.93)
Other cancer	1.22	(1.16-1.28)	1.19	(1.15-1.23)	1.20	(1.14-1.25)	1.14	(1.08-1.21)	1.25	(1.19-1.32)	1.50	(1.33-1.68)	1.36	(1.25-1.47)	1.45	(1.25-1.69)	1.43	(1.27-1.61)
Infectious diseases	1.81	(1.41-2.32)	1.74	(1.45-2.10)	1.57	(1.22-2.01)	3.44	(2.54-4.66)	1.29	(1.05-1.58)	3.15	(1.30-7.59)	3.87	(3.09-4.85)	5.65	(3.64-8.77)	8.94	(6.24-12.80)
Respiratory diseases	4.12	(3.72-4.57)	2.48	(2.29-2.68)	2.99	(2.73-3.27)	3.40	(3.02-3.81)	4.41	(3.97-4.89)	2.85	(2.07-3.91)	3.59	(2.93-4.39)	3.81	(2.63-5.53)	2.57	(1.87-3.53)
Pneumonia	3.73	(3.24-4.30)	2.42	(2.12-2.75)	2.33	(2.00-2.71)	2.54	(1.90-3.37)	3.04	(2.48-3.74)	1.66	(0.93-2.97)	1.76	(1.18-2.62)	2.98	(1.54-5.79)	1.46	(0.72-2.99)
Other respiratory diseases	4.57	(3.94-5.31)	2.51	(2.27-2.78)	3.41	(3.05-3.82)	3.59	(3.16-4.08)	4.94	(4.38-5.57)	3.49	(2.39-5.10)	4.45	(3.52-5.64)	4.24	(2.70-6.65)	2.90	(2.04-4.13)
Alcohol-related causes	3.10	(2.85-3.38)	3.90	(3.51-4.33)	3.89	(3.37-4.48)	2.37	(2.10-2.68)	2.39	(1.98-2.87)	6.03	(2.71-13.40)	4.25	(2.36-7.68)	3.47	(1.27-9.45)	5.82	(2.90-11.67)
External causes	2.69	(2.53-2.86)	2.01	(1.89-2.14)	2.54	(2.32-2.79)	3.25	(2.92-3.63)	2.15	(1.98-2.34)	1.60	(1.23-2.09)	2.28	(1.82-2.86)	1.88	(1.27-2.78)	3.60	(2.87-4.52)
Other causes	1.94	(1.80-2.09)	1.85	(1.76-1.94)	2.06	(1.93-2.19)	2.34	(2.18-2.50)	2.06	(1.93-2.19)	1.94	(1.72-2.18)	2.00	(1.80-2.24)	1.87	(1.53-2.29)	1.73	(1.46-2.05)
Total mortality	2.20	(2.15-2.25)	1.79	(1.76-1.81)	1.96	(1.92-2.00)	1.87	(1.82-1.93)	1.97	(1.92-2.02)	1.80	(1.70-1.90)	1.70	(1.62-1.77)	1.65	(1.52-1.79)	1.77	(1.66-1.89)

Table 2 Relative index of inequality (RII) for selected causes of death by educational level, and corresponding 95% confidence intervals (CI), nine European populations, 30–74 years (continued)

	Finland		Sweden		Norway		Denmark		Belgium		Turin		Barcelona		Madrid		Basque Country	
Cause of death	RII	95%-CI	RII	95%-CI	RII	95%-CI	RII	95%-CI	RII	95%-CI	RII	95%-CI	RII	95%-CI	RII	95%-CI	RII	95%-CI
WOMEN																		
Cardiovascular diseases	2.41	(2.29-2.54)	2.47	(2.38-2.57)	2.56	(2.44-2.69)	2.71	(2.50-2.95)	2.56	(2.39-2.74)	1.81	(1.52-2.14)	2.02	(1.73-2.35)	2.42	(1.77-3.30)	2.14	(1.61-2.84)
Ischaemic heart disease	2.75	(2.56-2.96)	2.79	(2.64-2.96)	3.04	(2.82-3.27)	3.50	(3.07-3.99)	3.11	(2.75-3.51)	1.99	(1.43-2.78)	2.31	(1.73-3.09)	2.13	(1.19-3.83)	2.35	(1.35-4.11)
Cerebrovascular disease	2.08	(1.89-2.28)	2.06	(1.91-2.22)	2.02	(1.84-2.22)	2.11	(1.81-2.46)	2.05	(1.82-2.32)	1.42	(1.06-1.90)	1.67	(1.28-2.18)	2.36	(1.33-4.19)	2.20	(1.35-3.59)
Other circulatory diseases	2.08	(1.84-2.35)	2.36	(2.18-2.56)	2.42	(2.19-2.68)	2.43	(2.09-2.83)	2.56	(2.31-2.85)	2.08	(1.57-2.74)	2.13	(1.67-2.73)	2.66	(1.65-4.29)	1.95	(1.24-3.07)
Cancer	1.21	(1.15-1.27)	1.33	(1.28-1.37)	1.40	(1.34-1.47)	1.35	(1.28-1.42)	1.17	(1.10-1.23)	1.12	(0.99-1.27)	1.03	(0.93-1.15)	0.90	(0.74-1.09)	0.90	(0.76-1.06)
Stomach cancer	1.42	(1.14-1.77)	1.88	(1.56-2.26)	1.77	(1.41-2.23)	1.53	(1.01-2.32)	2.41	(1.72-3.39)	3.17	(1.49-6.77)	1.95	(1.12-3.38)	2.27	(0.92-5.59)	1.79	(0.78-4.07)
Lung cancer	1.87	(1.57-2.23)	1.86	(1.70-2.04)	2.93	(2.58-3.33)	2.42	(2.13-2.73)	1.63	(1.36-1.96)	0.74	(0.52-1.06)	0.48	(0.34-0.68)	0.34	(0.18-0.67)	0.33	(0.20-0.56)
Breast cancer	0.84	(0.75-0.93)	0.87	(0.81-0.94)	0.77	(0.69-0.86)	0.83	(0.74-0.94)	0.82	(0.74-0.91)	0.94	(0.73-1.21)	0.78	(0.63-0.96)	0.51	(0.35-0.74)	0.91	(0.64-1.29)
Other cancer	1.27	(1.19-1.35)	1.36	(1.31-1.42)	1.39	(1.31-1.47)	1.30	(1.20-1.39)	1.25	(1.17-1.34)	1.23	(1.04-1.45)	1.22	(1.07-1.40)	1.16	(0.90-1.49)	0.99	(0.80-1.22)
Infectious diseases	1.93	(1.41-2.66)	2.16	(1.70-2.74)	2.04	(1.52-2.72)	3.10	(1.91-5.04)	2.12	(1.54-2.92)	2.40	(0.69-8.37)	5.31	(3.18-8.86)	2.90	(1.27-6.65)	4.63	(2.42-8.87)
Respiratory diseases	3.06	(2.62-3.56)	2.61	(2.36-2.89)	3.00	(2.68-3.37)	3.51	(3.07-4.01)	3.05	(2.53-3.68)	1.95	(1.17-3.25)	1.40	(0.92-2.13)	2.85	(1.16-6.99)	1.59	(0.75-3.37)
Pneumonia	3.17	(2.60-3.85)	2.95	(2.44-3.56)	2.14	(1.78-2.57)	2.88	(1.96-4.23)	2.87	(2.07-3.98)	1.15	(0.50-2.65)	1.21	(0.57-2.55)	2.81	(0.64-12.39)	2.42	(0.58-10.11)
Other respiratory diseases	2.89	(2.26-3.69)	2.48	(2.20-2.80)	3.69	(3.19-4.28)	3.61	(3.13-4.16)	3.14	(2.50-3.94)	2.58	(1.34-4.96)	1.49	(0.90-2.48)	2.87	(0.93-8.87)	1.33	(0.56-3.20)
Alcohol-related causes	3.82	(3.18-4.60)	3.79	(3.08-4.67)	3.39	(2.56-4.49)	2.20	(1.78-2.72)	1.66	(1.26-2.19)	6.34	(1.40-28.76)	3.36	(0.98-11.56)	1.49	(0.28-8.00)	4.39	(1.02-18.96)
External causes	1.65	(1.48-1.84)	1.34	(1.22-1.47)	1.18	(1.02-1.37)	1.86	(1.58-2.18)	1.33	(1.18-1.52)	0.93	(0.63-1.38)	1.27	(0.88-1.83)	1.16	(0.58-2.34)	1.93	(1.19-3.13)
Other causes	2.08	(1.91-2.26)	2.45	(2.30-2.62)	2.05	(1.89-2.21)	2.27	(2.06-2.49)	2.13	(1.96-2.32)	1.57	(1.32-1.85)	2.23	(1.87-2.65)	1.95	(1.37-2.76)	2.34	(1.70-3.20)
Total mortality	1.84	(1.78-1.89)	1.84	(1.80-1.88)	1.92	(1.87-1.98)	1.91	(1.84-1.99)	1.73	(1.67-1.79)	1.40	(1.29-1.52)	1.51	(1.40-1.62)	1.40	(1.22-1.61)	1.44	(1.28-1.63)

ity. Among women, smaller or negative absolute inequalities in cancer mortality also contribute importantly to smaller absolute inequalities in mortality in Spain (Table A5 in appendix).

Analyses of survey data

Among men, inequalities in smoking are smaller in Spain than in most other populations (Figure 2) because of comparatively prevalent smoking among higher educated Spanish men (p-value < 0.0001 for the comparison between Spanish men and the rest of the countries), while among women, they are small or absent in Spain because higher educated Spanish women smoke more than the lower educated.

Similarly, the smaller inequalities in sedentary lifestyle in the Basque Country are due to the fact that the higher educated are less physically active (p-value < 0.0001). With regard to obesity, the inequalities are substantial in all countries (Figure 2).

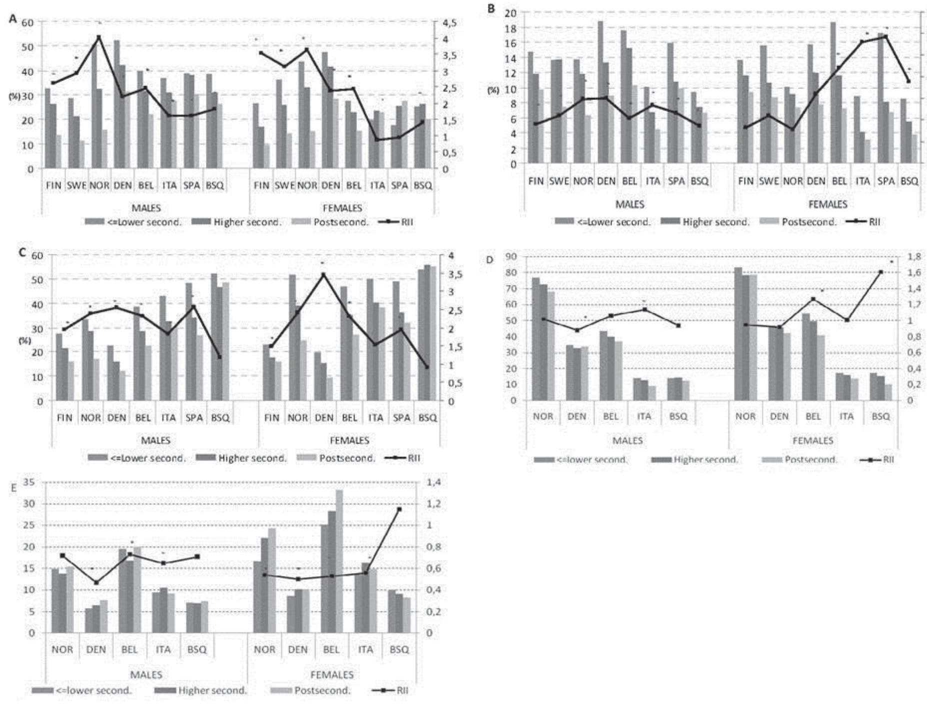

Figure 2 Age-adjusted prevalence and relative index of inequality of (A) current smoking, (B) obesity, (C) sedentary lifestyle, (D) visit to GP and (E) visit to specialist
Legend: FIN = Finland, SWE = Sweden, NOR = Norway, DEN = Denmark, BEL = Belgium, ITA = Italy, SPA = Spain, BSQ = Basque Country
* Statistically significant RII values (p<0.05)

After adjustment for self-assessed health, inequalities in health services utilization tended to favour the lower educated regarding visits to GP in most populations, including Spain. The opposite was observed for the use of specialized services, with the exception of the Basque Country.

DISCUSSION

Summary of findings

The Spanish populations have considerably smaller absolute inequalities in total mortality than other Western European populations. This is the result of both lower average levels of mortality and smaller relative inequalities in mortality. However, the analysis by cause of death reveals an important heterogeneity: smaller relative inequalities in total mortality in Spain are due mainly to comparatively small inequalities in mortality from CVD (men) and cancer (women). Inequalities in mortality from most other causes are not smaller in Spain than elsewhere, and inequalities in infectious disease mortality are even substantially larger.

Spain also has smaller inequalities in smoking and sedentary lifestyle, but not in health services utilization and its inequalities in obesity among women are larger than in the other populations. On the basis of these four determinants, one cannot therefore conclude that the exposure of lower socioeconomic groups to health risks is generally more favourable in Spain than elsewhere.

Limitations

Although education as a measure of socioeconomic position remains constant during adult life and old age [15, 16], reverse causation is less likely [17] and educational level is comparable across European countries when broader categories classified according to the ISCED are used [18], the impact of education on individual overall socioeconomic position may differ between countries.

The comparability of the mortality rates may be compromised by differences between countries in calendar year at start and duration of follow-up. While we adjusted our results for different follow-up periods, we could not correct them for different starting years. Since there were mostly earlier for Northern Europe, and since inequalities in mortality have been widening in these European countries [19], any bias due to differences in starting year would tend to lead any differences in the magnitude of mortality inequalities in Spain to be underestimated. Regarding the differences in length of follow-up, 'sensitivity analysis' (comparison of countries with similar length of follow-up) gives the same results. The data available on the prevalence of determinants and the mortality follow-up applied to the same period. Data that would allow proper time-lag to be incorporated between exposure and outcome in our analysis were not available. However, it is unlikely that the social patterning of these risk factors changes substantially within a 5- or 10-year period.

We cannot exclude that some of our cause-specific results are affected by inaccuracies such as differences in certification or coding of causes of death between countries and socioeconomic groups [20]. However, we believe that those results using broad cause-of-death categories are likely to be robust.

Differences in the magnitude of inequalities in mortality between Northern and Southern European populations may be biased by the fact that we compared national mortality data for Northern European countries with urban or regional mortality data in Southern European countries. Although Turin, Barcelona, Madrid and the Basque Country are relatively more prosperous than other regions in Italy and Spain, results show that inequalities in mortality in Turin, Barcelona and Madrid (where the share of the urban population is very large) are not greater than in the Basque Country (which contains only three medium-sized cities). In addition, on the basis of national mortality data during the 1980s, Kunst et al. [21] have shown smaller inequalities in mortality in Italy and Spain as a whole. Recently, Regidor et al. [22] reported small inequalities in mortality among older people in Spain. We therefore think that the comparatively small inequalities in mortality observed in Barcelona, Madrid and the Basque Country can be generalized to Spain as a whole.

Interpretation

The smaller educational inequalities in mortality observed in Spain are likely to be an effect of a later socioeconomic modernization of Spain than that of Northern Europe. The socioeconomic modernization refers to the historical process of large-scale socioeconomic changes in society, such as rising prosperity, industrialization, urbanization and expansion of mass education. This may have led to smaller educational inequalities in mortality in two ways.

The first is that, due to later socioeconomic modernization, educational attainment still may be less important as a social stratifier in Spain than in Northern Europe. During the 1990s, the proportion of low educated people was still about 70% in Spain, against only 30–50% in Northern Europe (Table A6 in appendix). Spain's very rapid economic development after the Franco dictatorship [23] may have created a mismatch between education and other status-attainment variables such as income and occupational class.

This is confirmed by a review of comparative studies which found weaker relationship between educational attainment and occupational class in Spain compared with Northern European countries [24, 25] and the Netherlands [26]. The health survey data also suggested a weaker relationship between educational level and income in the Basque Country than in several Northern European countries, particularly among men (Table A7 in appendix).

The second possible pathway is that later socioeconomic development has delayed the epidemiologic transition [27]. The transition from a mortality regime dominated by infectious diseases to one dominated by CVD and cancer occurred several decades later in Spain than in Northern Europe [28]. The small absolute inequalities in CVD mortality in Spain are partly because average rates of mortality from CVD, particularly IHD, have remained low, especially among men (Tables A2, A3 and A4 in appendix). While the increase in IHD mortality started many years later than in Northern Europe, the decline started only a few years later [29]. The decline in IHD mortality in Spain after 1975 has been ascribed to the decline in smoking (only among men) and to improvements in medical care (e.g., cardiovascular drugs and intensive care units) [29]. In other words, Spain already started to benefit from advances in knowledge about risk factors for IHD and advances in medical care before the epidemic could reach a higher peak.

That IHD mortality has never reached great heights in Spain is probably also due to the role of the Mediterranean diet with comparatively high consumption of wine, fish, fruits, vegetables and olive oil [30]. In view of the fact that partial adherence to the Mediterranean diet seems to explain the low average rates of mortality from IHD in Spain, it seems likely that adherence to this diet by lower socioeconomic groups also explains part of the smaller inequalities in IHD mortality and the low rates of IHD mortality among the high educated despite their high prevalence of smoking and physical inactivity. This is confirmed by a review of inequalities in diet in different European countries, which shows that the association between education and fruit and vegetable consumption is inconsistent in Spain (and clearly positive in Northern Europe), while the higher educated in Spain consume more animal fat and fewer vegetable oils than the lower educated [31]. Not all studies, however, reach the same conclusions [32, 33].

Another reason for the smaller relative inequalities in IHD mortality in Spain can probably also be found in the different timing of epidemiologic developments. Previous studies have concluded that Southern European countries tend to be at an earlier stage of the smoking epidemic, in which smoking is still more prevalent in upper socioeconomic groups, especially among older people and women [19].

Regarding cancer mortality, smaller absolute inequalities among women in the three Spanish populations were due partly to the strong reverse gradients for breast and lung cancer. Breast cancer is related to reproductive behaviour (a particularly high age at first pregnancy), and reverse gradients of breast cancer arise because higher educated women are the first to delay pregnancy to higher ages [34]. The stronger reverse gradient in Spain may be due to the fact that this aspect of modernization started later, too [34].

Spain had very large inequalities in mortality from infectious diseases, due mainly to AIDS. During the 1990s, large inequalities in AIDS mortality in Spain were driven by a combination of lower access and adherence to treatment and to unfavourable material conditions among vulnerable groups [35]. The introduction of highly active antiretroviral therapy (HAART) has contributed importantly to narrowing absolute inequalities in AIDS mortality in Spain [36].

CONCLUSION

Educational inequalities in cause-specific mortality and its determinants are not consistently smaller in Spain than in other Western European populations. Smaller absolute inequalities in total mortality in Spain reflect smaller absolute inequalities in mortality from CVD and cancer. On the other hand, Spain does not have smaller inequalities in mortality from many other causes of death, and as many of these relate to living conditions, our findings suggest that smaller inequalities in total mortality in Spain do not reflect a generally more favourable situation with regard to social inequality.

Smaller inequalities in mortality from CVD and cancer are likely to be due to Spain's later socioeconomic modernization. While the Spanish example shows that inequalities in total mortality are not inevitable, the favourable situation in terms of inequalities in mortality from CVD and cancer in this country seems to be a historical coincidence rather than the outcome of deliberate policies. Unfortunately, in view of the on-going changes in social-protection policies in Spain and the changing socioeconomic distribution of risk factors for mortality in the Spanish population [37], this favourable situation is also likely to be transitory.

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APPENDIX

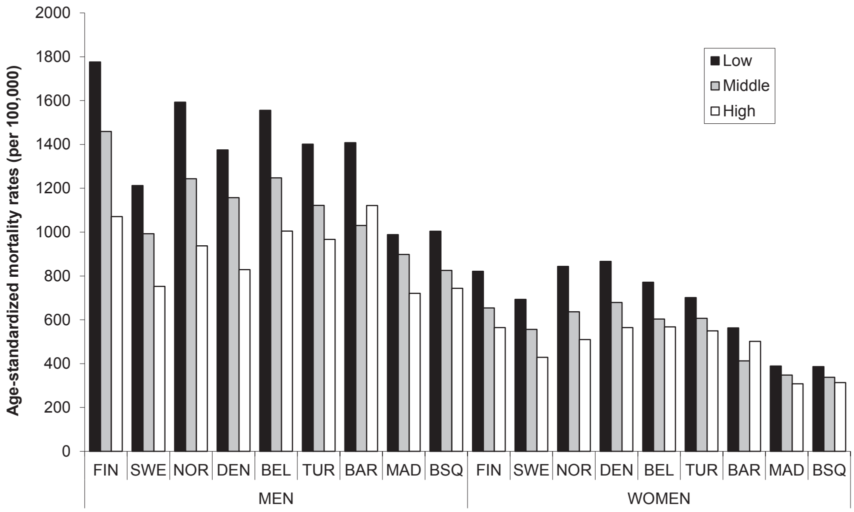


Figure A1 Age-standardized mortality rates (per 100,000 person-years) according to educational level, 30–74 years
Legend: FIN = Finland, SWE = Sweden, NOR = Norway, DEN = Denmark, BEL = Belgium, TUR = Turin, BAR = Barcelona, MAD = Madrid, BSQ = Basque Country

Table A1 ICD codes of causes of death selected for the analysis

Cause of death	ICD-9 codes	ICD-10 codes
Cardiovascular diseases	390–459	I00–I99
Ischaemic heart disease	410–414	I20–I25
Cerebrovascular disease	430–438	I60–I69
Other circulatory diseases	Rest (390–459)	Rest (I00–I99)
Cancer	140–239	C00–D48
Stomach cancer	151	C16
Lung cancer	162–163, 165	C33–C34, C39
Breast cancer	174–175	C50
Other cancer	Rest (140–239)	Rest (C00–D48)
Infectious diseases	001–139	A00–B99
Respiratory diseases	480–487, 490–494, 496	J10–J18, J40–J47
Pneumonia	480–487	J10–J18
Other respiratory diseases	490–494, 496	J40–J47
Alcohol-related causes	291,303,305.0,425.5, 571.0–571.3, 577.0–577.1, E860	F10, I42.6, K70, K85–K86.0, X45
External causes	E800–E999 (except E860)	V01–Y98 (except X45)
Other causes	Rest (001–E999)	Rest (A00–Y98)

Table A2 Age-standardized mortality rates (per 100,000), low education, 30–74 years

Cause of death	Finland	Sweden	Norway	Denmark	Belgium	Turin	Barcelona	Madrid	Basque
MEN									
Cardiovascular diseases	784.8	544.8	680.3	419.7	497.2	418.0	373.3	254.4	254.5
Ischaemic heart disease	537.5	346.5	427.8	232.9	214.0	169.4	166.3	105.7	108.5
Cerebrovascular disease	139.5	88.1	114.2	76.2	98.2	100.1	89.3	48.7	58.7
Other circulatory diseases	107.9	110.2	138.3	110.6	185.0	148.5	117.8	100.0	87.4
Cancer	425.5	341.9	456.4	420.7	537.7	520.0	579.8	411.5	418.5
Stomach cancer	29.3	18.8	30.1	14.3	24.6	30.3	33.5	29.0	32.5
Lung cancer	144.0	72.5	126.6	129.4	221.1	182.3	181.4	121.8	111.0
Other cancer	252.2	250.5	299.7	276.9	292.0	307.4	364.9	260.7	274.9
Infectious diseases	12.1	9.1	11.8	14.1	16.8	6.8	63.2	41.7	40.6
Respiratory diseases	123.5	56.1	104.5	101.6	132.6	58.5	91.7	70.8	55.8
Pneumonia	59.8	20.9	33.4	15.2	29.1	13.7	17.5	19.1	8.1
Other respiratory diseases	63.7	35.2	71.2	86.5	103.5	44.9	74.2	51.7	47.8
Alcohol-related causes	97.2	38.3	48.8	71.7	23.2	10.5	10.3	7.3	11.9
External causes	184.2	89.0	95.7	101.5	103.4	57.0	53.7	36.2	77.2
Other causes	148.9	132.9	195.1	245.7	244.9	330.6	235.7	166.2	145.8
Total mortality	1,776.2	1,212.3	1,592.6	1,374.9	1,555.7	1,401.5	1,407.7	988.2	1,004.3

Table A2 Age-standardized mortality rates (per 100,000), low education, 30–74 years (continued)

Cause of death	Finland	Sweden	Norway	Denmark	Belgium	Turin	Barcelona	Madrid	Basque
WOMEN									
Cardiovascular diseases	329.8	239.7	295.9	201.6	262.0	197.4	155.1	107.3	96.4
Ischaemic heart disease	183.9	120.2	149.4	89.9	86.6	55.3	46.0	29.5	27.0
Cerebrovascular disease	92.4	60.1	77.2	53.4	70.2	62.9	47.4	30.8	31.5
Other circulatory diseases	53.4	59.5	69.4	58.2	105.2	79.3	61.8	47.1	37.9
Cancer	248.2	271.0	316.4	352.2	262.1	267.0	230.6	164.1	164.8
Stomach cancer	13.2	9.9	13.3	6.4	9.5	12.3	11.3	11.6	9.5
Lung cancer	24.4	40.5	55.1	86.2	26.0	29.3	15.3	9.4	10.6
Breast cancer	44.6	43.0	47.0	63.1	63.0	59.6	51.4	32.1	34.5
Other cancer	165.9	177.6	201.1	196.5	163.5	165.8	152.6	110.8	110.2
Infectious diseases	7.6	6.5	8.6	5.9	9.7	3.8	15.6	11.8	11.9
Respiratory diseases	41.7	38.3	63.0	89.4	35.7	22.5	17.6	13.9	12.1
Pneumonia	26.3	11.6	20.1	9.7	11.8	6.6	5.2	5.1	3.6
Other respiratory diseases	15.5	26.7	43.0	79.8	23.9	15.9	12.5	8.8	8.5
Alcohol-related causes	23.0	10.3	13.0	25.5	10.0	3.6	2.7	2.6	3.7
External causes	53.5	34.8	30.7	42.0	43.8	24.2	18.5	12.5	19.4
Other causes	117.6	92.2	116.0	150.0	148.2	182.3	123.2	76.7	78.0
Total mortality	821.3	692.9	843.6	866.6	771.5	701.0	563.3	389.0	386.3

Table A3 Age-standardized mortality rates (per 100,000), middle education, 30–74 years

Cause of death	Finland	Sweden	Norway	Denmark	Belgium	Turin	Barcelona	Madrid	Basque
MEN									
Cardiovascular diseases	641.5	424.1	522.2	360.5	421.1	369.3	302.1	253.8	229.5
Ischaemic heart disease	437.8	259.8	321.0	193.3	183.8	152.8	139.9	111.7	102.9
Cerebrovascular disease	118.4	73.4	92.9	68.0	85.6	81.8	61.7	46.9	48.9
Other circulatory diseases	85.3	90.8	108.3	99.1	151.6	134.6	100.5	95.2	77.7
Cancer	364.0	315.1	394.9	411.3	445.9	405.7	437.3	403.6	355.7
Stomach cancer	22.1	15.8	22.4	11.1	15.1	17.4	14.7	23.5	15.7
Lung cancer	103.4	61.6	90.1	119.1	148.5	124.3	134.3	118.0	88.7
Other cancer	238.4	237.7	282.4	281.1	282.3	263.9	288.2	262.1	251.3
Infectious diseases	11.9	7.3	9.3	7.5	15.1	4.0	37.5	19.5	19.9
Respiratory diseases	82.4	42.0	70.0	70.9	78.5	37.7	48.1	48.0	39.3
Pneumonia	41.4	15.0	23.4	10.0	20.0	8.8	11.3	12.5	6.1
Other respiratory diseases	41.0	27.0	46.7	61.0	58.5	28.8	36.9	35.5	33.2
Alcohol-related causes	78.1	26.0	31.7	59.7	18.7	5.1	4.3	6.8	6.1
External causes	148.9	71.8	66.9	65.0	80.0	49.1	37.3	25.7	50.5
Other causes	132.5	106.5	148.6	182.5	188.5	251.5	163.8	140.6	124.4
Total mortality	1,459.3	992.7	1,243.5	1,157.4	1,247.7	1,122.3	1,030.4	898.0	825.4

Table A3 Age-standardized mortality rates (per 100,000), middle education, 30–74 years (continued)

Cause of death	Finland	Sweden	Norway	Denmark	Belgium	Turin	Barcelona	Madrid	Basque
WOMEN									
Cardiovascular diseases	242.2	174.5	201.4	139.1	175.1	154.7	98.3	71.9	68.7
Ischaemic heart disease	131.8	84.3	94.2	56.3	50.4	41.3	27.3	26.8	21.4
Cerebrovascular disease	70.3	47.2	58.2	41.0	52.9	54.2	30.1	17.7	25.5
Other circulatory diseases	40.1	42.9	48.9	41.8	71.8	59.1	40.9	27.4	21.9
Cancer	229.2	246.9	268.7	317.4	246.3	257.4	193.7	186.5	178.6
Stomach cancer	12.2	7.6	9.6	5.7	6.0	6.4	4.7	6.3	9.5
Lung cancer	18.6	35.1	35.1	65.5	22.6	33.4	22.8	18.8	16.2
Breast cancer	44.9	44.2	50.0	66.5	70.0	63.2	45.4	43.2	37.4
Other cancer	153.4	160.0	173.9	179.8	147.7	154.5	120.9	118.1	115.5
Infectious diseases	6.5	4.6	6.4	4.1	6.3	3.2	9.7	9.3	6.6
Respiratory diseases	28.9	27.6	38.4	60.1	22.6	17.4	13.6	10.0	13.5
Pneumonia	17.7	7.1	13.7	6.2	6.5	6.3	5.2	3.6	3.7
Other respiratory diseases	11.2	20.5	24.7	53.9	16.2	11.1	8.4	6.3	9.8
Alcohol-related causes	14.0	7.0	8.4	21.8	9.1	1.9	0.8	3.1	3.1
External causes	45.7	31.0	26.7	29.2	36.4	22.7	17.7	9.9	14.3
Other causes	87.6	64.9	86.7	107.6	107.5	149.3	78.8	57.1	53.3
Total mortality	654.0	556.5	636.8	679.3	603.4	606.7	412.7	347.7	338.0

Table A4 Age-standardized mortality rates (per 100,000), high education, 30–74 years

Cause of death	Finland	Sweden	Norway	Denmark	Belgium	Turin	Barcelona	Madrid	Basque
MEN									
Cardiovascular diseases	472.0	313.2	368.8	253.9	340.6	310.0	346.0	227.4	228.7
Ischaemic heart disease	310.4	188.3	220.9	129.0	147.8	120.9	158.1	101.1	97.9
Cerebrovascular disease	92.1	55.5	68.8	51.1	67.1	63.4	73.6	43.0	61.7
Other circulatory diseases	69.5	69.4	79.2	73.8	125.7	125.6	114.3	83.3	69.1
Cancer	306.9	267.8	338.9	319.2	363.4	349.3	481.0	298.5	319.4
Stomach cancer	17.5	11.0	19.6	8.6	12.1	9.9	17.4	16.4	14.9
Lung cancer	63.2	41.4	61.3	70.6	104.2	101.1	137.1	89.4	84.3
Other cancer	226.2	215.5	258.0	240.0	247.1	238.3	326.5	192.8	220.2
Infectious diseases	8.1	5.7	8.1	7.1	13.8	3.7	32.0	19.4	13.7
Respiratory diseases	48.3	24.9	44.1	34.7	51.5	32.1	49.7	29.7	31.1
Pneumonia	25.8	10.4	18.4	8.6	14.3	13.4	15.1	10.2	7.2
Other respiratory diseases	22.4	14.5	25.7	26.1	37.2	18.7	34.6	19.5	23.9
Alcohol-related causes	41.3	10.7	16.6	34.6	12.7	3.6	5.3	2.5	4.0
External causes	92.3	50.0	48.7	46.6	63.4	38.9	35.7	27.2	36.8
Other causes	102.2	80.3	111.8	132.3	159.6	229.2	171.8	115.9	109.8
Total mortality	1,071.0	752.6	936.9	828.4	1,005.0	966.8	1,121.6	720.6	743.5

Table A4 Age-standardized mortality rates (per 100,000), high education, 30–74 years (continued)

Cause of death	Finland	Sweden	Norway	Denmark	Belgium	Turin	Barcelona	Madrid	Basque
WOMEN									
Cardiovascular diseases	183.5	114.8	135.9	102.7	153.7	134.4	121.6	65.9	61.4
Ischaemic heart disease	90.4	51.0	62.1	38.1	48.7	35.2	33.7	14.3	15.3
Cerebrovascular disease	57.9	32.6	43.1	32.1	45.5	52.2	42.2	22.7	15.8
Other circulatory diseases	35.2	31.2	30.6	32.5	59.5	47.0	45.7	28.9	30.4
Cancer	224.1	214.9	247.0	287.3	242.6	236.5	250.3	157.1	170.7
Stomach cancer	9.8	6.3	9.8	4.7	6.0	7.3	10.7	9.2	4.2
Lung cancer	17.3	21.9	23.1	45.4	19.0	35.2	23.0	13.1	21.6
Breast cancer	53.1	48.4	58.7	71.6	70.9	56.5	64.9	48.7	36.3
Other cancer	143.9	138.3	155.4	165.7	146.7	137.5	151.7	86.1	108.6
Infectious diseases	4.3	3.8	4.3	2.6	7.2	0.4	7.2	6.4	6.9
Respiratory diseases	20.5	17.1	26.3	33.0	19.1	12.7	16.4	7.3	7.1
Pneumonia	13.3	6.0	12.9	5.5	7.7	6.4	4.4	3.4	1.8
Other respiratory diseases	7.2	11.1	12.4	27.4	11.5	6.3	11.9	3.9	5.3
Alcohol-related causes	11.3	3.6	4.6	14.4	7.2	1.2	2.6	0.6	1.7
External causes	41.2	26.9	27.2	32.6	40.2	25.3	15.7	11.9	11.4
Other causes	79.7	47.5	64.5	92.0	97.7	138.9	87.7	59.3	54.5
Total mortality	564.7	428.5	509.6	564.6	567.7	549.4	501.5	308.4	313.8

Table A5 Slope index of inequality according to cause of death (per 100,000), nine European populations, average age at death 30–74 years

Cause of death	Finland	Sweden	Norway	Denmark	Belgium	Turin	Barcelona	Madrid	Basque
MEN									
Cardiovascular diseases	525.5	313.5	402.3	213.2	260.2	162.6	89.5	44.7	54.5
Ischaemic heart disease	375.6	217.5	269.0	135.6	109.4	68.5	30.7	3.0	18.6
Cerebrovascular disease	80.1	42.5	57.1	31.5	48.9	56.1	40.8	8.5	4.9
Other circulatory diseases	69.7	53.5	76.1	45.8	102.0	38.7	18.7	33.5	31.5
Cancer	201.1	88.2	152.8	111.1	289.9	293.5	234.4	162.7	177.3
Stomach cancer	20.2	9.9	15.4	8.5	23.0	33.7	34.6	21.3	35.3
Lung cancer	135.4	37.3	85.3	66.8	203.4	142.6	94.3	48.6	49.2
Other cancer	48.2	41.3	50.8	35.9	64.3	116.7	105.1	92.6	93.6
Infectious diseases	6.3	4.3	4.4	11.0	4.1	6.3	57.5	44.9	45.5
Respiratory diseases	129.2	40.2	81.2	87.6	147.7	50.8	90.7	73.9	46.1
Pneumonia	59.1	14.5	21.7	10.5	26.6	6.3	8.8	17.1	2.9
Other respiratory diseases	70.3	25.8	59.2	77.1	120.5	44.6	81.7	57.0	43.5
Alcohol-related causes	80.3	33.3	38.8	48.0	16.7	12.2	10.2	7.0	14.1
External causes	140.6	50.5	62.1	79.7	67.1	24.6	35.5	19.9	71.1
Other causes	86.0	68.2	109.4	161.0	156.2	194.7	143.4	94.0	73.4
Total mortality	1,191.3	602.3	859.3	726.3	942.0	746.5	670.2	456.1	524.2

Table A5 Slope index of inequality according to cause of death (per 100,000), nine European populations, average age at death 30–74 years (continued)

Cause of death	Finland	Sweden	Norway	Denmark	Belgium	Turin	Barcelona	Madrid	Basque
WOMEN									
Cardiovascular diseases	248.5	174.8	214.9	161.1	215.7	109.2	100.1	85.3	67.9
Ischaemic heart disease	155.9	96.6	121.1	84.6	82.6	35.2	34.8	20.6	21.1
Cerebrovascular disease	59.5	36.6	45.0	34.0	46.0	21.3	23.0	23.8	22.9
Other circulatory diseases	34.0	41.4	48.3	42.4	87.0	52.9	42.5	40.8	23.9
Cancer	45.2	71.4	95.4	98.4	39.4	29.9	7.2	-18.1	-17.4
Stomach cancer	4.4	5.2	6.4	2.5	7.4	11.9	7.0	8.5	5.3
Lung cancer	13.5	21.2	41.1	61.8	11.8	-8.8	-11.6	-10.3	-11.7
Breast cancer	-7.9	-6.0	-13.0	-11.8	-12.4	-3.9	-12.9	-22.5	-3.2
Other cancer	37.6	51.1	60.0	48.1	35.8	33.4	30.0	16.1	-1.5
Infectious diseases	4.4	4.0	4.9	4.9	6.5	3.0	17.5	10.5	12.5
Respiratory diseases	36.9	28.4	49.2	83.5	33.4	14.0	5.7	12.7	5.4
Pneumonia	23.7	9.2	12.4	7.8	10.7	0.9	1.0	4.6	2.8
Other respiratory diseases	13.2	19.1	36.9	75.8	22.7	13.4	4.8	8.1	2.4
Alcohol-related causes	19.7	8.5	9.5	16.2	4.7	4.6	2.5	1.1	4.2
External causes	22.9	8.9	4.7	21.3	12.0	-1.8	4.2	1.9	11.6
Other causes	73.7	64.1	67.1	99.8	100.8	77.4	89.2	47.3	59.6
Total mortality	443.7	362.5	456.0	484.4	394.9	228.0	221.1	127.1	137.2

Table A6 Educational distribution (in %), mortality data, 30–74 years

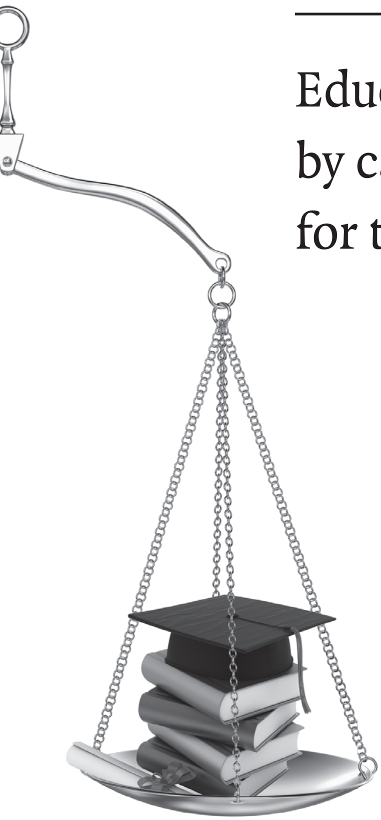
Country	Educational level		
	Lower secondary and less	Upper secondary	Tertiary
Finland	50.1	29.3	20.6
Sweden	40.6	41.7	17.7
Norway	33.1	47.7	19.2
Denmark	45.1	34.9	20.0
Belgium	64.4	20.3	15.3
Italy (Turin)	71.5	19.8	8.6
Spain (Barcelona)	71.5	12.1	16.4
Spain (Madrid)	70.4	14.8	14.9
Spain (Basque)	70.9	16.2	12.9

Table A7 Prevalence ratios of being in the lowest income quintiles (4-5) by educational level in the population over 50 years

Country	Education	Men		Women	
		Prevalence ratio	95%-CI	Prevalence ratio	95%-CI
Norway	low	4.81	(3.57-6.47)	3.36	(2.65-4.25)
	middle	2.77	(2.05-3.75)	2.04	(1.60-2.61)
	high	1		1	
Sweden	low	3.43	(2.74-4.29)	3.91	(3.19-4.79)
	middle	1.80	(1.42-2.29)	2.24	(1.81-2.78)
	high	1		1	
Denmark	low	2.80	(2.50-3.14)	2.73	(2.47-3.02)
	middle	1.93	(1.71-2.18)	1.77	(1.57-2.00)
	high	1		1	
Belgium	low	2.26	(1.98-2.58)	2.07	(1.80-2.38)
	middle	1.48	(1.26-1.73)	1.46	(1.24-1.71)
	high	1		1	
Basque Country	low	2.06	(1.69-2.53)	2.34	(1.47-3.72)
	middle	1.18	(0.89-1.56)	0.90	(0.41-1.99)
	high	1		1	

4

Educational inequalities in mortality by cause of death: first national data for the Netherlands



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ABSTRACT

Objectives

Using new facilities for linking large databases, we aimed to evaluate for the first time the magnitude of relative and absolute educational inequalities in mortality by sex and cause of death in the Netherlands.

Methods

We analysed data from Dutch Labour Force Surveys (1998–2002) with mortality follow-up 1998–2007 among people aged 30–79 years. We calculated hazard ratios using Cox proportional hazards model, age-standardized mortality rates and partial life expectancy by education. We compared results for the Netherlands with those for other European countries.

Results

The relative risk of dying was about two times higher among primary educated men and women as compared to their tertiary educated counterparts, leading to a gap in partial life expectancy of 3.4 years (men) and 2.4 years (women). Inequalities in mortality are similar to those in other countries in North-Western Europe, but inequalities in lung cancer mortality are substantially larger in the Netherlands, particularly among men.

Conclusions

The Netherlands has large inequalities in mortality, especially for smoking-related causes of death. These large inequalities require the urgent attention of policy makers.

INTRODUCTION

Socioeconomic inequalities in total and cause-specific mortality have been reported from most European countries [1, 2], but until recently these data were not available for the Netherlands, due to deficiencies in the national data collection system [3]. The Netherlands has a strong tradition of research into socioeconomic inequalities in health but this is mainly built on national self-reported data [4, 5], regional mortality data from specific cohorts such as the GLOBE [6, 7] and MORGEN studies [8, 9], or ecological studies [10, 11]. Although these studies have clearly demonstrated that socioeconomic inequalities in mortality are present in the Netherlands, it is so far unclear whether the magnitude and cause-specific patterning of these inequalities are similar or different from those in other North-Western European countries, partly because these studies are not directly comparable to similar studies in other countries.

Studies of mortality by socioeconomic position have found substantial differences in the magnitude of inequalities between European populations [1, 2]. Broadly speaking, three geographical areas, each with their own 'regime' of socioeconomic inequalities in cause-specific mortality and related risk factors, can be distinguished. North-Western Europe (e.g., the Scandinavian countries, England and Wales, Belgium) is characterized by large inequalities in mortality from cardiovascular diseases and cancer, and from conditions due to smoking and alcohol consumption, and by small inequalities in mortality from conditions amenable to health care. Southern Europe (i.e., Spain and Italy) is characterized by small inequalities in mortality from cardiovascular diseases and cancer (women only), from conditions due to smoking and alcohol consumption (women only), and from conditions amenable to health care. Finally, Central and Eastern Europe (e.g., Czech Republic, Hungary, Baltic states) is characterized by huge inequalities in mortality from cardiovascular diseases, cancer (men only), and injury, from conditions due to smoking (men only) and alcohol consumption, and from conditions amenable to health care [2, 12, 13].

The aim of this study was to quantify inequalities in total and cause-specific mortality by education in the Netherlands, in order to compare the Netherlands with other European countries, and in order to identify entry-points for tackling inequalities in mortality. We focused on education as a measure of socioeconomic status (instead of, e.g., income or occupational class) because it is the most stable measure and has several advantages over other measures of socioeconomic status. Education is easy to measure, is easily reported and is relevant for both men and women regardless of their employment conditions. It is completed in early adulthood; therefore, contrary to other socioeconomic indicators, reverse causality (ill-health leading to low socioeconomic position, instead of vice versa) is unlikely to happen, except for major mental disorders, and education avoids the problem of health-related social mobility later in life [14, 15]. Education is closely linked to mortality. An increasing body of the literature suggests that a large part of this association is causal [16, 17]. Education captures the knowledge-related assets of a person. Higher education can be interpreted as a better ability to understand and follow health prevention messages, to use the health care system and to modify his/her behaviour. In addition, education is partly determined by childhood socioeconomic circumstances, it is associated with a lower probability of unemployment, better working conditions and higher income [14, 18].

METHODS

Study population

To estimate socioeconomic inequalities in mortality, we linked death records to a large national survey containing information on education level, i.e., the Dutch Labour Force Survey (LFS). The Dutch LFS is a household survey carried out by Statistics Netherlands since 1987. Its representative sample of the Dutch population is drawn from the population administrations of Dutch municipalities. The target population consists of persons 15 years and older excluding people living in institutions. Although the main objective of the Dutch LFS is to collect statistics about the employment status of persons and households, it also covers persons 65 years and older. The information is gathered by means of a face-to-face or phone interview and checked for internal inconsistencies. The response rate fluctuates around 60% over the years [19]. An under- or over-representation of certain population groups in the response rate is corrected through weighting. Mortality data classified by sex, age and underlying cause of death were obtained from the death records collected by Statistics Netherlands. These death records were available for the years 1998–2007.

Statistics Netherlands assigns an encoded personal number to all death records and all respondents to the Dutch LFS which is unique to each person and identifies that person in the population register, and we used this to assess the survival status and cause of death of respondents to the Dutch LFS. Five baseline years of the Dutch LFS (1998–2002) were available for the linkage with the death records. We selected people at age 30 years and older at baseline and followed them 6 years from each baseline year (i.e., we followed the people included in the death registries for 1998–2003, 1999–2004, 2000–2005, 2001–2006 and 2002–2007). The individuals who died beyond the follow-up time for each baseline year were treated as alive.

Measures

Socioeconomic status was measured by the highest completed educational level. For the sake of comparability with data from other countries (see below), we recoded the Dutch educational level into four categories according to the International Standard Classification of Education (ISCED): primary education (ISCED 0, 1), lower secondary education (ISCED 2), upper secondary education (ISCED 3, 4), and tertiary education (ISCED 5, 6). The Netherlands' educational profile is on average comparable with that in other North-Western European countries for both men and women. However, 60–79-year old men in the Netherlands are less often low educated than men of the same age in other North-Western European countries. Dutch women are more often low educated at younger ages (30–59 years) than their counterparts in the Nordic countries.

We investigated total as well as cause-specific mortality. The causes of death were classified according to the 10th revision of the International Classification of Diseases. We analysed five broader causes of death: cardiovascular diseases (CVD) (I00–I99), cancer (C00–D48), respiratory diseases (J00–J06, J10–J18, J20–J22, J40–J47), other diseases (rest of A00–R99), and external causes (V01–Y98). Specific causes of death were selected on the basis of their relative importance and a sufficient number of deaths: ischaemic heart disease (IHD) (I20–I25), cerebrovascular disease (I60–I69), other cardiovascular diseases (rest of I00–I99), colorectal cancer (C18–C21), lung cancer (C33–C34), female breast cancer (C50), prostate cancer (C61), and other neoplasms (rest of C00–D48).

Statistical analysis

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. All analyses were conducted separately for men and women using the statistical package STATA version 11.0. Individuals with unknown educational level were excluded from the analysis (1.6%). After the exclusion of persons who did not fulfil our criteria, the dataset includes 332,869 individuals (164,507 men; 168,362 women), and 9,875 deaths (6,079 men; 3,796 women) in 1,802,289 person-years (889,511 men; 912,778 women). More detailed characteristics of the dataset can be obtained from Table A1 in appendix. This represents approximately 2% of the Dutch population, and about 1% of all deaths occurring in these six years.

As a measure of absolute inequality, we calculated age-standardized mortality rates (ASMR) by educational level by means of direct standardization using the European Standard Population. Relative inequalities were calculated using the Cox proportional hazards model with cause-specific baseline hazard. We treated risks of dying of particular causes of death as independent and applied standard Cox proportional hazards models without taking into account competing risks [20].

$$h(t)=h_0(t)\exp\left(\sum_{k=1}^{p}\beta_k x_k\right)$$

where $h(t)$ is the expected hazard at time t, $h_0(t)$ is the baseline hazard, β is the regression coefficient of an explanatory variable x and k is the number of the explanatory variables. Age was used as time variable. The cause-specific hazard rates are assumed to be proportional translating to covariate effects that are constant over time.

As a summary measure, we calculated population attributable fractions (PAF) and partial life expectancies between ages 30 and 79 years according to educational level. The PAF quantifies the proportion of all deaths in the population that would not occur if everyone had the mortality of the high educated [21].

$$PAF=\frac{\sum_{i=1}^{n} P_i(RR_i-1)}{\sum_{i=1}^{n} P_i(RR_i-1)+1}$$

where P_i is the prevalence and RR_i is the relative risk of each educational level i. The partial life expectancies were calculated by the following formula proposed by Arriaga [22] using functions of the life tables.

$${}_ie_x=\frac{T_x-T_{x+i}}{l_x}$$

where ${}_ie_x$ is the partial life expectancy between exact ages x and $x+i$, T_x and T_{x+i} are the numbers of person-years lived after exact ages x and $x+i$, and l_x is the number of person-years surviving to the exact age x. We constructed abridged life tables for the exact ages between 30 and 79 years according to the standard life table technique [23] using the age- and education-specific death rates. In addition, we applied the method of life expectancy decomposition [22] in order to obtain age- and cause-specific contributions to the difference in partial life expectancy between primary and tertiary educated individuals.

Comparison with other European countries

We compared absolute inequalities in mortality in the Netherlands with those in other European countries using data from the EURO-GBD-SE study [24]. In this study, cause-specific mortality data by education from 21 European populations were collected and harmonized. In this harmonization process we compared all variables available in the national studies, identified similarities and dissimilarities in their operationalization and constructed common variables that could be measured with the data available from different countries. We calculated ASMRs by sex, education and cause of death (total mortality, CVD, cancer and external causes) and rate differences between less than secondary and tertiary educated for each country. Countries were grouped by geographical region: North-West (Finland, Sweden, Norway, Denmark, England and Wales, Belgium, France, Switzerland, Austria), South (Barcelona, Basque Country, Madrid, Turin, Tuscany), and Central/East (Hungary, Czech Republic, Poland, Estonia). For the sake of comparability across European countries, we grouped primary and lower secondary educated men and women together in all countries investigated.

RESULTS

Relative inequalities in total mortality show a clear gradient of increasing mortality with decreasing level of education (Table 1). Primary educated men and women had a risk of dying twice as high as their tertiary educated counterparts. Mortality also decreased with increasing educational level for most causes of death, and in most cases, the 95% confidence intervals (CI) of the hazard ratio (HR) for the primary educated did not include one. The main exceptions were colorectal and prostate cancer among men, and colorectal cancer, breast cancer and external causes of death among women, for which no clear educational differences in mortality were found. On the other hand, relative inequalities in mortality were very large for respiratory diseases: the risk of dying from respiratory diseases was about five times higher among primary educated men (HR = 4.85; CI: 3.21–7.32) and women (HR = 5.07; CI: 2.33–11.05) than among their tertiary educated counterparts. For CVD and lung cancer, relative inequalities were also large, both among men and women.

Absolute inequalities in mortality are presented in Table 2. The absolute differences in ASMR between primary and tertiary educated were particularly large for CVD and cancer among both men and women and for lung cancer among men. Although relative inequalities in mortality are higher among women than among men for many causes of death, such as CVD, IHD and lung cancer (Table 1), absolute inequalities are usually lower among women. It is interesting to note that the ASMR of tertiary educated men (547.1 per 100,000 person-years) is in-between that of primary educated (663.4) and lower secondary educated women (455.2), and that mortality among primary educated men (1,094.3) is more than three times higher than that among tertiary educated women (342.0).

Table 1 Hazard ratios (HR), 95% confidence intervals (95% CI) and number of deaths (D) for total and cause-specific mortality (reference category = tertiary education), men and women, 30–79 years, the Netherlands, 1998–2007

Causes of death	Education											
	Primary[a]			Lower secondary[b]			Upper secondary[c]			Tertiary[d]		
	HR	95%-CI	D	HR	95%-CI	D	HR	95%-CI	D	HR	95%-CI	D
MEN												
All-cause mortality	1.98	(1.81–2.15)	1,163	1.65	(1.52–1.78)	1,814	1.32	(1.22–1.43)	2,153	1	-	949
Cardiovascular diseases	2.34	(1.99–2.74)	379	1.97	(1.70–2.29)	599	1.52	(1.32–1.76)	671	1	-	255
Ischaemic heart disease	2.24	(1.77–2.84)	165	2.03	(1.63–2.52)	277	1.53	(1.24–1.90)	310	1	-	118
Cerebrovascular disease	2.51	(1.67–3.77)	63	2.11	(1.45–3.08)	100	1.95	(1.35–2.81)	127	1	-	37
Other cardiovascular diseases	2.38	(1.85–3.07)	151	1.87	(1.47–2.37)	222	1.35	(1.07–1.71)	234	1	-	100
Cancer	1.60	(1.39–1.83)	418	1.52	(1.35–1.71)	731	1.29	(1.15–1.45)	924	1	-	417
Lung cancer	2.83	(2.20–3.63)	174	2.38	(1.88–3.00)	268	1.69	(1.34–2.12)	282	1	-	97
Colorectal cancer	0.75	(0.49–1.15)	31	0.80	(0.57–1.14)	61	0.87	(0.63–1.18)	98	1	-	66
Prostate cancer	1.47	(0.87–2.48)	29	1.72	(1.09–2.70)	63	1.28	(0.82–2.02)	63	1	-	27
Other neoplasms	1.34	(1.10–1.63)	184	1.34	(1.13–1.59)	338	1.26	(1.07–1.47)	481	1	-	225
Respiratory diseases	4.85	(3.21–7.32)	103	3.09	(2.06–4.63)	125	1.79	(1.18–2.72)	94	1	-	29
Other diseases	1.85	(1.52–2.25)	215	1.26	(1.05–1.51)	274	1.13	(0.95–1.35)	372	1	-	193
External causes of death	2.10	(1.43–3.09)	51	1.69	(1.20–2.37)	85	1.03	(0.74–1.45)	92	1	-	55

Table 1 Hazard ratios (HR), 95% confidence intervals (95% CI) and number of deaths (D) for total and cause-specific mortality (reference category = tertiary education), men and women, 30–79 years, the Netherlands, 1998–2007 (continued)

Causes of death	Education											
	Primary[a]			Lower secondary[b]			Upper secondary[c]			Tertiary[d]		
	HR	95%-CI	D	HR	95%-CI	D	HR	95%-CI	D	HR	95%-CI	D
WOMEN												
All-cause mortality	2.03	(1.79–2.30)	1,122	1.39	(1.23–1.56)	1,425	1.17	(1.03–1.33)	914	1	-	335
Cardiovascular diseases	3.20	(2.40–4.27)	356	1.92	(1.44–2.55)	382	1.47	(1.09–1.98)	200	1	-	55
Ischaemic heart disease	4.06	(2.44–6.76)	140	2.14	(1.28–3.55)	132	1.67	(0.98–2.83)	70	1	-	17
Cerebrovascular disease	2.32	(1.36–3.95)	79	1.63	(0.97–2.74)	99	1.25	(0.72–2.15)	52	1	-	17
Other cardiovascular diseases	3.21	(2.02–5.12)	137	1.98	(1.25–3.14)	151	1.49	(0.92–2.41)	78	1	-	21
Cancer	1.61	(1.36–1.92)	449	1.25	(1.06–1.47)	663	1.13	(0.96–1.34)	485	1	-	190
Lung cancer	3.33	(2.11–5.26)	107	1.92	(1.22–3.01)	119	1.86	(1.18–2.94)	95	1	-	23
Colorectal cancer	1.67	(0.89–3.14)	41	1.56	(0.86–2.83)	70	1.12	(0.59–2.11)	35	1	-	13
Breast cancer	1.12	(0.81–1.55)	89	0.86	(0.64–1.17)	136	0.82	(0.60–1.11)	115	1	-	65
Other neoplasms	1.53	(1.19–1.97)	212	1.29	(1.02–1.64)	338	1.18	(0.92–1.50)	240	1	-	89
Respiratory diseases	5.07	(2.33–11.05)	79	2.73	(1.25–5.95)	76	1.19	(0.51–2.80)	21	1	-	7
Other diseases	1.98	(1.48–2.64)	217	1.30	(0.98–1.72)	262	1.05	(0.78–1.41)	155	1	-	62
External causes of death	1.00	(0.54–1.87)	21	0.99	(0.58–1.69)	42	1.17	(0.71–1.95)	53	1	-	21

The four educational groups were constructed from the different school types in the educational system in the Netherlands.

[a] Primary education includes BO = basisonderwijs (elementary education)

[b] Lower secondary education includes VMBO = voorbereidend middelbaar beroepsonderwijs (pre-vocational secondary education)

[c] Upper secondary education includes HAVO = hoger algemeen voortgezet onderwijs (senior general secondary education), VWO = voorbereidend wetenschappelijk onderwijs (pre-university education), MBO = middelbaar beroepsonderwijs (secondary vocational training)

[d] Tertiary education includes HBO = hoger beroepsonderwijs (higher professional education), WO = wetenschappelijk onderwijs (university education)

Table 2 also presents the PAFs. These show that if all men and women in the Netherlands would have the ASMR of the tertiary educated, mortality in the population as a whole would decrease by about a quarter (27.8% among men, 24.9% among women).

Table 2 Age-standardized mortality rates by education, rate difference between primary and tertiary educated and population attributable fraction (PAF) for total and cause-specific mortality, men and women, 30–79 years, the Netherlands, 1998–2007

Causes of death	Mortality rate by education[a]				Mortality rate difference primary vs. tertiary[a]	PAF (in %)
	Primary	Lower secondary	Upper secondary	Tertiary		
MEN						
All-cause mortality	1,094.3	915.2	734.1	547.1	547.2	27.8
Cardiovascular diseases	352.0	302.6	236.3	156.7	195.3	36.7
Ischaemic heart disease	151.1	139.2	107.8	69.2	81.8	37.0
Cerebrovascular disease	59.9	51.1	47.2	24.9	35.0	44.6
Other cardiovascular diseases	141.0	112.3	81.3	62.5	78.5	32.9
Cancer	385.2	368.3	310.9	235.9	149.3	23.2
Lung cancer	159.4	135.2	95.5	55.5	103.9	44.3
Colorectal cancer	28.1	30.3	32.0	38.3	-10.2	n.a.
Prostate cancer	26.7	32.3	24.2	17.2	9.5	24.8
Other neoplasms	171.0	169.9	159.2	123.6	47.5	18.1
Respiratory diseases	99.6	64.7	36.9	21.7	77.9	54.9
Other diseases	200.7	136.5	123.9	109.8	90.9	17.0
External causes of death	56.9	43.1	26.1	23.0	33.9	22.4
WOMEN						
All-cause mortality	663.4	455.2	380.7	342.0	321.4	24.9
Cardiovascular diseases	204.2	123.0	96.2	70.0	134.2	43.6
Ischaemic heart disease	80.9	41.9	32.8	22.7	58.2	50.9
Cerebrovascular disease	45.1	31.8	25.0	19.4	25.7	32.2
Other cardiovascular diseases	78.2	49.3	38.4	28.0	50.2	44.5
Cancer	272.7	210.1	190.6	174.2	98.6	17.5
Lung cancer	66.2	37.5	37.8	25.7	40.5	48.4
Colorectal cancer	23.2	21.8	15.7	11.8	11.4	23.8
Breast cancer	56.2	43.8	41.8	46.7	9.5	n.a.
Other neoplasms	127.1	107.1	95.3	89.9	37.2	18.8
Respiratory diseases	43.5	23.5	10.2	9.1	34.5	54.2
Other diseases	127.8	83.9	66.2	72.4	55.4	20.1
External causes of death	15.2	14.7	17.5	16.4	-1.2	5.7

[a] per 100,000 person-years
n.a. = not available

The results for partial life expectancy between ages 30 and 79 are in line with our findings on relative and absolute inequalities (Table 3). Tertiary educated men and women live longer than their less educated counterparts and women live longer than men regardless of education. Partial life expectancy was 42.8 years among primary and 46.2 years among tertiary educated men, giving a difference of 3.4 years. Among women, partial life expectancy was 45.1 years among primary and 47.5 years among tertiary educated, giving a difference of 2.4 years. The gap in partial life expectancy between men and women was 2.3 years among the primary educated, and only 1.3 years among the tertiary educated.

Table 3 Partial life expectancy (in years) between ages 30 and 79 by sex and education, the Netherlands, 1998–2007

	Education				Total
	Primary	Lower secondary	Upper secondary	Tertiary	
Men	42.8	44.0	45.1	46.2	44.8
Women	45.1	46.5	47.1	47.5	46.6

The contribution of different causes of deaths to differences in partial life expectancy are presented in Figures 1 and 2. In total, CVD accounts for 35% and 37% of the difference in partial life expectancy among men and women, respectively. Cancer was a second major contributor accounting for 27% and 35% of the difference in partial life expectancy among men and women, with lung cancer making a particularly large contribution. Lung cancer accounts for 72% of the cancer contribution among men and 47% of the cancer contribution among women. We found a negative contribution of colorectal cancer to the difference in partial life expectancy among men, due to the reverse social gradient for this cause of death already noted in Table 1. Whereas CVD, in particular IHD, is a major contributor to the excess mortality of primary educated at middle and older ages (50–74 years), external causes contribute importantly to the differences between primary and tertiary educated at younger ages (30–44 years), particularly among men. Among women, we found negative contributions of external causes and breast cancer across all age groups, and of lung cancer at older ages (70–79 years), due to a reverse gradient for the latter cause of death among older women (results not shown).

Table 4 presents rate difference (per 100,000) between less than secondary and tertiary educated men and women in all-cause mortality, CVD and cancer mortality, and external causes across European 'regimes' compared with the Netherlands. The rate difference in all-cause mortality is 430 for men and 185 for women in the Netherlands. These estimates fall within the range of rate differences reported for other North-Western

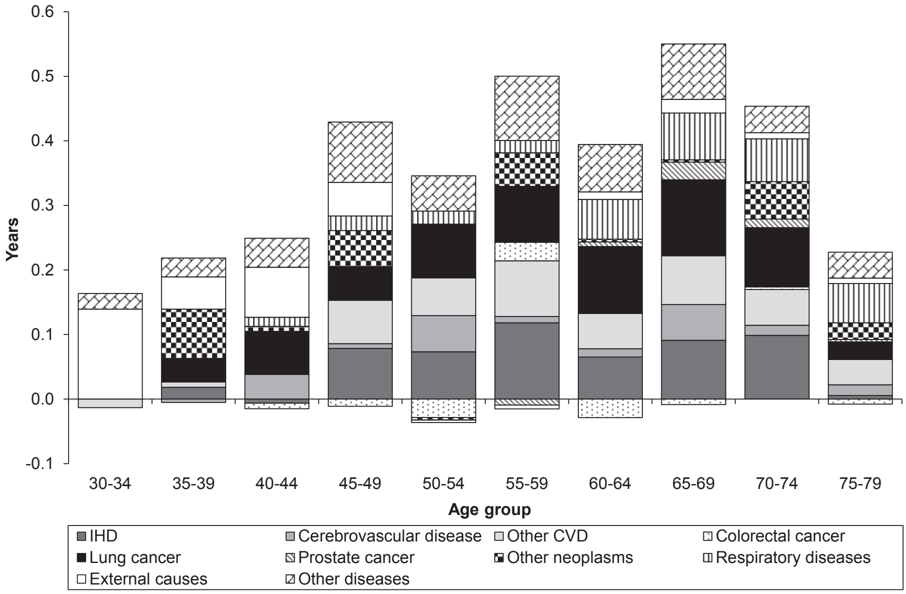

Figure 1 Contribution (in years) of age groups and causes of death to the difference in partial life expectancy between ages 30 and 79 between primary and tertiary educated men, the Netherlands, 1998–2007
Legend: IHD = ischaemic heart disease, CVD = cardiovascular diseases

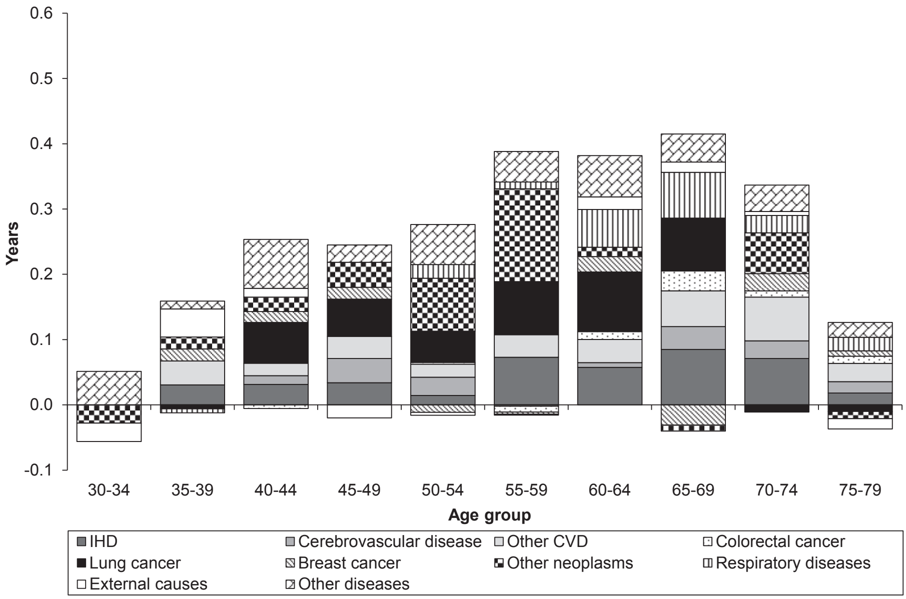

Figure 2 Contribution (in years) of age groups and causes of death to the difference in partial life expectancy between ages 30 and 79 between primary and tertiary educated women, the Netherlands, 1998–2007
Legend: IHD = ischaemic heart disease, CVD = cardiovascular diseases

European countries. The rate difference for all-cause mortality in the Netherlands was higher than the maximum observed in Southern Europe (men: 325; women: 98) and much lower than the minimum found in Eastern Europe (men: 1,158; women: 413). The same is true for mortality from CVD, cancer and external causes (men only).

Table 4 Rate difference (per 100,000 person-years) between less than secondary and tertiary educated for total and cause-specific mortality, men and women, 30–79 years, comparison between the Netherlands and European 'regimes', 1998–2007

Cause of death	Netherlands	North-West[a]		South[b]		Central/East[c]	
		Min	Max	Min	Max	Min	Max
MEN							
All-cause mortality	430	410	615	262	325	1,158	1,788
CVD	164	116	237	35	68	457	713
Cancer	138	73	210	96	147	248	448
External causes	24	10	116	13	37	90	431
WOMEN							
All-cause mortality	185	160	319	51	98	413	691
CVD	82	51	103	15	40	208	359
Cancer	57	23	89	-5	23	45	116
External causes	-2	3	32	0	7	17	127

CVD = cardiovascular diseases
[a] North-West 'regime' was represented by Finland, Sweden, Norway, Denmark, England and Wales, Belgium, France, Switzerland, Austria
[b] South 'regime' was represented by Spain (Barcelona, Basque Country, Madrid), Italy (Turin, Tuscany)
[c] Central/East 'regime' was represented by Hungary, Czech Republic, Poland, Estonia

DISCUSSION

Summary of findings

In the Netherlands, the relative risk of dying of those with primary education only, as compared to those with tertiary education, is 1.98 (95% CI: 1.81–2.15) among men, and 2.03 (95% CI: 1.79–2.30) among women, leading to a gap in partial life expectancy of 3.4 and 2.4 years among men and women, respectively. The magnitude of relative and absolute inequalities in mortality by education is similar to that in other countries in North-Western Europe. Like in other European countries, educational inequalities in mortality in the Netherlands are mainly driven by CVD and cancer, but inequalities in lung cancer mortality are substantially larger in the Netherlands than in other countries of North-Western Europe, particularly among men. No inequalities in mortality were found for colorectal cancer (men and women), prostate cancer (men), breast cancer (women), and external causes (women).

Limitations

This is the first nationally representative study of socioeconomic inequalities in mortality in the Netherlands, which has become feasible because Statistics Netherlands has created new facilities for linking databases, in this case, databases with socioeconomic information to databases on mortality and causes of death [25]. However, because the Netherlands does not have a census, we had to rely on a large survey for information on the educational achievement of individuals. To a large extent, the validity of our findings depends on the representativeness of this survey. There are several potential problems. First, the institutionalized population is not included in the Dutch LFS, and because people living in institutions tend to have both a lower level of education [26] and a higher risk of mortality this could have biased our results. We believe that this bias is likely to be small, because in the Netherlands the proportion of institutionalized people under the age 80 years is negligible [26] and because we restricted the analysis to individuals aged 30–79 years.

Another potential problem affecting the representativeness of our findings is the high non-response (40–45%) of the Dutch LFS. A low response rate does not necessarily mean that our estimates of inequalities in mortality are biased. This will only be the case if the magnitude of relative and/or absolute inequalities in mortality differs between respondents and non-respondents. Studies of non-respondents to surveys have shown that these usually have higher rates of morbidity and mortality than respondents [27]. We also know that the non-response rate in the Dutch LFS is higher among lower educated men and women [28]. However, whether the association between education and mortality differs between respondents and non-respondents is unknown. We think that our estimates of relative inequalities may well be unbiased, but because of the likely under-representation of people with health problems among respondents to the Dutch LFS we may have underestimate absolute inequalities in mortality. We therefore compared the mortality rates observed in our study and those registered for the complete Dutch population by Statistics Netherlands and found that our study underestimates average mortality rates by approximately 12%. This implies that we may have underestimated absolute inequalities in mortality between educational groups, as presented in Tables 2 and 4, by a similar percentage. In a sensitivity analysis, we have used this percentage to upwardly adjust the absolute inequalities in mortality in the Netherlands presented in Table 4. This brings the Dutch results closer to the middle of the range of North-Western European countries (results not shown) and shows that our substantive results are not seriously biased. Also, there is little reason to think that our estimates of relative inequalities in mortality are biased.

We used education as an indicator of socioeconomic position, but a single indicator of socioeconomic status does not comprehensively portray the entire picture of health inequalities [15]. As mentioned above, education has several advantages compared to occupation and income [15, 29], but although education is highly correlated with occupation and income, we cannot assume that the same results will be obtained with other indicators of socioeconomic position.

Data on inequalities in cause-specific mortality might be biased if there are differences between educational groups in accuracy of diagnoses, certification of causes of death or coding of underlying cause of death. Harteloh and others studied the reliability of cause-of-death statistics in the Netherlands and found that for major causes of death such as cancer and heart diseases the reliability was higher than 90% [30]. International comparative studies showed that the reliability of cause-of-death statistics in the Netherlands compares favourably with that in other countries [31]. On the other hand, it is unknown, in the Netherlands as elsewhere, whether reliability of cause-of-death information differs between socioeconomic groups. We therefore assessed whether there are differences in the proportion of ill-defined causes of death across educational categories (results not shown). Although this proportion is higher in the Netherlands than in most other European countries, we did not find statistically significant differences in the proportion of these causes of death among educational groups (p-value: men = 0.218; women = 0.597).

Interpretation

As noted in the introduction, an educational gradient in all-cause mortality has been reported from all European countries with available data. We show that this educational gradient can also be found in the Netherlands. The magnitude of educational inequalities in all-cause mortality in the Netherlands is comparable to that in other North-Western European countries [2]. Cause-specific patterns are also largely similar, both at the level of broad groups of causes of death (such as CVD and cancer), and at the level of specific causes. Whereas breast cancer was reported to have a reverse educational gradient in most European countries except France, Finland and Barcelona [32], we did not find statistically significant differences in breast cancer mortality between educational groups in the Netherlands. We found no differences by education in mortality from external causes among women in the Netherlands, as has been found before for injuries for Norway, Switzerland, Turin and Barcelona [12].

A cause of death for which we found larger inequalities in the Netherlands than elsewhere is lung cancer. Like other North-Western European countries the Netherlands is in the fourth stage of the smoking epidemic [33], during which smoking increasingly becomes concentrated among those with lower socioeconomic positions [34]. In earlier stages of the epidemic, smoking prevalence rates have reached very high values in the Netherlands, which has led to a relative stagnation of life expectancy during the 1980s and 1990s in both men and women [35], and which probably also explains the large contribution of lung cancer (20% men; 16% women) to inequalities in mortality in the Netherlands.

The Netherlands has a strong tradition of investigating inequalities in mortality, and there is therefore a lot of scientific evidence on the explanation of inequalities in mortality in this country. Studies have shown that people in lower educated groups have a higher prevalence of a less than good perceived general health, more chronic diseases, higher disability rates and higher risks of all-cause mortality compared to higher educated groups [7, 36]. A substantial part of the worse health observed among lower educated groups has been found to be attributable to unhealthy behaviours, such as smoking [7, 37] , physical inactivity [7, 38] or excessive alcohol consumption [7, 39]. Material living conditions, working conditions, psychosocial stress and social support contribute to the educational inequalities as well [36, 37]. All this implies that the Netherlands is in a good position to start tackling the inequalities in mortality found in our study [40].

Conclusion

Cross-country comparisons of socioeconomic inequalities in mortality are an important source of information for understanding the mechanisms that generate these inequalities. The exploration of such mechanisms is essential for policy makers in order to develop effective policies and large-scale interventions to reduce the observed burden in morality due to educational disparities. We reported large educational inequalities in mortality in the Netherlands and showed that their magnitude and cause-specific patterning are similar to those observed in other countries in North-Western Europe. These educational inequalities in mortality in the Netherlands are partly driven by cause of death attributable to lifestyle-related risk factors such as smoking. These findings are important for the development of efficient health interventions and require the urgent attention of policy makers.

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APPENDIX

Table A1 Distribution of education and age by sex, 30–79 years, the Netherlands, 1998–2007

	MEN		WOMEN	
	%	Number of subjects	%	Number of subjects
Education				
primary	10.8	17,760	14.3	24,128
lower secondary	22.7	37,397	30.7	51,614
upper secondary	41.1	67,692	37.4	62,988
tertiary	25.3	41,658	17.6	29,632
Age group				
30-34	15.1	24,876	15.7	26,401
35-39	15.2	24,986	15.6	26,259
40-44	14.5	23,919	14.6	24,657
45-49	13.6	22,374	13.6	22,824
50-54	13.1	21,583	12.7	21,387
55-59	10.1	16,607	9.6	16,225
60-64	7.8	12,839	7.6	12,741
65-69	5.1	8,381	4.2	7,121
70-74	3.3	5,427	3.6	5,993
75-79	2.1	3,515	2.8	4,754

5

Trends in inequalities in premature mortality: a study of 3.2 million deaths in 13 European countries

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ABSTRACT

Background

Over the last decades of the 20th century, a widening of the gap in death rates between upper and lower socioeconomic groups has been reported for many European countries. For most countries, it is unknown whether this widening has continued into the first decade of the 21st century.

Methods

We collected and harmonized data on mortality by educational level among men and women aged 30–74 years in all countries with available data: Finland, Sweden, Norway, Denmark, England and Wales, Belgium, France, Switzerland, Spain, Italy, Hungary, Lithuania and Estonia.

Results

Relative inequalities in premature mortality increased in most populations in the North, West and East of Europe, but not in the South. This was mostly due to smaller proportional reductions in mortality among the lower than the higher educated, but in the case of Lithuania and Estonia, mortality rose among the lower and declined among the higher educated. Mortality among the lower educated rose in many countries for conditions linked to smoking (lung cancer, women only) and excessive alcohol consumption (liver cirrhosis and external causes). In absolute terms, however, reductions in premature mortality were larger among the lower educated in many countries, mainly due to larger absolute reductions in mortality from cardiovascular disease and cancer (men only). Despite rising levels of education, population attributable fractions of lower education for mortality rose in many countries.

Conclusions

Relative inequalities in premature mortality have continued to rise in most European countries, and since the 1990s, the contrast between the South (with smaller inequalities) and the East (with larger inequalities) has become stronger. While the population impact of these inequalities has further increased, there are also some encouraging signs of larger absolute reductions in mortality among the lower educated in many countries. Reducing inequalities in mortality critically depends upon speeding up mortality declines among the lower educated, and countering mortality increases from conditions linked to smoking and excessive alcohol consumption such as lung cancer, liver cirrhosis and external causes.

INTRODUCTION

During the 1980s and 1990s socioeconomic inequalities in mortality have widened in many countries. This has been well documented for relative inequalities in mortality between educational or occupational groups in Northern, Western and Southern Europe [1-5]. For absolute inequalities in mortality, findings have been less consistent, with increases reported for some countries such as Finland [2-4, 6] and Norway [3-5], but not for others such as Sweden [2-4] and Italy [2, 3]. Inequalities in life expectancy between socioeconomic groups have generally increased as well [6-12]. In Eastern Europe, inequalities in mortality have increased too, on a relative and on an absolute scale [13, 14]. Widening inequalities have also been reported for non-European high-income countries, such as the USA [15-18] and New Zealand [19, 20].

Although some studies have started to look at trends into the 21st century, a comprehensive analysis of recent trends, allowing a comparison of these trends between countries, is lacking. We therefore studied changes in mortality by education in all European countries with available data between the 1990s and 2000s, and focused on whether relative and absolute inequalities in mortality have widened or narrowed, and if so, which causes of death have contributed to these developments. We consider relative and absolute inequalities to be relevant: while the first are independent from average rates of mortality and therefore useful for analytical purposes, the second indicate the real impact that these inequalities have on the mortality risks of people with a lower socioeconomic position, which is useful for informing public health decisions [21].

METHODS

Data

The data were obtained from official mortality registers and cover 13 countries: 4 countries in Northern Europe (Finland, Sweden, Norway, Denmark), 4 countries in Western Europe (England and Wales, Belgium, France and Switzerland), 2 countries in Southern Europe (Spain and Italy), and 3 countries in Eastern Europe (Hungary, Lithuania and Estonia). These are all European countries with comparable data for the 1990s and 2000s which, together, are likely to represent the full range of inequality trends in the subcontinent. Most data cover complete national populations, as in the case of the national longitudinal mortality registers of the Nordic countries. The exceptions are England and Wales (a 1% representative sample of the population; known as the Office of National Statistics Longitudinal Mortality Study), France (a 1% representative sample of the population; the so-called Echantillon Démographique Permanent created by the

Table 1 Mortality data sources

Country	Type of study	Years	Years of follow-up	Person-years	Deaths	Educational structure (in %)		
						Low	Mid	High
Finland	Longitudinal	1990–2000	10	25,874,201	270,232	50.1	29.3	20.6
Finland[a]	Longitudinal	2001–2007	7	15,435,298	105,379	33.9	36.8	29.3
Sweden	Longitudinal	1991–2000	10	43,042,216	393,038	40.6	41.7	17.7
Sweden	Longitudinal	2001–2006	6	28,087,496	187,168	27.1	50.3	22.6
Norway	Longitudinal	1990–2000	10	19,956,767	213,022	33.1	47.7	19.2
Norway	Longitudinal	2001–2006	5	11,645,682	70,191	19.7	55.0	25.3
Denmark	Longitudinal	1996–2000	5	13,926,291	136,065	45.1	34.9	20.0
Denmark	Longitudinal	2001–2005	5	14,498,528	122,728	38.6	37.7	23.7
England & Wales[b]	Longitudinal	1991–1996	5.5	1,530,278	14,966	85.1	-	14.9
England & Wales[b]	Longitudinal	2001–2006	5	1,432,977	9,145	80.7	-	19.3
Belgium	Longitudinal	1991–1995	5	23,684,150	206,444	63.1	21.0	15.9
Belgium	Longitudinal	2004–2005	2	11,221,276	73,001	48.6	25.2	26.2
France[c]	Longitudinal	1990–1999	10	2,478,782	20,215	56.1	32.3	11.6
France[d]	Longitudinal	1999–2005	6	1,521,946	8,796	42.4	40.4	17.2
Switzerland[e]	Longitudinal	1990–2000	10	27,910,587	255,275	30.3	54.5	15.2
Switzerland[e]	Longitudinal	2001–2005	5	15,635,957	82,195	19.8	57.8	22.4
Barcelona	Repeated CS	1992–1998	7	6,285,178	39,830	64.9	18.0	17.1
Barcelona	Repeated CS	2000–2006	7	6,858,828	35,143	55.7	21.5	22.8
Basque Country	Longitudinal	1996–2001	5	6,048,696	34,230	69.9	16.8	13.3
Basque Country	Longitudinal	2001–2006	5	6,312,758	32,169	60.9	20.5	18.6
Madrid	Longitudinal	1996–1997	1.5	4,122,305	25,356	64.9	18.1	17.1
Madrid	Longitudinal	2001–2003	1.5	4,967,231	26,279	56.6	21.9	21.5
Turin	Longitudinal	1991–2001	10	4,873,109	50,621	71.5	19.8	8.6
Turin	Longitudinal	2001–2006	5	2,422,742	14,186	59.2	27.4	13.4
Hungary	CS unlinked	1988–1991	4	22,408,012	297,749	59.4	30.2	10.4
Hungary	CS unlinked	1999–2002	4	22,479,484	282,601	43.6	43.2	13.2
Lithuania[f]	CS unlinked	1988–1990	3	5,135,151	45,449	44.6	42.1	13.4
Lithuania[f]	CS unlinked	2000–2002	3	5,199,153	48,092	22.5	59.5	18.0
Estonia	CS unlinked	1987–1991	5	4,011,470	45,611	41.9	42.6	15.5
Estonia	CS unlinked	1998–2002	5	3,684,050	50,035	26.2	55.7	18.1

All data, unless otherwise mentioned, refer to the age group 30–74 years.
[a] 20% of Finns are excluded (at random)
[b] 1% representative sample of the population
[c] 1% representative sample of the population; people from overseas areas, military and students are excluded
[d] 1% representative sample of the population; people born outside France mainland are excluded
[e] Non-Swiss nationals excluded
[f] age range 30–69 years
CS = cross-sectional

French National Institute of Statistics (INSEE)), Spain (Barcelona, Madrid and Basque Country only; urban and regional mortality registers) and Italy (Turin only; known as the Turin Longitudinal Study). A full overview of data sources is given in Table 1.

For each country, numbers of deaths by 5-year age group, sex and educational group were obtained for the 1990s and the 2000s. These data were mostly collected in the framework of a longitudinal mortality follow-up of population censuses carried out around 1991 and around 2000, respectively. Although around 2010, a more recent census has been held in many countries, mortality follow-up will only be complete after 5–10 years, and at the moment of writing (2014), our data, therefore, represent the most recent data available for those countries. Data for Hungary, Lithuania and Estonia derive from unlinked cross-sectional studies in which numerator data (deaths by educational group, as counted in the mortality register) and denominator data (persons by educational group, as counted in a census) have been collected at approximately the same point in time. 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) weights were used in the analysis to account for the difference. A total of around 3.2 million deaths are included in this study, deriving from around 360 million person-years of observation.

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 men and women in all European populations under study. Additionally, education is the most stable measure of socioeconomic position because it is normally completed early in adulthood which avoids reverse causation problems (i.e., health outcomes at older ages cannot change a person's level of education) [22]. 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'). In the 1990s dataset for England and Wales only two levels of education could be distinguished ('low and mid' vs. 'high'), and we therefore also classified the English data for the 2000s in this way. In order to reduce problems with the educational classification of elderly people, the main analysis is limited to the age-group 30–74 years. Because average life expectancy at birth exceeded 74 years in most European countries during the study-period, we label mortality in this age-range as 'premature'.

In addition to all-cause mortality, we analysed four broad cause-of-death groups that together account for all deaths (cardiovascular disease, cancer, other diseases, and external causes), and five specific causes of death each that signal potential explanatory factors (ischaemic heart disease (smoking, diet, hypertension, hypertension detection and treatment, myocardial infarction treatment), cerebrovascular disease (hypertension, hypertension detection and treatment, stroke treatment), lung cancer (smoking), liver cirrhosis (excessive alcohol consumption), and road traffic accidents (excessive alcohol consumption, road safety)). Cause-of-death information was not available for mortality by education in France. Causes of death were classified according to the 9th or 10th revision of the International Classification of Diseases (ICD). ICD-code numbers are given in appendix (Table A1).

Data for the 1990s were collected in the framework of the Eurothine study and have been used for international comparative purposes before [23]. Data for the 2000s were collected in the framework of the EURO-GBD-SE study [24]. Data were centrally harmonized to enhance comparability between countries and over time.

Methods

We calculated age-standardized mortality rates and their 95% confidence intervals (CIs) [25] by period, country, level of education, and sex, using the European Standard Population as defined by WHO. Age-adjusted rate ratios comparing the 'low' and 'mid' educated with the 'high' educated and their 95% CIs were calculated with Poisson regression using STATA statistical software version 12.0.

The age-standardized mortality rates were used to calculate proportional and absolute changes in mortality by country, level of education, and sex, and subtraction of these changes among the 'high' educated from those among the 'low' educated allowed us to evaluate differences in proportional and absolute mortality change between educational groups.

The age-standardized mortality rates were also used to calculate population attributable fractions of education for mortality for the two points in time. This is a straightforward measure of the population impact of inequalities in mortality [21]. The population attributable fraction takes into account inequalities in mortality between educational groups and the size of educational groups, and quantifies the proportion of all deaths in the population that could be avoided or postponed if everyone had the mortality rates of the high educated [21, 26].

Most countries with longitudinal data classified person-years and deaths by age at baseline, and as length of follow-up differed between studies (Table 1) adjustment was necessary. This adjustment procedure was developed and validated within the EURO-GBD-SE study [27], and was used wherever deaths were classified by age at baseline. Further details can be found in appendix (Table A2).

RESULTS

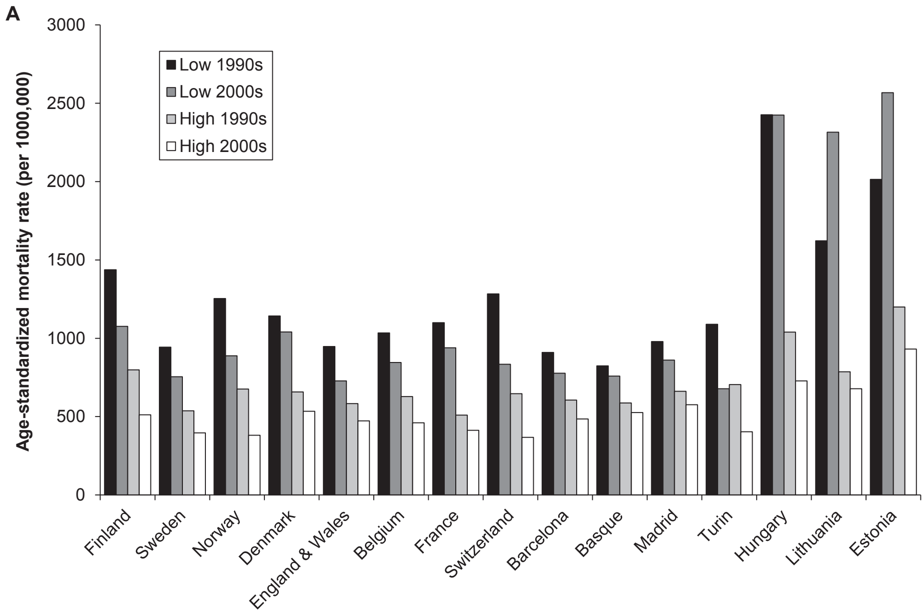
All-cause mortality

Age-standardized mortality rates by education for the 1990s and 2000s can be found in Figure 1 and appendix Table A3, whereas rate ratios are presented in Table 2. Mortality declined between the 1990s and 2000s in all educational groups, except the low educated in Hungary, Lithuania and Estonia among whom mortality remained stable or increased. Mortality among the high educated in Hungary, Lithuania and Estonia was similar to that among the low educated in many Western European countries (Figure 1).

Among men, relative inequalities in mortality increased in most populations, with the exceptions of England and Wales, France, Barcelona, the Basque Country, Madrid and Turin, where no clear changes were found. Among women, about half the countries had widening and half had stable inequalities. The rise in relative inequalities was very strong in Hungary, Lithuania and Estonia, particularly for men (Table 2).

As a result of these changes, the variation in magnitude of inequalities in mortality between European countries has increased considerably. In the 1990s, the South (represented by Barcelona, the Basque Country, Madrid and Turin) already tended to have smaller inequalities in mortality than the North and West, and the North and West than the East (represented by Hungary, Lithuania and Estonia), particularly among men. In the 2000s, the same pattern is still found, but with substantially larger differences between countries (Table 2).

These changes in relative inequalities in mortality between the 1990s and 2000s are the result of large differences between educational groups in *proportional* mortality change (see the column for all causes in Tables 3A and 3B). For example, in the case of Finnish men, mortality declined 10.7%-points more among the high than among the low educated, as mortality declined by 35.9% among the high and 25.2% among the low educated. Light grey shading in Table 3 indicates that mortality declined less among the low than among the high educated; dark grey shading indicates that mortality actually increased among the low educated. The latter is seen for all-cause mortality in Lithuania



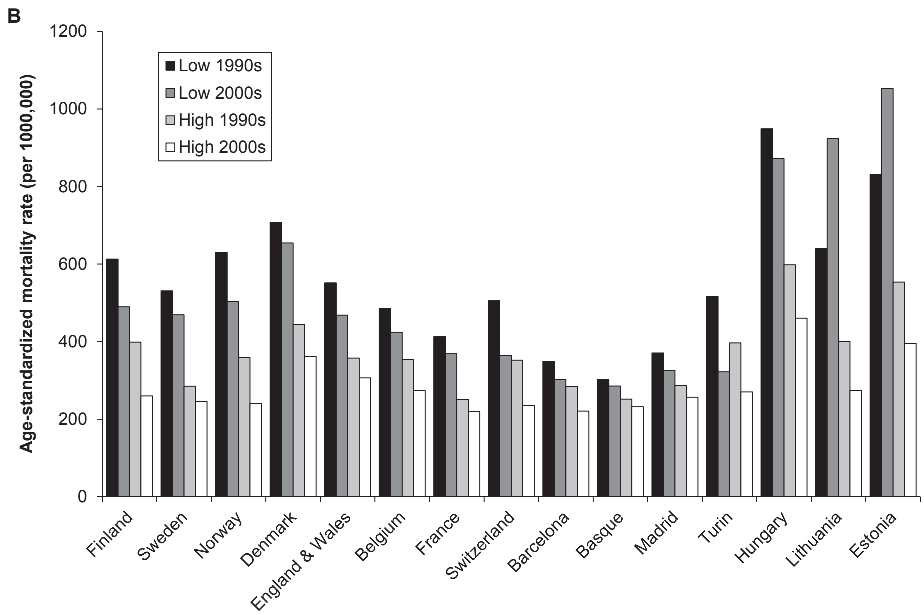


Figure 1 All-cause mortality among the low and high educated, by country and sex, 1990s and 2000s, (A) men, (B) women

Note: Mortality standardized to the European Standard Population. Low = 'no, primary or lower secondary education' (ISCED 0, 1, 2). High = 'tertiary education' (ISCED 5, 6). For full details, including 95% confidence intervals, see Table A3 in appendix.

Table 2 Changes between the 1990s and 2000s in rate ratios (RR) by education for all-cause mortality, by country and sex

Country	Edu	MEN				WOMEN			
		1990s		2000s		1990s		2000s	
		RR	95% CI	RR	95% CI	RR	95% CI	RR	95% CI
NORTH									
Finland	low	1.97	(1.93–2.01)	**2.08**	(2.03–2.13)	1.59	(1.55–1.64)	**1.84**	(1.78–1.90)
	mid	1.60	(1.57–1.64)	1.61	(1.57–1.65)	1.22	(1.19–1.26)	1.35	(1.30–1.39)
	high	1		1		1		1	
Sweden	low	1.78	(1.75–1.81)	**1.90**	(1.86–1.94)	1.88	(1.84–1.93)	1.88	(1.83–1.93)
	mid	1.42	(1.39–1.44)	1.47	(1.44–1.51)	1.47	(1.43–1.50)	1.42	(1.38–1.46)
	high	1		1		1		1	
Norway	low	1.88	(1.83–1.92)	**2.35**	(2.27–2.44)	1.76	(1.70–1.82)	**2.12**	(2.02–2.22)
	mid	1.43	(1.40–1.47)	**1.63**	(1.57–1.68)	1.30	(1.26–1.35)	**1.45**	(1.38–1.52)
	high	1		1		1		1	
Denmark	low	1.77	(1.73–1.82)	**2.00**	(1.95–2.06)	1.62	(1.57–1.68)	**1.85**	(1.79–1.91)
	mid	1.46	(1.42–1.50)	1.53	(1.49–1.57)	1.24	(1.20–1.29)	1.34	(1.29–1.39)
	high	1		1		1		1	
WEST									
England & Wales	low[a]	1.65	(1.51–1.80)	1.55	(1.43–1.69)	1.55	(1.36–1.75)	1.52	(1.36–1.69)
	high	1		1		1		1	
Belgium	low	1.69	(1.65–1.73)	**1.86**	(1.81–1.92)	1.40	(1.35–1.44)	**1.57**	(1.51–1.64)
	mid	1.30	(1.27–1.34)	**1.40**	(1.36–1.46)	1.10	(1.06–1.14)	**1.25**	(1.19–1.31)
	high	1		1		1		1	
France	low	2.23	(2.04–2.44)	2.37	(2.14–2.62)	1.64	(1.42–1.90)	1.80	(1.55–2.09)
	mid	1.60	(1.46–1.76)	1.70	(1.54–1.89)	1.17	(1.00–1.36)	1.38	(1.18–1.62)
	high	1		1		1		1	
Switzerland	low	1.95	(1.91–1.98)	**2.22**	(2.16–2.29)	1.43	(1.38–1.49)	1.54	(1.47–1.63)
	mid	1.41	(1.38–1.43)	**1.52**	(1.48–1.56)	1.11	(1.07–1.15)	1.13	(1.08–1.19)
	high	1		1		1		1	
SOUTH									
Barcelona	low	1.51	(1.45–1.57)	1.60	(1.54–1.66)	1.29	(1.20–1.38)	1.40	(1.32–1.49)
	mid	1.02	(0.97–1.08)	1.18	(1.12–1.24)	0.83	(0.75–0.91)	1.09	(1.01–1.18)
	high	1		1		1		1	
Basque Country	low	1.49	(1.42–1.57)	1.51	(1.44–1.58)	1.25	(1.14–1.38)	1.39	(1.28–1.51)
	mid	1.20	(1.12–1.27)	1.16	(1.10–1.23)	1.12	(1.00–1.26)	1.22	(1.10–1.35)
	high	1		1		1		1	
Madrid	low	1.55	(1.48–1.63)	1.56	(1.49–1.63)	1.37	(1.24–1.50)	1.30	(1.20–1.40)
	mid	1.30	(1.22–1.38)	1.27	(1.20–1.35)	1.18	(1.05–1.32)	1.23	(1.11–1.35)
	high	1		1		1		1	
Turin	low	1.58	(1.49–1.67)	1.66	(1.53–1.80)	1.28	(1.17–1.40)	1.22	(1.09–1.36)
	mid	1.19	(1.12–1.27)	1.17	(1.07–1.28)	1.09	(0.99–1.21)	1.12	(0.98–1.27)
	high	1		1		1		1	

Chapter 5

Table 2 Changes between the 1990s and 2000s in rate ratios (RR) by education for all-cause mortality, by country and sex (continued)

Country	Edu	MEN				WOMEN			
		1990s		2000s		1990s		2000s	
		RR	95% CI	RR	95% CI	RR	95% CI	RR	95% CI
EAST									
Hungary	low	2.35	(2.30–2.39)	**3.26**	(3.19–3.32)	1.67	(1.62–1.73)	**2.09**	(2.03–2.16)
	mid	0.99	(0.97–1.02)	**1.49**	(1.46–1.53)	1.27	(1.22–1.32)	1.28	(1.24–1.32)
	high	1		1		1		1	
Lithuania[b]	low	2.21	(2.10–2.32)	**3.09**	(2.96–3.23)	1.61	(1.50–1.73)	**2.66**	(2.50–2.84)
	mid	1.69	(1.60–1.78)	**1.97**	(1.89–2.06)	1.28	(1.19–1.38)	**1.65**	(1.55–1.75)
	high	1		1		1		1	
Estonia	low	1.83	(1.75–1.91)	**2.61**	(2.50–2.72)	1.51	(1.42–1.61)	**2.29**	(2.17–2.43)
	mid	1.44	(1.37–1.51)	**2.04**	(1.95–2.13)	1.35	(1.26–1.44)	**1.77**	(1.67–1.88)
	high	1		1		1		1	

In **bold**: no overlap in 95% confidence interval (CI) of rate ratio (RR) between 2000s and 1990s
[a] low and middle educated combined
[b] age 30–69 years
Edu = education

and Estonia only. In other countries, widening relative inequalities in all-cause mortality are due to less declines among the low than among the high educated. Among men in England and Wales and Barcelona and among women in England and Wales, Madrid and Turin, there was more proportional decline in all-cause mortality among the low than among the high educated.

However, Tables 3C and 3D show that differences between educational groups in *absolute* mortality change have often favoured the low educated. For example, in the case of Finnish men, mortality declined by 75.3 deaths per 100,000 more among the low than among the high educated, as it went down by 361.9 and 286.6 deaths per 100,000, respectively. In many populations, including Finland (men only), Sweden, Norway, England and Wales, Belgium (men only), France, Switzerland, Barcelona, Basque Country (men only), Madrid, and Turin, absolute reductions in mortality have been larger among the low than among the high educated. Please note that there is no contradiction between smaller proportional reductions and larger absolute reductions in mortality: the latter also depend on starting levels of mortality which are always higher among the low educated.

Cause-specific mortality

A pattern of generally smaller proportional reductions in mortality among the low educated is found for many specific causes of death, including all cardiovascular disease,

Table 3A Differences between low and high educated in proportional mortality decline between the 1990s and 2000s, by country and cause of death, men

Country	Difference between low and high educated in proportional mortality decline (%-points)									
	All causes	All cardiovascular	Ischaemic heart disease	Cerebrovascular disease	All cancer	Lung cancer	All other diseases	Liver cirrhosis	All external	Road traffic accidents
NORTH										
Finland	-10.7	-10.9	-9.5	-6.7	-6.2	-11.0	-14.5	-22.8	-9.0	-24.2
Sweden	-6.2	-5.7	-6.4	-7.1	-3.2	-9.1	-12.4	-20.1	-18.8	-25.7
Norway	-14.5	-10.9	-10.0	-7.9	-14.3	-27.4	-22.4	-15.4	-24.1	-21.9
Denmark	-9.8	-5.0	-3.0	-6.6	-8.0	-1.4	-14.4	-26.5	-3.9	-7.3
WEST										
England & Wales	4.1	-1.9	-0.8	7.0	-1.3	-4.7	28.4	-20.3	48.3	-32.0
Belgium	-8.4	-9.0	-9.2	-4.5	-4.5	-2.3	-7.2	13.0	-13.7	-30.6
France	-4.5	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Switzerland	-8.2	-8.7	-7.7	-11.4	-4.9	-5.0	-16.0	-18.7	1.7	-14.7
SOUTH										
Barcelona	1.4	-10.1	-12.3	-18.1	5.9	11.3	8.2	-13.3	1.7	8.3
Basque Country	-2.5	-8.9	-11.0	-22.7	1.8	-2.2	-0.3	15.8	-4.2	-17.7
Madrid	-0.8	-8.0	-11.3	-27.2	2.6	-9.3	10.1	-35.9	-20.7	-25.8
Turin	-5.0	-0.7	3.9	11.0	-8.6	-22.6	-6.2	46.2	6.2	18.5
EAST										
Hungary	-29.9	-37.2	-41.4	-26.4	-38.8	-42.0	-17.4	3.7	-10.5	-9.8
Lithuania	-56.6	-48.2	-41.1	-38.1	-28.0	-32.2	-69.5	n.a.	-50.7	-45.0
Estonia	-49.8	-43.9	-40.2	-33.2	-26.2	-22.4	-83.9	n.a.	-53.1	-19.7

More mortality decline (or less mortality increase) among low than among high educated.
Less mortality decline among low than among high educated.
Mortality increase among low educated, mortality decline (or less mortality increase) among high educated.

Difference between low and high educated in proportional mortality decline was calculated by subtracting the percentage mortality decline among the high educated from the percentage mortality decline among the low educated. In algebraic form: $100*(R_{1990,L}-R_{2000,L})/R_{1990,L} - 100*(R_{1990,H}-R_{2000,H})/R_{1990,H}$ in which R = age-standardized mortality rate, 1990 = 1990s, 2000 = 2000s, L = low educated, and H = high educated. For example, in the case of Finnish men, mortality declined by 35.9% among the high and 25.2% among the low educated, which is 10.7%-points more among the high than among the low educated. Grey shading indicates a disadvantage for the low educated; no shading indicates a disadvantage for the high educated. Difference in mortality decline could not be calculated for liver cirrhosis among women in Turin because of 0 deaths among high educated women in this population in the 2000s. Please note that the sum of the cause-specific changes does not always exactly equal the change for all-cause mortality, because of various adjustments and rounding.

Table 3B Differences between low and high educated in proportional mortality decline between the 1990s and 2000s, by country and cause of death, women

Country	Difference between low and high educated in proportional mortality decline (%-points)									
	All causes	All cardiovascular	Ischaemic heart disease	Cerebrovascular disease	All cancer	Lung cancer	All other diseases	Liver cirrhosis	All external	Road traffic accidents
NORTH										
Finland	-14.7	-15.9	-12.9	-14.8	-8.4	-31.0	-30.8	-62.2	-35.5	-24.5
Sweden	-2.1	-11.4	-14.5	-3.0	-9.3	-19.5	-18.5	25.2	-16.5	-10.5
Norway	-12.8	-6.1	-7.6	-5.7	-14.2	-35.0	-24.7	-53.6	-54.2	-32.9
Denmark	-10.8	-6.0	-6.7	0.0	-12.9	-21.6	-14.0	-19.8	-6.4	14.0
WEST										
England & Wales	0.9	-7.6	-7.8	2.4	-4.2	69.3	25.2	16.1	-12.9	333.2
Belgium	-10.0	-8.0	-11.9	-2.7	-10.0	-8.2	-16.4	-37.2	-10.5	-28.3
France	-1.5	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Switzerland	-5.4	-4.8	1.9	-11.3	-4.8	-21.4	-14.7	-4.9	-9.3	0.8
SOUTH										
Barcelona	-0.8	13.1	22.5	11.7	-7.3	-31.2	5.4	-42.7	-22.3	-17.3
Basque Country	-2.2	9.4	9.5	42.9	-1.8	-57.9	-15.2	-2.9	-6.8	51.4
Madrid	1.4	-16.2	14.5	-9.2	-0.4	-8.9	20.7	72.4	5.9	65.4
Turin	5.7	5.3	15.1	-13.7	9.9	-4.9	-2.2	n.a.	1.8	16.0
EAST										
Hungary	-14.9	-12.1	-22.7	2.8	-23.2	-68.5	-11.5	12.9	-25.8	-22.6
Lithuania	-76.1	-62.9	-47.8	-48.0	-62.0	-52.7	-78.2	n.a.	-121.3	-71.0
Estonia	-55.3	-49.5	-48.4	-28.2	-24.1	-62.9	-102.4	n.a.	-124.4	-27.1

(no shading) More mortality decline (or less mortality increase) among low than among high educated.

(light grey) Less mortality decline among low than among high educated.

(dark grey) Mortality increase among low educated, mortality decline (or less mortality increase) among high educated.

Difference between low and high educated in proportional mortality decline was calculated by subtracting the percentage mortality decline among the high educated from the percentage mortality decline among the low educated. In algebraic form: $100*(R_{1990,L}-R_{2000,L})/R_{1990,L} - 100*(R_{1990,H}-R_{2000,H})/R_{1990,H}$ in which R = age-standardized mortality rate, 1990 = 1990s, 2000 = 2000s, L = low educated, and H = high educated. For example, in the case of Finnish women, mortality declined by 34.8% among the high and 20.1% among the low educated, which is 14.7%-points more among the high than among the low educated. Grey shading indicates a disadvantage for the low educated; no shading indicates a disadvantage for the high educated. Difference in mortality decline could not be calculated for liver cirrhosis among women in Turin because of 0 deaths among high educated women in this population in the 2000s. Please note that the sum of the cause-specific changes does not always exactly equal the change for all-cause mortality, because of various adjustments and rounding.

Table 3C Differences between low and high educated in absolute mortality decline between the 1990s and 2000s, by country and cause of death, men

Country	Difference between low and high educated in absolute mortality decline (deaths per 100,000)									
	All causes	All cardiovascular	Ischaemic heart disease	Cerebrovascular disease	All cancer	Lung cancer	All other diseases	Liver cirrhosis	All external	Road traffic accidents
NORTH										
Finland	75.3	61.3	61.8	12.7	13.8	17.3	-3.7	-14.5	-5.5	-1.9
Sweden	48.4	52.7	42.3	5.2	2.9	0.2	-5.1	-2.3	-11.1	-1.9
Norway	70.8	98.2	77.7	15.1	-12.7	-6.1	-7.3	-0.4	-12.7	-0.9
Denmark	-21.3	14.8	25.9	-1.9	-14.4	4.8	-18.7	-8.5	7.1	0.7
WEST										
England & Wales	108.4	59.0	48.9	9.7	16.0	18.6	31.2	-3.3	8.0	-0.7
Belgium	21.6	17.4	7.2	5.0	14.7	22.8	6.6	-1.1	-8.9	-3.7
France	62.9	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Switzerland	170.2	66.6	32.6	9.3	44.1	25.7	26.1	3.8	22.8	-0.9
SOUTH										
Barcelona	50.8	-7.8	-6.3	-2.5	25.4	13.1	35.1	-1.2	-1.9	0.6
Basque Country	4.4	-13.7	-7.9	-9.6	8.9	-1.5	3.8	0.2	5.3	-1.3
Madrid	33.0	-7.9	-10.2	-9.5	11.9	-5.4	35.1	-1.7	-6.1	-3.5
Turin	109.3	42.0	19.8	22.1	10.5	-1.3	55.3	-0.2	6.6	3.2
EAST										
Hungary	-309.5	-157.5	-110.6	-12.6	-179.6	-64.6	-39.6	-42.8	67.2	17.0
Lithuania	-802.6	-223.4	-120.1	-26.4	-81.3	-20.3	-186.8	n.a.	-311.1	-20.4
Estonia	-821.2	-304.4	-161.8	-48.6	-87.9	-14.5	-208.0	n.a.	-220.9	-2.9

More mortality decline (or less mortality increase) among low than among high educated.

Less mortality decline among low than among high educated.

Mortality increase among low educated, mortality decline (or less mortality increase) among high educated.

Difference between low and high educated in absolute mortality decline was calculated by subtracting the percentage mortality decline among the high educated from the absolute mortality decline among the low educated. In algebraic form: $(R_{1990,L}–R_{2000,L}) – (R_{1990,H}–R_{2000,H})$ in which R = age-standardized mortality rate, 1990 = 1990s, 2000 = 2000s, L = low educated, and H = high educated. For example, in the case of Finnish men, mortality declined by 361.9 and 286.6 per 100,000 among the low and high educated, respectively, and thus by 75.3 deaths per 100,000 more among the low educated. Grey shading indicates a disadvantage for the low educated; no shading indicates a disadvantage for the high educated. Difference in mortality decline could not be calculated for liver cirrhosis among women in Turin because of 0 deaths among high educated women in this population in the 2000s. Please note that the sum of the cause-specific changes does not always exactly equal the change for all-cause mortality, because of various adjustments and rounding.

Table 3D Differences between low and high educated in absolute mortality decline between the 1990s and 2000s, by country and cause of death, women

Country	Difference between low and high educated in absolute mortality decline (deaths per 100,000)									
	All causes	All cardiovascular	Ischaemic heart disease	Cerebrovascular disease	All cancer	Lung cancer	All other diseases	Liver cirrhosis	All external	Road traffic accidents
NORTH										
Finland	-15.6	29.3	28.9	5.5	-10.9	-5.2	-22.1	-9.7	-15.6	-1.2
Sweden	22.6	15.9	11.1	4.3	-13.9	-8.0	-13.4	-0.7	-4.0	-0.3
Norway	8.9	51.1	32.1	10.5	-19.8	-13.1	-13.6	-2.3	-14.0	-2.0
Denmark	-28.0	6.9	11.1	0.9	-27.2	-10.5	-15.7	-3.1	0.2	1.0
WEST										
England & Wales	32.6	17.8	20.8	4.9	-1.4	19.1	13.4	1.2	-2.6	2.2
Belgium	-18.7	14.2	5.3	3.9	-16.1	-3.8	-12.1	-2.2	-3.5	-2.2
France	13.4	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Switzerland	23.7	31.6	18.2	3.9	-1.7	-4.8	-1.5	0.8	-2.4	-0.2
SOUTH										
Barcelona	4.5	14.2	6.2	4.0	-10.5	-1.6	4.1	-0.9	-3.3	-0.7
Basque Country	-2.8	8.1	3.1	7.2	-3.1	-7.1	-6.7	0.1	-1.1	2.1
Madrid	14.1	-2.3	3.6	-1.3	0.0	-0.3	15.5	0.8	0.9	3.2
Turin	67.5	27.1	10.4	0.4	24.5	-1.8	27.8	n.a.	0.1	1.1
EAST										
Hungary	-60.6	16.2	-15.4	21.4	-61.9	-22.4	-8.1	-5.3	-6.8	-4.1
Lithuania	-410.9	-98.8	-26.1	-21.1	-117.4	-5.7	-75.2	n.a.	-119.4	-12.6
Estonia	-380.0	-130.6	-60.7	-15.1	-51.0	-10.6	-105.9	n.a.	-92.6	-2.9

(no shading) More mortality decline (or less mortality increase) among low than among high educated.

(light grey) Less mortality decline among low than among high educated.

(dark grey) Mortality increase among low educated, mortality decline (or less mortality increase) among high educated.

Difference between low and high educated in absolute mortality decline was calculated by subtracting the percentage mortality decline among the high educated from the absolute mortality decline among the low educated. In algebraic form: $(R_{1990,L}-R_{2000,L}) - (R_{1990,H}-R_{2000,H})$ in which R = age-standardized mortality rate, 1990 = 1990s, 2000 = 2000s, L = low educated, and H = high educated. For example, in the case of Finnish women, mortality declined by 123.1 and 138.6 per 100,000 among the low and high educated, respectively, and thus by -15.6 deaths per 100,000 more among the low educated. Grey shading indicates a disadvantage for the low educated; no shading indicates a disadvantage for the high educated. Difference in mortality decline could not be calculated for liver cirrhosis among women in Turin because of 0 deaths among high educated women in this population in the 2000s. Please note that the sum of the cause-specific changes does not always exactly equal the change for all-cause mortality, because of various adjustments and rounding.

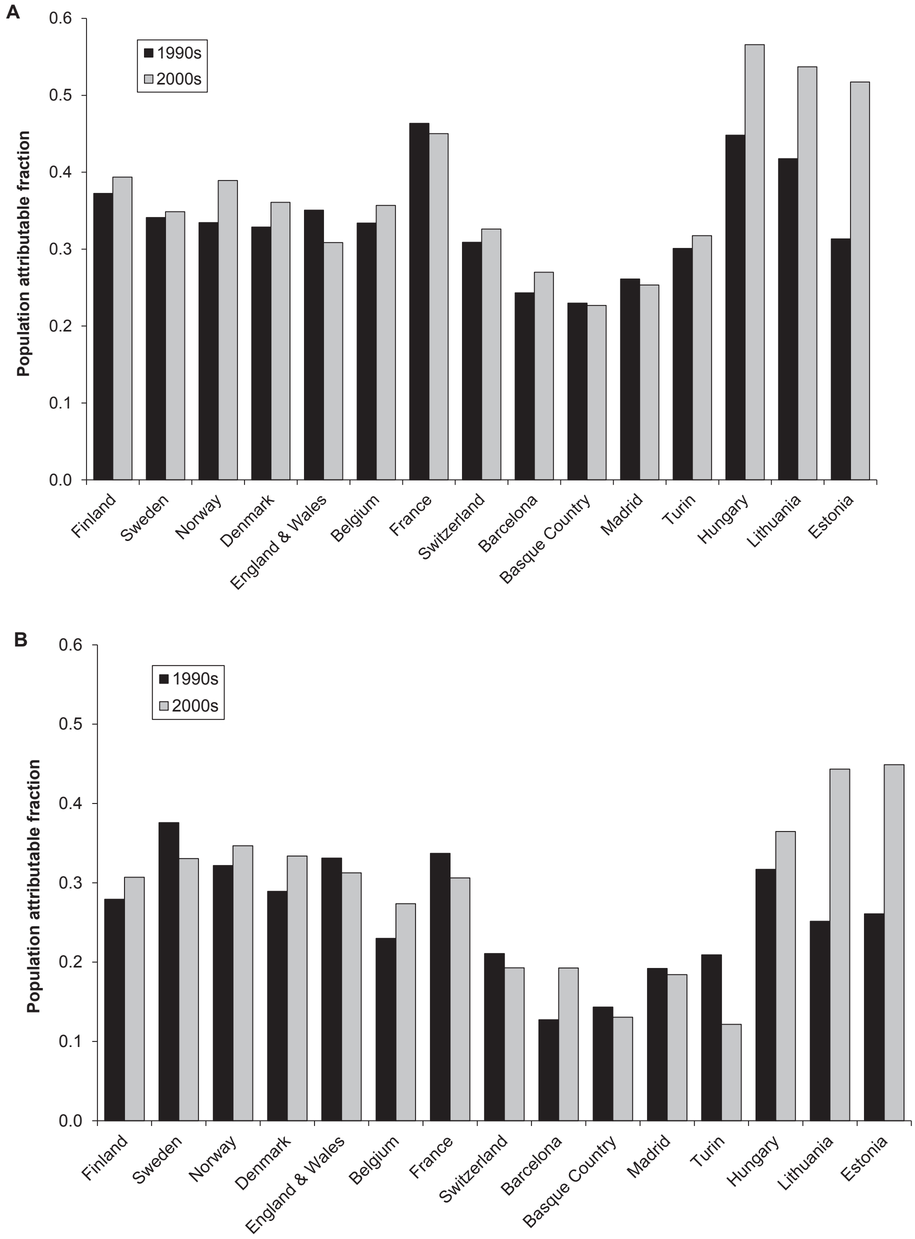


Figure 2 Changes between the 1990s and 2000s in population attributable fraction of education for all-cause mortality, by country and gender, (A) men, (B) women

Note: Population attributable fractions were calculated as $(M - M_{high})/M$, in which M = Age-standardized mortality rate in the whole population, and M_{high} = Age-standardized mortality rate among the high educated [26].

Chapter 5

ischaemic heart disease, cerebrovascular disease, all cancer, lung cancer (men only), and all other diseases (Tables 3A and 3B). Among men, the main exceptions are liver cirrhosis and external causes, for which several countries have experienced increases in mortality among the low educated. Among women, mortality has increased among the low educated for liver cirrhosis and external causes, and also for lung cancer in many countries. Rising all-cause mortality among the low educated in Lithuania and Estonia is due to rising mortality from a wide range of causes of death.

As mentioned above, in Northern, Western and Southern Europe absolute reductions in all-cause mortality have been larger among the low than among the high educated in many countries. This was often due, in large part, to larger absolute reductions for cardiovascular disease (Tables 3C and 3D). Among Finnish men, for example, the difference in decline of mortality between low and high educated was 75.3 deaths per 100,000 for all-cause mortality, of which 61.3 deaths per 100,000 are accounted for by cardiovascular disease mortality. In many countries, other causes of death, mainly cancer and all other diseases, contributed as well, but less so among women, which partly explains why larger absolute reductions in all-cause mortality among the low educated are more clearly and more often seen among men than among women.

Population attributable fractions

Over time, the proportion of higher educated has increased in all populations (Table 1), and larger inequalities in mortality between educational groups, therefore, do not necessarily imply that the population impact of these inequalities has become larger. However, as Figure 2 shows, the population attributable fractions have risen somewhat in many countries, among men and among women, particularly in Hungary, Lithuania and Estonia.

DISCUSSION

Summary of findings

Relative inequalities in premature mortality increased in most populations in the North, West and East of Europe, but not in the South. This was mostly due to smaller proportional reductions in mortality among the lower than the higher educated, but in the case of Lithuania and Estonia mortality rose among the lower and declined among the higher educated. Mortality among the lower educated rose in many countries for conditions linked to smoking (lung cancer, women only) and excessive alcohol consumption (liver cirrhosis and external causes). In absolute terms, however, reductions in premature mortality were larger among the lower educated in many countries, mainly due to larger absolute reductions in mortality from cardiovascular disease and cancer (men only). Despite rising levels of education, population attributable fractions of lower education for mortality rose in many countries.

Strengths and limitations

This is the most comprehensive analysis of trends in inequalities in mortality ever conducted, covering 13 countries with different socioeconomic and health conditions. However, its broad international scope inevitably raises issues of data comparability. Despite extensive harmonization efforts, our comparisons between countries and over time 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, Lithuania and Estonia, mortality data were collected in a cross-sectional unlinked design. A study comparing cross-sectional unlinked and longitudinal mortality data in Lithuania found that the former overestimated inequalities in mortality, but the bias was larger at older ages and significantly attenuated when the age limits were set to 30–74 years as in our study [28].

There are also differences between countries in population coverage. The most notable relate to Spain and Italy, for which only a few urban and relatively prosperous populations could be included that are not necessarily representative of the whole of Spain or Italy. However, studies of the situation in the 1980s, which used national data for Spain and Italy from methodologically less-refined sources, also found smaller inequalities in mortality there than in other European countries [2, 29], as did recent national-level studies from Spain [30] and Italy [31, 32], so there is no reason to think that our study misrepresents the situation in these Southern European countries.

Information on education was fairly complete in all countries, and the proportion of individuals with missing education ranged between 2% and 6% only. We reclassified national educational levels into the ISCED scheme, and this should have removed most differences in classification between countries. The main problem in our study concerns England and Wales, for which we had to pool together the 'low' and 'mid' educated because of the crude educational classification used in the 1990s mortality data. However, the sensitivity analysis reported in appendix (Table A4), in which a two-group classification was used in all countries, confirms that whereas many other countries experienced an increase in relative inequalities in all-cause mortality, England and Wales did not, and its absolute inequalities therefore also went down more than elsewhere. It would have been useful to add another indicator of socioeconomic position to our analysis, such as occupational class or income, but income is generally unavailable in mortality registers, whereas data on occupational class that are comparable between countries and over time are available for a small number of countries only [23].

As our analysis has focused on changes over time within countries, between-country variations in data collection do not pose a major risk of bias. Potentially more important are changes over time in data collection, but these have been minimal (Table 1). The main change has been in the length of follow-up and in the classification of person-years and deaths by age (see Table A2 in appendix). As our adjustment method for the latter problem could not be validated for the 1990s, and some uncertainty therefore remains concerning the comparability of absolute levels of mortality between the 1990s and 2000s, we have restricted analyses of absolute changes to within-country comparisons between the low and high educated, which are unlikely to be substantially biased. Still, our results require confirmation from national-level studies that are more strictly harmonized over time than is feasible in an international comparative study.

Our analysis covers the age group 30–74 years at baseline, and thereby excludes younger age groups, and also underrepresents older age groups which currently carry the largest share of the burden of mortality, particularly in Western Europe where average life expectancy at birth in the 2000s exceeded 75 years for men and 80 years for women. This implies that our results cannot necessarily be generalized to mortality in the whole population, and this may also explain discrepancies with the few national studies which have followed trends in inequalities in life expectancy into the 2000s and which cover a wider age range [9, 11]. In our data, educational inequalities in life expectancy from the age of 30 years have increased in most countries, whereas inequalities in partial life expectancy between age 30 and 75 have been stable or declined (results not shown).

Interpretation

This is the first study to systematically document and compare trends since the 1990s in inequalities in mortality for a larger number of countries. It shows that after the turn of the century, relative inequalities have continued to widen in most European countries, but that in contrast to previous periods [3] absolute reductions of mortality seem to have been larger among the low educated in many countries in the North, West and South of Europe. This may announce a future narrowing of the gap in mortality between educational groups, but for the time being, rising population attributable fractions indicate an increasing, not a diminishing public health problem.

As these larger absolute declines were often partly due to larger absolute reductions in mortality from cardiovascular disease, changes in 'proximate' determinants of cardiovascular disease, such as health-related behaviours (e.g., smoking, diet, exercise) and/

or health care interventions (e.g., hypertension detection and treatment, thrombolytic therapy), must have been larger among the low educated. Smoking-related inequalities are widening in many European countries [33, 34], so smoking is an implausible explanation. A recent narrowing of absolute inequalities in cardiovascular disease mortality has previously been reported for England [35], and has more likely been caused by an even distribution of treatment benefits [35] than of risk factor changes [36]. It is unlikely, on the other hand, that England's more favourable trends are related to its national policy to tackle health inequalities because the latter has not had clear population-wide effects [6, 37, 38].

Southern Europe presents a partly different pattern. Inequalities in mortality are smaller than elsewhere, and the relative gap has also widened less over time, as has been shown before for Barcelona [39]. Part of the explanation for smaller inequalities in mortality in Southern Europe is that inequalities in mortality from smoking-related and alcohol-related conditions, and from conditions amenable to medical intervention are relatively small, particularly among women [23]. Despite rising mortality from lung cancer among low educated women, and from liver cirrhosis among low educated men, Barcelona, the Basque Country, Madrid and Turin have been able to strengthen their favourable positions because differences in mortality decline between the low and high educated often were smaller than in other countries (Tables 3A and 3B). Further study of downstream and upstream determinants of inequalities in mortality in Southern Europe may help to better exploit this 'good practice' for mutual learning.

Inequalities in mortality in Eastern Europe have exploded during the study period, and in Lithuania and Estonia this was not due to differential mortality decline, as in other parts of Europe and in Hungary, but to a combination of rising mortality among the low, and declining mortality among the high educated [13]. The same has been observed in Russia [40]. It is likely that these unfavourable developments were caused by the economic crisis and the subsequent economic reforms that followed the collapse of the Soviet Union. In the early 1990s, Estonia and Lithuania experienced large declines in national income and large increases in unemployment rates, and more so than Eastern European countries that had not been part of the Soviet Union [13]. Our results point to the important contribution of mortality from external causes to the widening gap in all-cause mortality in these two countries (Table 3), which suggests a mediating role of excessive alcohol consumption. Migration patterns (e.g., selective emigration of higher educated and relatively healthier persons towards the West) may also have played a role.

CONCLUSIONS

Relative inequalities in premature mortality have continued to rise in most European countries, and since the 1990s the contrast between the South (with smaller inequalities) and the East (with larger inequalities) has become stronger. While the population impact of these inequalities has further increased, there are also some encouraging signs of larger absolute reductions in mortality among the lower educated in many countries. Reducing inequalities in mortality critically depends upon speeding up mortality declines among the lower educated, and countering mortality increases from conditions linked to smoking and excessive alcohol consumption such as lung cancer, liver cirrhosis and external causes.

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APPENDIX

Table A1 ICD codes of causes of death selected for the analysis

Causes of death	ICD-9 codes	ICD-10 codes
Ischaemic heart disease	410–414	I20–I25
Cerebrovascular disease	430–438	I60–I69
Lung cancer	162[a]	C33–C34[a]
Liver cirrhosis[b]	571.0–571.3, 577.0–577.1[c]	K70, K85–K86.0[c]
Road traffic accidents	E800–E829[d]	V01–V89, Y85[d]
Cardiovascular diseases	390–459	I00–I99
Cancer	140–239	C00–D48
Other diseases	Rest (001–799)	Rest (A00–R99)
External causes	E800–E999	V01–Y98

[a] 162–163, 165 (ICD-9) and C33–34, C39 (ICD-10) in most studies in the 1990s
[b] Alcoholic cirrhosis of liver and pancreas
[c] Not available for Estonia and Lithuania
[d] In Barcelona, England and Wales, Estonia and Lithuania, road traffic accidents were combined with other traffic accidents coded as E800–E848 (ICD-9) and V01–V99, Y85 (ICD-10)

Table A2 Data design and length of follow-up of Eurothine (1990s) and EURO-GBD-SE (2000s) datasets, with a note on the method of adjustment for age at baseline

Country	Eurothine (1990s)		EURO-GBD-SE (2000s)	
	Design	Follow-up (years)	Design	Follow-up (years)
Finland	age at baseline	10	age at death	7
Sweden	age at baseline	10	age at baseline	6
Norway	age at baseline	10	age at baseline	5
Denmark	age at baseline	5	age at baseline	5
England & Wales	age at baseline	5.5	age at death	5
Belgium	age at baseline	5	age at baseline	2
France	age at baseline	10	age at death	6
Switzerland	age at baseline	10	age at baseline	5
Barcelona	repeated CS	7	repeated CS	7
Basque Country	age at death	5	age at death	5
Madrid	age at death	1.5	age at death	1.5
Turin	age at baseline	10	age at death	5
Hungary	CS unlinked	4	CS unlinked	4
Lithuania	CS unlinked	3	CS unlinked	3
Estonia	CS unlinked	5	CS unlinked	5

Note: In longitudinal studies with classification by age at baseline, people are not allowed to move into the next age category as they grow older, and therefore age-specific mortality estimates obtained in these studies will be upwardly biased as compared to studies with classification by age at death. This upward bias will be larger with longer follow-up periods (and is generally absent in cross-sectional (CS) studies). For longitudinal studies with classification by age at baseline we therefore developed an adjustment method 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 2000s 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 [27]. As we did not have 1990s mortality data classified both by age at baseline and age at death, we could not directly validate this method for this time-period in which length of follow-up was generally larger. We were, however, able to compare our adjusted results with data from the Human Mortality Database (http://www.mortality.org/), and again found the method to work well, although the upward bias could not completely be removed for countries with long follow-up periods. We therefore restrict analyses of changes in absolute levels of mortality between the 1990s and 2000s to within-country comparisons of low and high educated, which are unlikely to be substantially biased, because the upward bias will have roughly the same effects on the low and high educated within a single country.

Table A3 Age-standardized mortality rates (per 100,000 person-years), by country, educational group, time-period and sex, 30–74 years

Country	Edu	MEN				WOMEN			
		1990s		2000s		1990s		2000s	
		ASMR	95%-CI	ASMR	95%-CI	ASMR	95%-CI	ASMR	95%-CI
NORTH									
Finland	low	1,438	(1,428–1,447)	1,076	(1,065–1,086)	613	(608–618)	490	(483–496)
	mid	1,158	(1,143–1,173)	808	(796–819)	471	(463–480)	340	(333–347)
	high	798	(784–812)	511	(501–522)	399	(389–409)	260	(253–267)
Sweden	low	944	(938–949)	754	(747–761)	531	(527–534)	469	(464–474)
	mid	745	(739–751)	573	(566–579)	409	(405–414)	344	(340–349)
	high	537	(528–546)	396	(388–404)	285	(279–291)	246	(240–252)
Norway	low	1,254	(1,243–1,265)	888	(873–903)	630	(624–636)	503	(493–513)
	mid	939	(930–948)	595	(586–605)	458	(452–464)	333	(327–340)
	high	676	(662–689)	381	(369–392)	359	(347–370)	241	(231–251)
Denmark	low	1,142	(1,130–1,154)	1,040	(1,028–1,052)	708	(700–715)	654	(646–662)
	mid	940	(928–953)	793	(782–803)	540	(529–551)	472	(463–481)
	high	657	(642–673)	534	(521–547)	443	(430–457)	362	(351–373)
WEST									
England & Wales	low[a]	947	(924–971)	728	(707–748)	552	(536–568)	468	(453–484)
	high	583	(536–631)	472	(434–510)	357	(314–401)	307	(276–338)
Belgium	low	1,035	(1,028–1,042)	846	(836–855)	485	(481–490)	424	(418–430)
	mid	799	(786–812)	633	(618–648)	382	(372–391)	336	(325–347)
	high	628	(615–642)	461	(448–474)	353	(342–364)	274	(263–284)
France	low	1,099	(1,074–1,124)	939	(908–971)	413	(400–425)	369	(353–385)
	mid	803	(771–835)	671	(642–700)	303	(281–325)	280	(259–300)
	high	509	(466–552)	412	(374–451)	251	(216–285)	220	(190–251)
Switzerland	low	1,283	(1,271–1,295)	834	(819–850)	505	(501–510)	365	(358–371)
	mid	895	(887–902)	549	(542–557)	390	(385–395)	259	(244–274)
	high	647	(637–656)	368	(359–376)	352	(339–365)	235	(224–246)

Table A3 Age-standardized mortality rates (per 100,000 person-years), by country, educational group, time-period and sex, 30–74 years (continued)

Country	Edu	MEN				WOMEN			
		1990s		2000s		1990s		2000s	
		ASMR	95%-CI	ASMR	95%-CI	ASMR	95%-CI	ASMR	95%-CI
SOUTH									
Barcelona	low	910	(897–922)	777	(765–789)	349	(343–356)	303	(297–309)
	mid	620	(597–644)	576	(556–596)	220	(205–236)	239	(225–252)
	high	606	(584–627)	485	(469–501)	285	(267–303)	221	(209–233)
Basque Country	low	824	(812–836)	759	(747–770)	302	(296–309)	285	(279–292)
	mid	691	(663–718)	597	(575–619)	270	(249–291)	253	(235–270)
	high	587	(558–615)	525	(503–548)	252	(230–274)	232	(215–249)
Madrid	low	979	(962–996)	861	(846–876)	371	(362–379)	326	(319–334)
	mid	866	(828–903)	721	(693–750)	324	(300–348)	313	(293–332)
	high	661	(631–692)	576	(552–600)	287	(262–313)	257	(238–276)
Turin	low	1,089	(1,073–1,105)	678	(662–695)	516	(507–525)	322	(312–332)
	mid	836	(806–866)	472	(448–496)	442	(419–464)	293	(273–313)
	high	705	(668–742)	404	(373–434)	397	(361–432)	270	(241–299)
EAST									
Hungary	low	2,426	(2,414–2,438)	2,424	(2,411–2,437)	949	(943–955)	872	(866–878)
	mid	1,515	(1,494–1,535)	1,128	(1,117–1,139)	868	(852–884)	525	(517–533)
	high	1,039	(1,020–1,059)	728	(714–741)	598	(578–618)	461	(447–474)
Lithuania[b]	low	1,622	(1,599–1,644)	2,315	(2,281–2,350)	640	(628–651)	924	(903–945)
	mid	1,233	(1,205–1,260)	1,367	(1,344–1,389)	488	(472–504)	444	(432–455)
	high	787	(749–824)	678	(651–705)	401	(374–427)	274	(259–289)
Estonia	low	2,014	(1,985–2,044)	2,567	(2,528–2,606)	831	(816–846)	1,053	(1,031–1,075)
	mid	1,621	(1,584–1,658)	1,904	(1,871–1,936)	722	(702–742)	694	(678–710)
	high	1,200	(1,150–1,249)	931	(895–968)	554	(521–586)	395	(375–416)

[a] low and mid educated combined
[b] age 30–69 years
ASMR = age-standardized mortality rate, 95%-CI = 95% confidence interval

Chapter 5

Table A4 Sensitivity analysis: effect of combining low and mid educated in one group. Rate Ratios (RR) of low-mid vs. high educated, 1990s and 2000s, 30–74 years

Country	Education	MEN				WOMEN			
		1990s		2000s		1990s		2000s	
		RR	95%-CI	RR	95%-CI	RR	95%-CI	RR	95%-CI
NORTH									
Finland	low-mid	1.87	(1.83–1.90)	1.89	(1.85–1.93)	1.48	(1.44–1.53)	**1.62**	(1.57–1.67)
	high	1		1		1		1	
Sweden	low-mid	1.63	(1.60–1.66)	1.68	(1.64–1.72)	1.71	(1.67–1.75)	1.63	(1.59–1.67)
	high	1		1		1		1	
Norway	low-mid	1.64	(1.61–1.67)	**1.87**	(1.81–1.93)	1.53	(1.48–1.59)	**1.68**	(1.61–1.76)
	high	1		1		1		1	
Denmark	low-mid	1.63	(1.59–1.68)	**1.76**	(1.72–1.81)	1.50	(1.45–1.55)	**1.65**	(1.60–1.70)
	high	1		1		1		1	
WEST									
England & Wales	low-mid	1.65	(1.51–1.80)	1.55	(1.43–1.69)	1.55	(1.36–1.75)	1.52	(1.36–1.69)
	high	1		1		1		1	
Belgium	low-mid	1.61	(1.57–1.65)	**1.74**	(1.69–1.79)	1.34	(1.30–1.39)	**1.48**	(1.42–1.55)
	high	1		1		1		1	
Switzerland	low-mid	1.58	(1.56–1.61)	**1.70**	(1.66–1.74)	1.27	(1.22–1.32)	1.28	(1.22–1.35)
	high	1		1		1		1	
SOUTH									
Barcelona	low-mid	1.57	(1.50–1.63)	1.50	(1.45–1.56)	1.39	(1.29–1.49)	1.34	(1.26–1.42)
	high	1		1		1		1	
Basque Country	low-mid	1.44	(1.36–1.51)	1.43	(1.37–1.50)	1.23	(1.12–1.35)	1.35	(1.24–1.46)
	high	1		1		1		1	
Madrid	low-mid	1.50	(1.43–1.58)	1.50	(1.43–1.57)	1.34	(1.22–1.47)	1.28	(1.18–1.39)
	high	1		1		1		1	
Turin	low-mid	1.51	(1.43–1.59)	1.53	(1.41–1.66)	1.25	(1.14–1.37)	1.19	(1.07–1.33)
	high	1		1		1		1	
EAST									
Hungary	low-mid	2.00	(1.96–2.04)	**2.51**	(2.47–2.56)	1.58	(1.53–1.64)	**1.79**	(1.73–1.84)
	high	1		1		1		1	
Lithuania[a]	low-mid	2.00	(1.90–2.10)	**2.42**	(2.33–2.53)	1.47	(1.37–1.58)	**1.99**	(1.87–2.11)
	high	1		1		1		1	
Estonia	low-mid	1.68	(1.61–1.75)	**2.31**	(2.22–2.41)	1.44	(1.36–1.54)	**1.99**	(1.88–2.10)
	high	1		1		1		1	

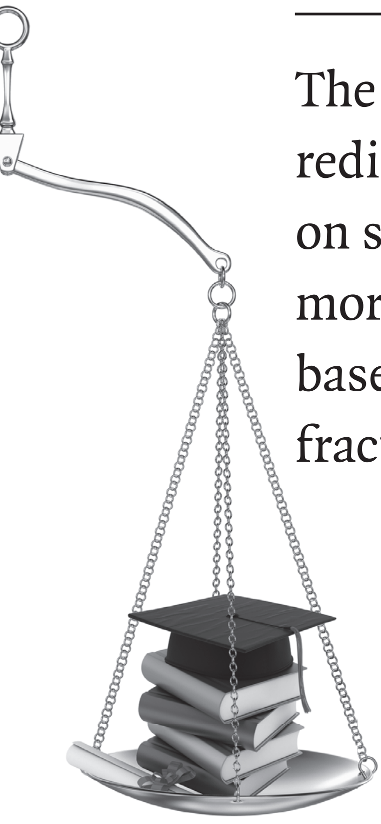
In **bold**: no overlap in 95%-CI of RR between 2000s and 1990s
[a] 30–69 years

Part III

Potential reduction of educational inequalities in mortality

6

The potential impact of a social redistribution of specific risk factors on socioeconomic inequalities in mortality: illustration of a method based on population attributable fractions



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ABSTRACT

Background

Socioeconomic differences in health are a major challenge for public health. However, realistic estimates to what extent they are modifiable are scarce. This problem can be met through the systematic application of the population attributable fraction (PAF) to socioeconomic health inequalities.

Methods

The authors used cause-specific mortality data by educational level from Belgium, Norway and Czech Republic and data on the prevalence of smoking, alcohol, lack of physical activity and high body mass index from national health surveys. Information on the impact of these risk factors on mortality comes from the epidemiological literature. The authors calculated PAFs to quantify the impact on socioeconomic health inequalities of a social redistribution of risk factors. The authors developed an Excel tool covering a wide range of possible scenarios and the authors compared the results of the PAF approach with a conventional regression.

Results

In a scenario where the whole population gets the risk factors prevalence currently seen among the highly educated inequalities in mortality can be reduced substantially. According to the illustrative results, the reduction of inequality for all risk factors combined varies between 26% among Czech men and 94% among Norwegian men. Smoking has the highest impact for both genders, and physical activity has more impact among women.

Conclusions

After discussing the underlying assumptions of the PAF, the authors concluded that the approach is promising for estimating the extent to which health inequalities can be potentially reduced by interventions on specific risk factors. This reduction is likely to differ substantially between countries, risk factors and genders.

INTRODUCTION

Inequalities in health between socioeconomic groups are increasingly recognized as one of the main challenges for health policy [1]. Studies from Europe have shown that health inequalities are substantial but that there are important variations between countries in the magnitude of health inequalities [2-4], suggesting great scope for reducing health inequalities. However, it is currently unknown to what extent they are actually modifiable, which is a serious barrier for effective policy making, because it hinders priority setting and the formulation of realistic quantitative targets.

We know that inequalities in risk factors between socioeconomic groups are larger in some countries than in others and that countries with smaller inequalities in risk factors have smaller inequalities in mortality [4]. Until recently, however, methods to quantify the impact of changing risk factor distributions have not been applied to proximate risk factors and social inequalities in health. We do that by linking risk factors to health outcomes through the population attributable fraction (PAF). The PAF, first introduced for a single dichotomous risk factors [5], has since been used to quantify the contribution of risk factors to disease burden, also for multiple and continuous risk factors, and for comparative risk assessment as input for public health interventions [6-9].

We demonstrate how the PAF can be applied to socioeconomic inequalities in mortality on the basis of a counterfactual scenario using example data from three European countries. The scenario implies that the prevalence of four risk factors, single and combined, is reduced to the level currently seen among the highest educated. This scenario is first analysed for its impact on mortality and consequently in terms of its impact on educational differences in mortality in order to show the usefulness of the proposed method and the potential for reduction of health inequalities.

DATA

To illustrate our approach, we use data that have previously been collected for the Eurothine project [4]. It allows differentiation by gender, five age groups (30–44, 45–59, 60–69, 70–79 and 80+), three educational groups (ISCED 0–2, ISCED 3–4, ISCED 5–6), all-cause mortality and three causes of death (ischaemic heart disease, cerebrovascular disease and lung cancer) for Norway, Belgium and the Czech Republic. These countries have different welfare arrangements [10] and differ by educational structure as well as in the prevalence of risk behaviours (Table A1 in appendix).

The data needed for calculating PAF are (1) prevalence data and (2) mortality rate ratios (RRs) for all categories of the risk factors: information on risk factor prevalence is based on national health surveys from Belgium (1997), Norway (2002) and the Czech Republic (2002), and mortality data were obtained from the national statistical offices of Belgium (1991–1995), Norway (1990–2000) and Czech Republic (1999–2003). All data sets are harmonized for international comparability, that is, categories of risk factors are made comparable as far as possible [11]. The RRs are gender and age specific and come from systematic reviews with statistical meta-analysis (Table A2 in appendix) [12, 13]. The relative risks are assumed to be the same for all countries.

METHODS

We adapt the PAF in order to estimate the impact of counterfactual distributions of risk factors on the magnitude of health inequalities. The PAF is an estimate of the proportion of a population health outcome that would be reduced if exposure to a risk factor were changed (equation 1 in Box 1) [14-17]. We calculate the PAF for four proximate risk fac-

Box 1: Population Attributable Fraction

Equation 1

$$PAF = \frac{\sum_{i=1}^{n} P_i RR_i - \sum_{i=1}^{n} P_i' RR_i}{\sum_{i=1}^{n} P_i RR_i}$$

n = number of exposure categories
P_i = proportion of population currently in the *i*th exposure category
P'_i = proportion of population in the *i*th exposure category in the counterfactual scenario
RR_i = relative risk of disease-specific mortality for the *i*th exposure category

Many diseases are cause by multiple risk factors. In order to estimate the combined impact of more than one risk factor on the occurrence of mortality, equation 2 is used to calculate an attributable fraction that takes into account multicausality [17].

Equation 2

$$PAF = 1 - \prod_{i=1}^{n} (1 - PAF_i)$$

PAF_i = the proportion of the disease preventable by reducing exposure to the *i*th risk factor.
The product of all $(1 - PAF_i)$ represents the fraction of disease not preventable through interventions on any of the *n* risk factors.

tors separately and combined. This impact is analysed separately for each educational group and then combined in order to calculate the scenario´s impact on mortality in the total population and on mortality differences between educational groups.

In order to obtain accurate estimates of the impact of our scenario on inequalities in mortality, we stratified the analysis by gender, age and cause of death. For example, there are substantial differences between men and women in how educational status relates to health [18] and in the determinants of educational inequalities in health [19]. Also, the impact of risk factors on mortality is different at different ages and according to different causes of death [20, 21]. The age-specific results (not shown) are used to calculate PAFs for all ages by summing up the saved deaths over age categories.

RESULTS

The impact of the scenarios will be addressed in two ways: first by calculating the PAF showing the reduction in mortality achieved by a social redistribution of risk factors and second, the impact of such redistribution on inequality in mortality.

The potential avoidance of deaths in the total population

Table 1 presents estimates of the expected decrease of cause-specific and all-cause mortality, given that the exposure to physical activity, alcohol, smoking and body mass index (BMI) would change to the level among the higher educated.

A change in the exposure of all risk factors would cause the largest reduction of all-cause mortality among Norwegian men (16.9%) for which smoking seems to contribute the most (10.6%). However, looking at Belgian women, the overall PAF of all-cause mortality is only 7.1 in which smoking and alcohol do not contribute much (1.4% and 0.2%, respectively). In order to understand these results, it is noteworthy that the magnitude of the PAF depends on two components: first, the difference in prevalence between educational groups and second, the impact of a risk factor on mortality. Smoking seems to be most important for men, while for women, physical inactivity is most important (except for the Czech Republic).

The potential reduction of inequalities in mortality between educational groups

Table 2 shows how our scenario reduces inequality in all-cause mortality, and Table 3 shows the same for three single causes of death. In both tables, we first present original mortality RRs for educational groups, with the highest educational group as the refer-

Table 1 The PAF (in %) of cause-specific and all-cause mortality in the total population given the scenario that the prevalence of physical activity, alcohol consumption, smoking and BMI (separately and combined) would be found at the level currently seen in the high educational group

Cause of death	Ischaemic heart disease					Cerebrovascular disease					Lung cancer					% of saved deaths from 3 causes out of saved deaths from all causes	All-cause mortality				
Risk factor	PA	ALC	Smoking	BMI	All	PA	ALC	Smoking	BMI	All	PA	ALC	Smoking	BMI	All		PA	ALC	Smoking	BMI	All
MEN																					
Belgium	2.9	2.3	3.6	2.2	10.2	2.0	0.6	1.9	0.8	5.0	0.0	0.0	13.9	0.0	13.9	45.18	1.9	0.4	3.5	1.7	7.1
Czech Republic	1.9	0.3	6.0	2.2	9.9	1.2	1.0	3.7	1.1	6.6	0.0	0.0	37.9	0.0	37.9	48.89	1.4	0.4	8.5	2.6	12.3
Norway	6.3	2.7	7.4	2.3	17.1	4.9	0.7	5.0	1.0	11.0	0.0	0.0	38.1	0.0	38.1	42.40	4.3	0.7	10.6	2.5	16.9
WOMEN																					
Belgium	3.9	2.3	1.2	3.5	10.1	3.4	0.2	0.8	1.4	5.6	0.0	0.0	8.4	0.0	8.4	26.06	3.1	0.2	1.4	2.5	7.1
Czech Republic	3.5	0.1	3.3	3.8	10.4	3.4	0.1	2.4	1.7	7.4	0.0	0.0	26.2	0.0	26.2	39.82	3.0	0.4	4.1	3.2	10.4
Norway	5.8	1.7	4.2	2.7	13.3	5.3	0.4	3.3	1.3	9.8	0.0	0.0	25.6	0.0	25.6	46.67	4.6	0.2	3.3	1.9	9.6

The PAFs for the total population are derived from specific PAFs for each educational group. The cause-specific calculations are separate from the all-cause calculations. Education is measured on three levels: (1) primary and lower secondary education (ISCED levels 0–2), (2) higher and post-secondary education (ISCED 3–4) and (3) tertiary education (ISCED 5–6). Tobacco consumption is measured as smoking status distinguishing two categories: smokers (current, regular and occasional) versus non-smokers (ex-smokers and never-smokers). Alcohol consumption is divided into four drinking categories ('D'): no alcohol (no drinks containing alcohol within the last year), DI (0–19.99 g of pure alcohol daily (women) and 0–39.99 g (men)), DII (20–39.99 g (women) and 40–59.99 g (men)) and DIII (>40 g (women) and >60 g (women)). Physical activity is measured in three categories: sedentary or almost sedentary, middle and high level of physical activity. The measurement of BMI is based on three categories (<25, 25–30 and more than 30 kg/m^2). Causes of death were coded according to the ICD 9th and 10th revision: ischaemic heart disease (ICD-9: 410–414; ICD-10: I20–I25), cerebrovascular disease (ICD-9: 430–438; ICD-10: I60–I69) and lung cancer (ICD-9: 162–163, 165; ICD-10: C33–C34, C39).

ALC = alcohol consumption, BMI = body mass index, PA = physical activity, PAF = population attributable fraction

Table 2 All-cause mortality (RR) by educational group for men and women in three European countries, and scenario RRs (with percentage reduction of inequality as compared to the original RRs) based on the assumption that the prevalence of physical activity, alcohol consumption, smoking and BMI (both separately and combined) would be distributed as in the highest educational group

	$_{original}RR$		$_{scenario}RR_{Physical\ activity}$				$_{scenario}RR_{Alcohol}$				$_{scenario}RR_{Smoking}$				$_{scenario}RR_{BMI}$				$_{scenario}RR_{All\ factors\ combined}$			
Educational level	Low	Mid	Low	% Red	Mid	% Red	Low	% Red	Mid	% Red	Low	% Red	Mid	% Red	Low	% Red	Mid	% Red	Low	% Red	Mid	% Red
MEN																						
Belgium	1.51	1.20	1.48	7	1.20	2	1.51	1	1.20	2	1.45	13	1.17	14	1.48	6	1.19	8	1.36	29	1.16	22
Czech Republic	2.49	1.36	2.45	3	1.36	2	2.48	1	1.36	2	2.24	17	1.30	17	2.42	5	1.35	3	2.11	26	1.28	23
Norway	1.50	1.22	1.42	17	1.18	18	1.49	3	1.22	2	1.28	44	1.12	45	1.46	9	1.19	14	1.03	94	1.08	64
WOMEN																						
Belgium	1.37	1.06	1.32	13	1.05	16	1.37	1	1.06	1	1.35	5	1.04	42	1.33	11	1.05	20	1.24	35	1.04	43
Czech Republic	1.88	1.23	1.82	7	1.21	10	1.87	1	1.23	1	1.81	9	1.14	39	1.81	8	1.21	8	1.62	29	1.17	28
Norway	1.41	1.14	1.33	20	1.11	24	1.41	0	1.14	1	1.35	15	1.11	21	1.38	8	1.13	12	1.17	59	1.08	46

RR = rate ratio of mortality according to educational attainment, low = primary and lower secondary education compared with tertiary education, mid = higher and post-secondary education compared with tertiary education, $_{scenario}RR$ = scenario rate ratio, BMI = body mass index

Table 3 Cause-specific mortality (RR) by educational group for men and women in three European countries and scenario RRs (with percentage reduction of inequality as compared with the original RRs) based on the assumption that the prevalence of physical activity, alcohol consumption, smoking and BMI (both separately and combined) would be distributed as in the highest educational group

	${}_{original}RR$		${}_{scenario}RR_{Physical\ activity}$				${}_{scenario}RR_{Alcohol}$				${}_{scenario}RR_{Smoking}$				${}_{scenario}RR_{BMI}$				${}_{scenario}RR_{All\ factors\ combined}$			
Education	Low	Mid	Low	% Red	Mid	% Red	Low	% Red	Mid	% Red	Low	% Red	Mid	% Red	Low	% Red	Mid	% Red	Low	% Red	Mid	% Red
Ischaemic heart disease																						
MEN																						
Belgium	1.39	1.21	1.34	13	1.20	4	1.34	11	1.20	6	1.32	17	1.18	15	1.35	10	1.19	9	1.19	52	1.15	28
Czech Republic	2.47	1.38	2.41	4	1.37	2	2.46	0	1.38	2	2.29	12	1.33	12	2.40	5	1.37	3	2.16	21	1.31	19
Norway	1.69	1.32	1.55	20	1.26	21	1.62	10	1.30	7	1.50	28	1.25	22	1.64	7	1.29	10	1.17	76	1.16	51
WOMEN																						
Belgium	1.64	1.04	1.57	11	1.03	32	1.60	7	1.04	9	1.62	3	1.02	51	1.57	10	1.02	38	1.41	36	1.01	80
Czech Republic	2.26	1.26	2.18	6	1.23	12	2.26	0	1.26	0	2.18	7	1.19	26	2.16	8	1.24	8	1.94	25	1.20	23
Norway	1.72	1.26	1.60	17	1.21	18	1.69	5	1.24	6	1.62	14	1.22	15	1.67	8	1.23	10	1.31	57	1.16	38
Cerebrovascular disease																						
MEN																						
Belgium	1.41	1.19	1.37	9	1.19	2	1.40	3	1.18	4	1.37	8	1.17	8	1.39	3	1.18	4	1.3	25	1.16	15
Czech Republic	2.52	1.28	2.49	2	1.27	3	2.50	2	1.27	4	2.41	7	1.25	10	2.49	2	1.27	2	2.31	14	1.23	17
Norway	1.38	1.20	1.29	24	1.15	22	1.37	4	1.19	3	1.27	28	1.16	21	1.36	4	1.19	7	1.07	80	1.11	44
WOMEN																						
Belgium	1.38	1.06	1.33	14	1.05	14	1.38	1	1.06	1	1.37	4	1.05	25	1.36	6	1.06	9	1.27	28	1.04	35
Czech Republic	1.96	1.09	1.89	7	1.07	27	1.95	0	1.09	1	1.9	6	1.05	49	1.92	4	1.08	11	1.76	21	1.05	44
Norway	1.35	1.12	1.26	25	1.08	32	1.39	2	1.12	3	1.29	18	1.09	24	1.33	6	1.11	10	1.11	70	1.06	54

Table 3 Cause-specific mortality (RR) by educational group for men and women in three European countries and scenario RRs (with percentage reduction of inequality as compared with the original RRs) based on the assumption that the prevalence of physical activity, alcohol consumption, smoking and BMI (both separately and combined) would be distributed as in the highest educational group (continued)

	$_{original}RR$		$_{scenario}RR_{Physical\ activity}$				$_{scenario}RR_{Alcohol}$				$_{scenario}RR_{Smoking}$				$_{scenario}RR_{BMI}$				$_{scenario}RR_{All\ factors\ combined}$			
Education	Low	Mid	Low	% Red	Mid	% Red	Low	% Red	Mid	% Red	Low	% Red	Mid	% Red	Low	% Red	Mid	% Red	Low	% Red	Mid	% Red
Lung cancer																						
MEN																						
Belgium	2.18	1.43	2.18	0	1.43	0	2.18	0	1.43	0	1.83	29	1.29	32	2.18	0	1.43	0	1.78	34	1.31	26
Czech Republic	3.99	1.83	3.99	0	1.83	0	3.99	0	1.83	0	2.31	56	1.41	50	3.99	0	1.83	0	2.22	59	1.43	48
Norway	1.99	1.43	1.99	0	1.43	0	1.99	0	1.43	0	1.05	95	0.95	111	1.99	0	1.43	0	0.71	130	1.03	94
WOMEN																						
Belgium	1.41	1.23	1.41	0	1.23	0	1.41	0	1.23	0	1.27	33	1.08	66	1.41	0	1.23	0	1.27	35	1.14	39
Czech Republic	1.56	1.42	1.56	0	1.42	0	1.56	0	1.42	0	1.14	75	0.91	121	1.56	0	1.42	0	1.08	87	1.14	67
Norway	2.19	1.40	2.19	0	1.40	0	2.19	0	1.40	0	1.47	61	1.09	77	2.19	0	1.40	0	1.42	65	1.10	74

In three cases, the reduction of inequality in per cent is larger than 100, which means that the social gradient in cause-specific mortality is reversed.

Chapter 6

ence group, and second, scenario RRs with percentage reduction of inequality. The scenario RRs result from reducing the original levels of mortality in each educational group by the PAF values presented in Table 1.

The reduction of inequality is expressed in percentages, that is, how much the excess mortality (RR-1) is reduced. Increasing the level of physical activity has a comparatively large effect in Norway. The resulting reduction of inequality is 17% and 20% for Norwegian men and women, respectively. A similar change in the pattern of alcohol consumption would hardly alter the RRs. However, a change in the smoking pattern seems to be associated with a large decrease of inequality in some countries and mainly with respect to Norwegian men where a 44% reduction of inequality is observed. This substantial reduction occurs because the social smoking gradient is particularly high among Norwegian men and even more so in the higher ages where most deaths occur. With regard to the scenario RRs of BMI, it seems that inequalities in health would be reduced only modestly by a redistribution of BMI but still slightly more than for alcohol. The combined impact of all four risk factors would reduce inequalities in health in all countries, particularly for men but still substantial for women. Reductions of inequality between lowest and highest educated groups are between 26% (Czech men) and an almost total elimination of inequalities among Norwegian men (94%). With regard to

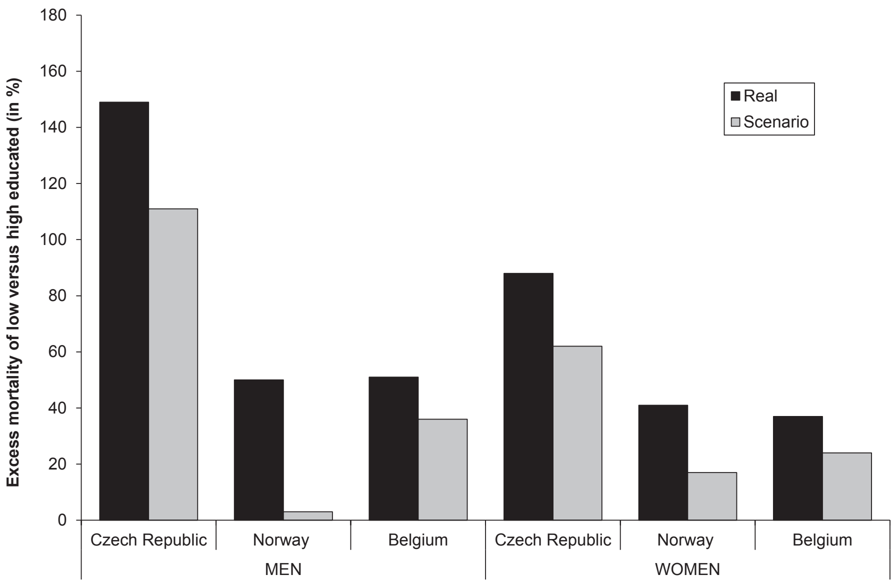

Figure 1 The potential reduction of health inequalities given the scenario that all educational groups have the same behaviour as the higher educated in terms of physical activity, alcohol consumption, smoking and body mass index

the cause-specific results in Table 3, we see that the scenario on physical activity has an almost equal impact on inequality in ischaemic heart disease and cerebrovascular disease, alcohol on ischaemic heart disease, smoking on lung cancer and BMI on ischaemic heart disease.

Figure 1 provides a graphical presentation of the impact of our scenario on social inequality in all-cause mortality. It presents the excess mortality of the low compared with the high educated in per cent (y-axis), and this for the original RRs (real) and the adjusted RRs (scenario). The graphical presentation confirms the results described above suggesting that inequalities in all-cause mortality can potentially be reduced substantially in all countries for both men and women by a redistribution of the four risk factors. In the case of Norwegian men, this scenario may be sufficient to almost eliminate social inequality in mortality.

DISCUSSION

We have shown how the PAF approach can be used to calculate the impact of changes in the social distribution of proximate risk factors, first on mortality and second on the magnitude of socioeconomic inequalities in mortality in different countries. The fraction of all-cause mortality preventable by a redistribution of physical activity, alcohol consumption, smoking and BMI to the level observed among the higher educated is typically above 10% for men and below 10% for women. There are large variations between countries, gender and risk factors, Norwegian men being the group with the highest fraction of avoidable deaths, mainly due to smoking. Inequalities in all-cause mortality can potentially be reduced for both men and women by a redistribution of risk factors by education but in most cases not sufficiently to totally eliminate them. Although the highest inequality in mortality exists in the Czech Republic, we see the highest potential reduction in Norway due to a higher impact of physical activity and smoking.

Although not exactly comparable, other studies show results of a similar order of magnitude: levelling both smoking behaviour and physical activity could reduce inequality in mortality by 25% for men and women combined in the Netherlands [22] and smoking behaviour alone reduces inequality by 32% in England [23]. Laaksonen et al. [24] show that levelling physical activity could reduce inequality for both lowest and middle educated by 14% among men and 9% among women and levelling smoking behaviour reduces inequality for the lowest educated by 28% among men and 22% among women. It should be mentioned that our choice of the highest socioeconomic group as the counterfactual prevalence implies that the percentage reduction in the excess RR will be the same as that in the absolute mortality rate. This would not be the case if an even more optimistic scenario was used, for example, total elimination of smoking. In the following, we will discuss specific limitations of our study, assumptions inherent to the PAF methodology and a comparison of the PAF approach to a regression analysis.

Limitations

First, the categories used in the prevalence data and the categories for which the RRs are found in the literature sometimes differed between countries and could not always be perfectly harmonized. Second, we used risk factor data that were measured at the same time or after the mortality data were registered. Ideally, the mortality outcome would be measured after the risk factor, including a risk factor-specific latency time. Depending on the trend of social differences in risk factor prevalence by country and risk factor, our PAFs may be overestimated or underestimated. We made sensitivity analyses based on Norwegian data from the cross-sectional Health Surveys conducted by Statistics Norway in 1975, 1985, 1995, 1998, 2002 and 2005. Overall, the trends in risk factors between 1975 and 2005 were similar between educational levels. Among men, social difference in alcohol consumption slightly widened, while they narrowed among women. In the first case, our PAF estimates would be too high and in the second too low. On the contrary, social differences in physical activity narrowed among men and widened among women. Finally, social differences in smoking behaviour increased, also implying an overestimation of the PAF estimates. However, most of these differences were marginal. By far the most differential trend occurred for smoking among women where the prevalence of persons who do not smoke daily decreased by 1.7% for low educated and increased by 5.2% for high educated every 10 years. A similar exercise with Belgian data of ever/never-smokers by birth cohort revealed similar trends for different educational groups. Because this problem in principle limits the substantial interpretation of the results [25], we would like to stress that this article is driven by illustrative purposes on how to apply the PAF method to socioeconomic differences in mortality. Third, for the same reason, we also did not calculate CIs for the results. This would be possible by calculating SEs for the normal distributions of log-rate-ratios and for the multinomial distributions of prevalences, using number of deaths and sample sizes, respectively. Given the necessary background data, one could obtain the SE and CIs of the resulting PAF distribution with bootstrapping. However, data gathering and computational effort are beyond the scope of this article.

The first fundamental assumption of the PAF approach is that the relative risks used in the PAF calculation accurately reflect the causal effects of the risk factors on mortality [7, 9]. We consider the assumption of causality from the proximate risk factor to mortality to be unproblematic because we relied on systematic reviews that have tried to filter out

the causal relationship between risk factors and mortality. For example, the relative risks collected by the GBD study were adjusted for correlation between risk factors, confounding and mediation [26]. The more uncertain causality from education to risk factors does not have to be assumed here because we simply show the effect of redistributing risk factors but we do not interpret our results as an explanation of health inequalities.
Second, the relative risks for the proximate risk factors are assumed to be the same for all three countries [8]. This assumption is necessary for practical reasons, simply because there are no high-quality literature reviews on the impact of risk factors for each country. Here again, we rely on the Global Burden of Disease project. There is an increasing body of evidence stating that, when the metric of exposure is comparable, the RRs are similar across populations in different world regions [26].

Third, the relative risks of the proximate risk factors are assumed to be the same for all educational groups. Whether a RR of, for example, smoking can be regarded as a biological constant or whether the impact of smoking differs between socioeconomic groups is still an open question [27]. Evidence from the Whitehall II study suggests that smoking is more harmful for those placed lower in the social hierarchy [28], and evidence from New Zealand shows that the impact of smoking on mortality varies over time and by ethnicity [29] but again there is no systematic data on how the impact of proximate risk factors differs by socioeconomic group.

Finally, the multicausal relationship in equation 2 is based on the assumption that exposures to risks are uncorrelated. In the present paper, we can account for the correlation with education by stratifying the analysis by educational group. Equation 2 also assumes that the effect of one risk factor is not mediated through another risk factor [30]. In reality, it is likely that changing the distribution of one risk factor will also affect the distribution of other risk factors. As noted above, this potential bias has been partly corrected by adjusted RRs. For the close relation between physical activity and BMI, there remains uncertainty whether all bias has been removed because we had to use RRs from several studies (Table A2 in appendix) using different correction methods.

The PAF approach compared with the conventional regression approach

The research questions of this study may also be addressed with other methods, such as regression analysis [19]. We therefore find it important to evaluate whether the PAF approach differs from a conventional Poisson regression in the quantification of the impact of a risk factor on social inequality in mortality. The cohort study GLOBE [31] provides individual data that can be exploited for a regression analysis as well as for the PAF calculation explained above. The categories for the variables are the same as in our PAF calculation above. Table 4 includes (1) the current situation (first three rows with

Table 4 Contribution of differential health behaviour to educational differences in mortality in a comparison between Poisson regression and the population attributable fraction (PAF) approach

	Regression approach	PAF approach		
Educational level	Mortality rate ratios between educational groups	Mortality rates (per 100.000)		Mortality rate ratios between educational groups
	Empty model	At onset		At onset
low	1.724		1496.4	1.724
middle	1.348		1169.9	1.348
high	1		868.1	1
			PAF values	
low			0.021	
middle			0.010	
high			0	
	Adjusted for smoking	Scenario 1: smoking behaviour is as among the High educated (mortality rates are reduced by the PAF values from above		
low	1.687		1464.3	1.687
middle	1.334		1158.0	1.334
high	1		868.1	1
			PAF values	
low			0.216	
middle		Smoking	0.200	
high			0.186	
low			0.140	
middle		BMI	0.126	
high			0.109	
low			0.485	
middle		Physical activity	0.441	
high			0.419	
low			0.653	
middle		3 risk factors combined	0.609	
high			0.578	
	Adjusted for smoking, BMI and physical activity and all interactions	Scenario 2: all three risk factors are eliminated (mortality rates are reduced by the PAF values for three risk factors combined from above)		
low	1.454		519.3	1.418
middle	1.380		457.2	1.249
high	1		366.2	1

Data source: GLOBE study [31] (n = 13,804)
BMI = body mass index

data), (2) a scenario where the smoking prevalence of the high educated is assumed for the whole population and (3) a scenario where the risk factors smoking, high BMI and low physical activity are completely eliminated. The left part of Table 4 contains the regression results: we first estimate the effect of education on mortality. Then, we adjust for smoking status in order to show how much levelling social differences in smoking would change social inequality in mortality. By controlling for smoking inequality in mortality between the highest and the lowest educational group decreases from 1.72 to 1.69. The right part of Table 4 shows the PAF approach: mortality rates and PAF values for the three educational groups, and below the mortality rates and RRs. For the first scenario where only the risk factor smoking is involved, the results of the PAF approach are the same as from the regression (1.72 and 1.69).

In the first scenario, the results of the two approaches are the same if and only if we use the RR for the impact of smoking from a regression that controls for education. The second scenario where all three risk factors are eliminated is equivalent to a regression model where the interaction of each risk factor with education and all two-way interactions are included. For this scenario, we see that the results from the PAF approach differ from the regression. This is because the combined effect of several risk factors in the PAF approach is calculated with equation 2, which assumes that risk factors are uncorrelated and that there is no mediation. This assumption has been discussed above, and the comparison in Table 4 shows the magnitude of the resulting bias in a real data set.

The main advantage of the PAF approach is that it can combine data from different sources, while a regression necessarily measures the risk exposure and the outcome in the same sample. This is not an advantage as such, but in many situations, country-specific data on both exposure and impact are not available. Moreover, results from large literature reviews (as used in our study) might be more accurate than small national surveys. The second advantage is that the PAF approach can address many scenarios where both prevalences and RRs are changed to any possible value in a straightforward way, while comparable regression results can only be obtained using a complex structure of dummy variables.

CONCLUSIONS

We show how the PAF methodology, which previously has only been used to calculate the contribution of risk factors to overall levels of health, can be systematically applied to socioeconomic inequalities in health. The results are similar to a conventional regression but the data requirements are much easier to meet, which facilitates comprehensive comparative studies across many countries. Our analysis shows the extent to which health inequalities can realistically be reduced by interventions on proximate risk factors. Such interventions may have targets that are more or less ambitious than the ones we have assumed here, but for policy setting, it is crucial to know the gender, country and risk factor-specific effects on health inequality.

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APPENDIX

Table A1 Prevalence (in %) of education and four proximate risk factors by country, gender, age and educational group (Belgium, Czech Republic and Norway)

BELGIUM		MEN					WOMEN				
		30-44	45-59	60-69	70-79	80+	30-44	45-59	60-69	70-79	80+
Education	low	47.9	64.4	76.0	81.1	84.9	49.5	70.9	82.8	88.5	91.4
	middle	29.4	19.8	14.4	10.4	7.4	27.9	17.3	11.2	6.7	5.0
	high	22.7	15.8	9.6	8.5	7.7	22.6	11.8	6.0	4.8	3.7
PA	**categories**										
low edu	no	37.4	40.4	33.1	49.8	66.4	50.0	41.9	47.1	64.1	82.4
	little	42.2	43.9	49.8	39.5	28.9	44.6	50.5	45.2	32.4	16.3
	much	20.3	15.6	17.1	10.7	4.6	5.4	7.6	7.8	3.5	1.3
mid edu	no	29.1	30.0	25.0	35.1	47.7	34.4	32.8	38.0	46.7	30.4
	little	43.3	50.5	57.1	55.4	52.3	55.3	57.5	54.1	49.7	69.6
	much	27.6	19.6	17.9	9.5	0.0	10.3	9.7	7.9	3.6	0.0
high edu	no	18.4	22.6	26.8	40.3	66.0	27.1	26.8	21.9	54.4	71.1
	little	55.5	57.6	51.7	45.3	26.0	61.2	59.2	69.4	40.8	23.7
	much	26.0	19.8	21.5	14.4	8.0	11.6	13.9	8.8	4.9	5.3
Alcohol	**categories**										
low edu	DIII	11.0	6.1	5.2	2.7	2.1	2.6	3.4	2.4	1.2	0.4
	DII	6.7	7.7	5.4	3.6	2.8	12.0	13.1	8.0	6.9	5.7
	DI	45.5	51.0	50.4	47.6	44.1	22.9	28.6	21.2	20.5	24.6
	no	36.8	35.2	39.1	46.1	51.0	62.5	54.9	68.4	71.5	69.4
mid edu	DIII	8.4	7.1	2.4	5.0	0.0	2.6	3.2	2.6	2.0	0.0
	DII	5.5	8.5	8.2	9.9	2.7	14.1	20.6	18.9	15.5	2.5
	DI	57.4	60.2	58.0	55.3	48.6	32.0	38.4	35.6	35.8	32.5
	no	28.6	24.2	31.4	29.8	48.6	51.3	37.8	42.9	46.6	65.0
high edu	DIII	3.9	5.7	7.1	3.1	4.3	1.9	5.9	3.4	2.1	0.0
	DII	5.9	9.6	8.7	5.5	2.2	16.8	22.8	18.5	17.5	2.9
	DI	64.5	66.4	60.2	63.3	54.3	45.2	38.3	37.7	27.8	38.2
	no	25.6	18.2	24.0	28.1	39.1	36.1	33.0	40.4	52.6	58.8
Smoking	**categories**										
low edu	smoker	54.6	44.3	25.3	22.2	8.8	41.8	28.4	13.1	5.5	4.0
	non-smoker	45.4	55.7	74.7	77.8	91.2	58.2	71.6	86.9	94.5	96.0
mid edu	smoker	41.4	39.6	25.8	16.4	15.4	33.5	28.7	12.3	10.5	4.8
	non-smoker	58.6	60.4	74.2	83.6	84.6	66.5	71.3	87.7	89.5	95.2
high edu	smoker	29.7	33.2	20.1	18.7	16.3	22.5	24.6	16.5	7.8	0.0
	non-smoker	70.3	66.8	79.9	81.3	83.7	77.5	75.4	83.5	92.2	100.0

BMI	**categories**										
low edu	30+	13.2	19.8	19.3	15.3	4.8	15.5	21.0	20.2	20.3	11.7
	25-30	39.2	46.9	46.4	43.5	35.9	25.6	32.0	39.5	36.2	25.4
	-25	47.6	33.3	34.3	41.2	59.3	58.9	47.0	40.3	43.6	62.9
mid edu	30+	12.2	14.8	19.4	9.9	8.7	7.8	13.2	14.6	12.2	4.3
	25-30	38.2	46.3	46.0	48.5	34.8	22.8	27.9	34.4	35.4	32.6
	-25	49.6	38.9	34.6	41.5	56.5	69.4	58.9	51.0	52.4	63.0
high edu	30+	7.2	11.8	11.1	10.6	2.0	4.3	8.2	8.2	11.9	6.1
	25-30	33.7	46.0	47.1	36.6	41.2	13.5	21.6	37.1	27.7	15.2
	-25	59.1	42.2	41.8	52.8	56.9	82.2	70.2	54.7	60.4	78.8

CZECH REPUBLIC		MEN					WOMEN				
		30-44	45-59	60-69	70-79	80+	30-44	45-59	60-69	70-79	80+
Education	low	57.1	63.6	64.6	66.3	73.8	47.6	59.6	74.7	87.0	89.7
	middle	27.9	23.3	23.5	21.5	17.7	39.9	32.1	20.6	10.6	9.0
	high	15.0	13.1	12.0	12.2	8.5	12.5	8.3	4.7	2.4	1.3
PA	**categories**										
low edu	no	57.4	69.3	69.9	73.6	73.6	76.2	73.5	78.1	92.9	92.9
	little	28.4	11.7	15.7	11.1	11.1	15.2	8.5	8.6	3.8	3.8
	much	14.2	19.0	14.5	15.3	15.3	8.6	18.0	13.3	3.2	3.2
mid edu	no	37.3	50.7	58.1	86.4	86.4	58.4	69.5	67.5	86.4	86.4
	little	47.0	32.0	19.4	4.5	4.5	31.2	21.9	25.0	9.1	9.1
	much	15.7	17.3	22.6	9.1	9.1	10.4	8.6	7.5	4.5	4.5
high edu	no	41.1	46.9	58.8	81.3	81.3	58.0	68.3	75.0	77.8	77.8
	little	50.0	42.9	11.8	12.5	12.5	34.0	19.5	8.3	11.1	11.1
	much	8.9	10.2	29.4	6.3	6.3	8.0	12.2	16.7	11.1	11.1
Alcohol	**categories**										
low edu	DIII	12.6	12.2	2.9	8.0	8.0	1.7	3.4	5.1	0.0	0.0
	DII	15.0	15.6	8.8	6.0	6.0	6.7	8.0	12.8	5.4	5.4
	DI	72.4	72.1	88.2	86.0	86.0	91.7	88.6	82.1	94.6	94.6
	no	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
mid edu	DIII	9.2	1.6	16.7	0.0	0.0	1.0	1.4	6.3	0.0	0.0
	DII	5.3	4.8	16.7	6.7	6.7	5.2	11.4	12.5	0.0	0.0
	DI	85.5	93.7	66.7	93.3	93.3	93.8	87.1	81.3	100.0	100.0
	no	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
high edu	DIII	4.1	13.6	8.3	0.0	0.0	5.6	0.0	11.1	0.0	0.0
	DII	4.1	2.3	0.0	25.0	25.0	11.1	6.9	0.0	0.0	0.0
	DI	91.8	84.1	91.7	75.0	75.0	83.3	93.1	88.9	100.0	100.0
	no	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Smoking	**categories**										
low edu	smoker	60.4	47.8	21.4	19.4	19.4	45.3	36.5	7.6	3.8	3.8
	non-smoker	39.6	52.2	78.6	80.6	80.6	54.7	63.5	92.4	96.2	96.2
mid edu	smoker	39.8	26.7	25.8	9.1	9.1	25.4	30.2	20.0	9.1	9.1
	non-smoker	60.2	73.3	74.2	90.9	90.9	74.6	69.8	80.0	90.9	90.9
high edu	smoker	23.2	28.6	5.9	12.5	12.5	22.0	14.3	16.7	0.0	0.0
	non-smoker	76.8	71.4	94.1	87.5	87.5	78.0	85.7	83.3	100.0	100.0
BMI	**categories**										
low edu	30+	14.6	21.0	27.4	21.1	21.1	15.1	29.5	35.6	27.7	27.7
	25-30	40.3	49.2	57.1	46.5	46.5	25.5	40.5	43.3	40.6	40.6
	-25	45.1	29.8	15.5	32.4	32.4	59.4	30.0	21.2	31.6	31.6
mid edu	30+	3.7	18.9	25.8	0.0	0.0	8.7	15.1	20.0	4.5	4.5
	25-30	60.5	56.8	45.2	54.5	54.5	16.7	47.2	42.5	54.5	54.5
	-25	35.8	24.3	29.0	45.5	45.5	74.6	37.7	37.5	40.9	40.9
high edu	30+	10.7	18.8	11.8	6.3	6.3	2.0	14.3	0.0	22.2	22.2
	25-30	39.3	68.8	52.9	50.0	50.0	20.0	47.6	25.0	33.3	33.3
	-25	50.0	12.5	35.3	43.8	43.8	78.0	38.1	75.0	44.4	44.4

NORWAY		MEN					WOMEN				
		30-44	45-59	60-69	70-79	80+	30-44	45-59	60-69	70-79	80+
Education	low	18.6	31.3	44.6	52.6	59.1	19.6	38.0	55.0	63.9	66.8
	middle	54.8	46.8	41.2	37.1	31.3	55.7	46.7	37.3	30.9	28.3
	high	26.6	21.8	14.3	10.3	9.5	24.7	15.3	7.7	5.2	4.9
PA	**categories**										
low edu	no	23.8	41.7	31.7	57.6	73.7	54.4	44.7	61.2	74.1	90.0
	little	30.0	34.6	37.5	25.9	21.1	32.4	36.8	22.3	20.9	10.0
	much	46.3	23.6	30.8	16.5	5.3	13.2	18.4	16.5	5.0	0.0
mid edu	no	22.5	31.5	33.5	42.6	62.2	32.1	37.5	48.6	65.8	79.0
	little	42.4	37.4	36.3	32.4	24.4	41.8	40.7	32.2	25.2	17.7
	much	35.1	31.1	30.2	25.0	13.3	26.1	21.8	19.1	9.0	3.2
high edu	no	13.8	17.2	22.6	25.5	73.3	16.5	22.6	41.2	44.8	72.2
	little	44.6	50.8	40.9	36.2	6.7	53.5	53.3	41.2	34.5	27.8
	much	41.6	32.0	36.6	38.3	20.0	30.0	24.1	17.6	20.7	0.0
Alcohol	**categories**										
low edu	DIII	0.0	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	DII	2.3	0.0	0.0	0.0	0.0	0.0	0.9	2.5	1.1	0.0
	DI	45.5	38.8	20.3	9.3	42.1	19.0	27.8	12.7	6.7	10.8
	no	52.3	58.8	79.7	90.7	57.9	81.0	71.3	84.8	92.2	89.2

mid edu	DIII	0.3	1.4	0.7	1.2	0.0	0.5	0.0	1.3	0.0	0.0
	DII	0.0	0.0	1.4	0.0	0.0	0.3	1.4	1.3	0.0	0.0
	DI	38.8	43.7	41.4	32.9	42.3	23.1	29.8	25.5	16.5	27.8
	no	61.0	54.9	56.4	65.9	57.7	76.2	68.8	72.0	83.5	72.2
high edu	DIII	0.4	0.5	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	DII	0.4	0.0	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0
	DI	39.8	54.8	55.8	51.3	30.8	73.9	39.1	31.7	37.0	10.0
	no	59.3	44.7	42.9	48.7	69.2	26.1	60.0	68.3	63.0	90.0
Smoking	**categories**										
low edu	smoker	67.5	58.3	37.5	30.6	17.9	66.2	53.9	32.8	20.0	11.3
	non-smoker	32.5	41.7	62.5	69.4	82.1	33.8	46.1	67.2	80.0	88.8
mid edu	smoker	46.4	44.7	33.3	12.8	22.2	46.2	48.5	26.5	16.1	12.9
	non-smoker	53.6	55.3	66.7	87.2	77.8	53.8	51.5	73.5	83.9	87.1
high edu	smoker	33.8	31.7	21.5	6.4	6.7	21.8	31.5	17.6	27.6	22.2
	non-smoker	66.2	68.3	78.5	93.6	93.3	78.2	68.5	82.4	72.4	77.8
BMI	**categories**										
low edu	30+	13.8	13.5	11.7	5.9	5.3	7.5	12.1	11.4	16.3	5.9
	25-30	43.8	39.7	44.7	42.4	44.7	28.4	36.2	40.4	35.6	36.8
	-25	42.5	46.8	43.7	51.8	50.0	64.2	51.7	48.2	48.1	57.4
mid edu	30+	14.1	10.7	8.4	3.7	2.3	7.2	8.7	13.8	9.4	3.3
	25-30	46.0	52.2	48.9	51.4	39.5	28.0	31.2	34.3	44.3	26.7
	-25	39.9	37.0	42.7	44.9	58.1	64.8	60.1	51.9	46.2	70.0
high edu	30+	5.6	7.3	4.3	2.1	0.0	5.7	7.8	10.4	3.6	0.0
	25-30	46.9	48.5	38.7	29.8	20.0	20.6	25.1	22.4	28.6	22.2
	-25	47.5	44.3	57.0	68.1	80.0	73.7	67.1	67.2	67.9	77.8

PA = physical activity, BMI = body mass index, edu = education

Table A2 Rate ratios of cause-specific and all-cause mortality according to four risk factors for men and women by age

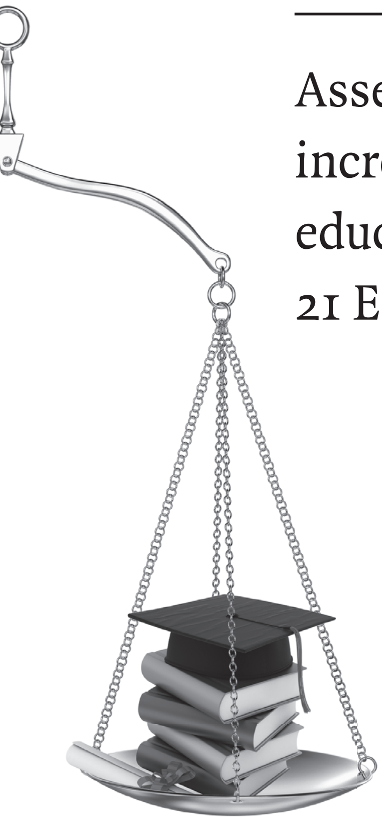
		MEN					WOMEN				
		30-44	45-59	60-69	70-79	80+	30-44	45-59	60-69	70-79	80+
All-cause mortality											
PA	No	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
	Little	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
	Much	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Alcohol	DIII	1.47	1.26	1.14	1.11	1.10	1.43	1.39	1.31	1.27	1.23
	DII	1.23	1.10	1.03	1.02	1.02	1.15	1.13	1.08	1.06	1.04
	DI	1.05	0.98	0.96	0.96	0.97	1.03	1.02	1.00	0.99	0.98
	No	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Smoking	Yes	1.90	2.47	2.33	2.06	1.53	1.09	1.80	2.26	2.22	1.73
	No	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
BMI	30+	1.55	1.52	1.41	1.30	1.20	1.50	1.47	1.36	1.20	1.10
	25-30	1.20	1.19	1.15	1.12	1.10	1.15	1.14	1.12	1.10	1.05
	-25	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Ischaemic heart disease											
PA	No	1.97	1.97	1.97	1.73	1.50	1.97	1.97	1.97	1.73	1.50
	Little	1.41	1.41	1.41	1.33	1.27	1.41	1.41	1.41	1.33	1.27
	Much	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Alcohol	DIII	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	DII	0.62	0.65	0.83	0.93	0.98	0.62	0.65	0.83	0.93	0.98
	DI	0.60	0.63	0.82	0.92	0.97	0.60	0.63	0.82	0.92	0.97
	No	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Smoking	Yes	5.51	3.04	1.88	1.44	1.05	2.26	3.78	2.53	1.68	1.38
	No	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
BMI	30+	2.16	1.99	1.46	1.25	1.07	2.40	2.02	1.53	1.30	1.07
	25-30	1.41	1.30	1.18	1.11	1.03	1.47	1.35	1.20	1.13	1.04
	-25	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Cerebrovascular disease											
PA	No	1.72	1.72	1.72	1.55	1.39	1.72	1.72	1.72	1.55	1.39
	Little	1.18	1.18	1.18	1.17	1.15	1.18	1.18	1.18	1.17	1.15
	Much	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Alcohol	DIII	3.84	2.52	1.69	1.32	1.00	1.33	1.22	1.10	1.05	1.00
	DII	0.83	0.88	0.94	0.97	1.00	1.07	1.05	1.02	1.01	1.00
	DI	0.83	0.88	0.94	0.97	1.00	0.88	0.91	0.96	0.98	1.00
	No	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Smoking	Yes	3.12	3.12	1.88	1.39	1.05	4.61	4.61	2.81	1.95	1.00
	No	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
BMI	30+	1.22	1.29	1.33	1.15	1.00	1.25	1.33	1.38	1.18	1.00
	25-30	1.09	1.12	1.14	1.07	1.00	1.10	1.13	1.15	1.08	1.00
	-25	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Lung cancer											
PA	No	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Little	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Much	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Alcohol	DIII	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	DII	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	DI	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	No	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Smoking	Yes	21.30	21.30	21.30	21.30	21.30	12.50	12.50	12.50	12.50	12.50
	No	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
BMI	30+	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	25-30	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	-25	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Data sources: All-cause mortality rate ratios for physical activity (PA), smoking, and cause-specific rate ratios for BMI are those used in van Kreijl et al. [13]. This is a comprehensive study report on the impact of risk factors on mortality in the Netherlands using the best available sources for rate ratios in the international literature (see their report p. 337–344 for all references). Rate ratios for alcohol (all-cause mortality and lung cancer mortality), and all-cause mortality rate ratios for BMI were the same as used in the DYNAMO-HIA project and are documented at the web page of the DYNAMO-HIA project and in Lhachimi et al. [12]. The associations provided in DYNAMO-HIA were based on a comprehensive review of the literature, which included a number of meta-analyses and systematic reviews. Studies were excluded if the outcome measure was a prognosis, pre-cancerous lesions, pre-disease markers, and if the study did not examine any major confounding factors such as age, sex or smoking. With respect to BMI, the search was restricted to studies that used BMI as a way of categorising adiposity, and which reported the risk in comparison with a 'normal' BMI of between 18kg/m^2 and 24.9 kg/m^2. The remaining cause-specific rate ratios were taken from Danaei et al. [20]. This study used data on risk factor exposures in the US population from nationally representative health surveys and disease-specific mortality statistics from the National Center for Health Statistics. They obtained the etiological effects of risk factors on disease-specific mortality by age, from systematic reviews and meta-analyses of epidemiological studies that had adjusted (i) for major potential confounders, and (ii) where possible, for regression dilution bias. They estimated the number of disease-specific deaths attributable to all non-optimal levels of each risk factor exposure, by age and sex. The authors quantified the sampling uncertainty of the estimates and also analysed how specific methods and data sources affected the quantitative results in extensive sensitivity analyses. This demonstrated that although the specific numerical results are uncertain, the overall findings on the relative mortality effects of the risk factors were robust.

7

Assessing the potential impact of increased participation in higher education on mortality: Evidence from 21 European populations



Kulhánová I, Hoffmann R, Judge K, Looman CWN, Eikemo TA, Bopp M, Deboosere P, Leinsalu M, Martikainen P, Rychtaříková J, Wojtyniak B, Menvielle G, Mackenbach JP, for the EURO-GBD-SE Consortium

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ABSTRACT

Although higher education has been associated with lower mortality rates in many studies, the effect of potential improvements in educational distribution on future mortality levels is unknown. We therefore estimated the impact of projected increases in higher education on mortality in European populations. We used mortality and population data according to educational level from 21 European populations and developed counterfactual scenarios. The first scenario represented the improvement in the future distribution of educational attainment as expected on the basis of an assumption of cohort replacement. We estimated the effect of this counterfactual scenario on mortality with a 10–15-year time horizon among men and women aged 30–79 years using a specially developed tool based on population attributable fractions (PAF). We compared this with a second, upward levelling scenario in which everyone has obtained tertiary education. The reduction of mortality in the cohort replacement scenario ranged from 1.9 to 10.1% for men and from 1.7 to 9.0% for women. The reduction of mortality in the upward levelling scenario ranged from 22.0 to 57.0% for men and from 9.6 to 50.0% for women. The cohort replacement scenario was estimated to achieve only part (4–25% (men) and 10–31% (women)) of the potential mortality decrease seen in the upward levelling scenario. We concluded that the effect of on-going improvements in educational attainment on average mortality in the population differs across Europe, and can be substantial. Further investments in education may have important positive side-effects on population health.

INTRODUCTION

Lower education has been associated with many health-related outcomes, including self-reported health, physical functioning, disability, morbidity and mortality [1-4]. Although social selection may partly explain this relationship (ill individuals underperform in school and therefore do not achieve a high level of education [5, 6], this probably has only a small impact and cannot explain the educational gradient in health [7].

Recently, studies exploiting natural experiments in which changes in educational level were exogenously imposed have indeed shown that the main explanation for educational inequalities in health is a causal effect of education on health [8-14]. The majority of the studies used school reforms or compulsory schooling laws and assessed their effect in a regression discontinuity design. The results imply that changes in educational attainment, such as those resulting from school reforms which aimed at increasing the amount of compulsory schooling and from the expansion of opportunities for higher education [15-17], may have had important positive side-effects for population health [18, 19]. It has been reported that an additional year of schooling increased life expectancy at the age of 35 by 1.7 years [12] or reduced the probability of dying by 1.1 percentage points for men and by 0.8–0.9 percentage points for women [14]. Lager and Torssander [11] have shown that a one-year increase in compulsory schooling was associated with a 4% lower risk of all-cause mortality after the age of 40.

Changes in society, such as the introduction of information and communication technology, require a growing participation in higher education [20, 21]. Consistent improvements in educational attainment over time for both genders have indeed been reported in all European countries [22-24]. On average across OECD countries, it has been shown that between 1998 and 2008 the proportion of the 25–64 year-old population with less than upper secondary education decreased from 37% to 29%. At the same time, the proportion with upper secondary and post-secondary non-tertiary education remained almost unchanged (42% in 1998 vs. 44% in 2008), whereas that with tertiary education increased from 21% to 28% [23]. The increase in the percentage of tertiary educated in the OECD countries is the result of a 3.4% average annual growth rate in tertiary education. The average annual growth in tertiary education even exceeded 5% between 1998 and 2008 in Italy, Portugal and Poland, European countries in which overall levels of tertiary education were low at the beginning of the decade [23]. Further, a few studies projected the trends in educational attainment in a large amount of countries [25-27], but they did not provide any estimates regarding the effect of increasing education on health.

In view of the documented health effects of education, these trends could well have an important impact on population health. However, studies that have quantified the effect of future improvements in educational attainment on population health are scarce. Although some recent studies quantified the health benefits obtained from investments in education in several populations, their estimates were related to the projection of future disability prevalence [28-30] or to the contribution of improvements in education to the reduction in child mortality [22]. To the best of our knowledge, there is no study assessing the effect of on-going improvements in educational attainment on adult mortality.

The aim of the present analysis was therefore to estimate future reductions in mortality due to further improvements in educational attainment in 21 European populations. To do so, we developed counterfactual scenarios using the changing social distribution of educational attainment over time, and applied these scenarios using currently observed mortality risks by country and level of education, and a method based on the population attributable fraction (PAF).

DATA AND METHODS

Data description

The analysis was based on mortality data from 21 European populations. Most data covered the entire national territory (Finland, Sweden, Norway, Denmark, England and Wales, Scotland, Netherlands, Belgium, France, Switzerland, Austria, Hungary, Czech Republic, Poland, Lithuania, Estonia). The exceptions were Italy and Spain, for which we had data limited to regional territory (Madrid and the Basque Country) or urban areas (Barcelona, Turin and Tuscany: Florence, Leghorn, Prato). Longitudinal data were available for most of the European populations investigated. For central/eastern European countries (Hungary, Czech Republic, Poland and Estonia), cross-sectional data, aggregated over a few years around the year 2000, were collected. These data consisted of deaths and exposure counts by sex, 5-year age groups and level of education (Table 1).

The registries of deaths were linked with census data (in most of the European populations) or with a Labour Force Survey (in the Netherlands). In some countries, it was not possible to achieve 100% linkage between the population and the death registries. The percentage of unlinked deaths was higher than 5% in Austria, Barcelona, the Basque Country and Madrid. In Madrid, approximately 20% of deaths had to be excluded due to linkage failure. To adjust for the unlinked deaths, weights were applied for those four populations. In Austria, the weight was broken down by sex and 5-year age groups. In

Table 1 Characteristics of mortality data

Population	Type of dataset	Period	Geographic coverage	Demographic coverage
Finland	longitudinal	2001–2007	national	20% of Finns are 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% of the population
Scotland	longitudinal	2001–2006	national	5.3% representative sample of the population
Netherlands	longitudinal	1998–2007	national	linkage based on the Labour Force Survey
Belgium	longitudinal	2001–2005	national	whole population
France	longitudinal	1999–2005	national	1% of the population, born outside France mainland excluded
Switzerland	longitudinal	2001–2005	national	Non-Swiss nationals excluded
Austria	longitudinal	2001–2002	national	whole population
Barcelona	repeated CS	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	Florence, Leghorn, Prato	whole population
Hungary	CS unlinked	1999–2002	national	whole population
Czech Republic	CS unlinked	1999–2003	national	whole population
Poland	CS unlinked	2001–2003	national	whole population
Lithuania	longitudinal	2001–2005	national	whole population
Estonia	CS unlinked	1998–2002	national	whole population

CS = cross-sectional

Barcelona, the Basque Country and Madrid, there were no variations by age and sex for excluded deaths. The weights therefore equal 1.06 (1/0.946) for Barcelona and the Basque Country, and 1.25 (1/0.8) for Madrid. Data where the percentage of unlinked death was lower than 5% were not weighted.

Measures

The educational level declared at the census at the beginning of the follow-up was harmonized across countries according to the International Standard Classification of Education (ISCED) and split into three internationally comparable categories. These corresponded to less than secondary education (ISCED 0, 1, 2; 'low'), secondary education (ISCED 3, 4; 'middle'), and tertiary education (ISCED 5, 6; 'high'). Individuals with missing information on their educational attainment were excluded from the analysis. In the datasets of Denmark, Lithuania and Finland, unknown education was classified together with no or only primary education, whereas in most of the other countries unknown education was coded separately.

Educational scenarios

On the basis of the literature and empirical evidence for rate of improvement in educational attainment, we developed a counterfactual scenario called 'cohort replacement scenario' by taking a time horizon of 10–15 years and producing estimates based on the following replacement: The educational attainment of those currently aged 45–59, 60–69 and 70–79 were replaced by the educational attainment of those currently aged 30–44, 45–59 and 60–69, respectively. Those currently aged 30–44 were in turn replaced by a new group aged 15–29, whose educational attainment was unknown and was therefore estimated on the basis of past trends. We assumed that the incoming cohort aged 15–29 achieved a level of educational attainment based on the trends observed in the improvement between those aged 30–44 and 45–59 years, and that the overall population in each age group remained constant. In addition, we constrained this scenario in such a way that the percentage of incoming people with low education aged 30–44 could not fall below 0.5% of that age group. However, among men in several countries (Sweden, Netherlands, Tuscany, Hungary, Lithuania, Estonia), the percentage with high education was lower for the 30–44 age group than for the 45–59 age group. This phenomenon was opposite to the general trend. As our aim was to estimate the impact of improvement in educational distribution on mortality, we made the percentage of high education for the incoming group aged 30–44 equal to the highest percentage recorded for any other age group. The group with middle education was treated as a residual. Although we observed some differences between the educational distribution in our mortality data and the educational distribution registered in the Eurostat Statistics Database [31] in few countries, we assume that these differences are partly attributable to a delayed registration of education.

Additionally, we compared the cohort replacement scenario to an upward levelling scenario, in which everyone has tertiary education. This theoretical scenario implies that all people have obtained the same, high level of education, and that educational inequalities in mortality have completely disappeared. To compare the more realistic cohort replacement scenario with the upward levelling scenario, we calculated what percentage of the upward levelling estimates was accounted for by the cohort replacement scenario.

As a sensitivity analysis, we developed a variation to the cohort replacement scenario. The sensitivity scenario was based on OECD annual growth rates [23] in which the future changes in the numbers of people in each education group, by age, were assumed to be the same as in the recent past. The future numbers in the incoming group of high and low educated people aged 15–29 years was constructed using a 15-year index value of OECD annual growth rate specific for each country investigated. The group with middle education was treated as a residual. The results of this scenario can be found in appendix (Tables A1 and A2).

Data analysis

All analyses were conducted separately for men and women aged 30–79 years and used the method of the population attributable fraction (PAF) [32]. The major assumption we had to make in order to use the PAF methodology was that the observed association between education and mortality reflects a causal effect. Generally speaking, the PAF estimates the proportion of disease cases that could be prevented by eliminating the exposure to a risk factor in the population [33]. In our case, we used the PAF to estimate the proportion of mortality that would be reduced if education were improved in the population:

$$PAF = \frac{\sum_{i=1}^{n} P_i RR_i - \sum_{i=1}^{n} P_i' RR_i}{\sum_{i=1}^{n} P_i RR_i}$$

where n is a number of exposure categories (educational categories), P_i is the proportion of population currently in the ith exposure category, P'_i is the proportion of population in the ith exposure category in the counterfactual scenario and RR_i is the relative risk of mortality for the ith exposure category.

The data needed for the PAF calculations are the current country-specific distribution of educational attainment (P_i), the scenario country-specific distribution of educational attainment (P'_i) and the country-specific mortality rate ratios (RR_i) for the three educational categories. The mortality rate ratios were calculated from the country-specific age-standardized mortality rates. The educational distribution and mortality rate ratios were calculated separately for men and women and for each age group (30–44, 45–59, 60–69 and 70–79) from our data for each European population. Due to the different study designs and follow-up times, specific correction factors were used to obtain comparable average age at death [34].

We first calculated age-specific PAFs in order to estimate new mortality rates and the number of saved deaths per 100,000 person-years in each age group. Afterwards we summed up the age-specific saved deaths per 100,000 person-years for the ages 30–79 years and calculated the overall PAF. The background information for the PAF calculations – the current population educational distribution, the mortality rate ratios and the counterfactual population educational distribution – can be found in appendix (Tables A3 and A4).

The confidence intervals for the impact of the population educational redistribution on mortality measured by PAF were computed by bootstrapping methods using R. The bootstrapping methods are resampling techniques for assessing uncertainty [35]. The input data needed for bootstrapping were country-specific numbers of deaths and person-years in each age group and educational category. The confidence intervals obtained by bootstrapping were then further used for calculation of confidence intervals around the saved deaths per 100,000 person-years.

RESULTS

The impacts of the cohort replacement and the upward levelling scenario are presented in Table 2 (proportional reduction of mortality, expressed as a percentage) and Table 3 (absolute reduction of mortality, expressed as saved deaths per 100,000 person-years). The results are shown for men and women aged 30–79 years by country. In this set of European populations, the proportional reduction of mortality in the cohort replacement scenario ranged from 1.9 to 10.1% among men and from 1.7 to 9.0% among women. Although the proportional reduction of mortality varied across European populations, we found no clear geographical pattern. The greatest reduction in mortality for men was observed in Hungary (10.1%) and for women in Finland and Hungary (9.0%). The smallest reduction in mortality was observed in Denmark among men (1.9%) and in Turin among women (1.7%). These variations result from the combination of the country-specific future improvement in education and the country-specific effect of education on mortality.

The impact of completely equalizing the educational distribution is illustrated by the upward levelling scenario, which assumes that all people in the population have obtained tertiary education, and that consequently they also have the mortality level of the tertiary educated. This scenario represents the hypothetical maximum of educational interventions in the given population. By eliminating educational inequality in the population, mortality may be reduced substantially (Figure 1). The potential reduction

Table 2 Percentage reduction in all-cause mortality in the cohort replacement and upward levelling scenarios, 30–79 years

Country	Cohort replacement scenario				Upward levelling scenario			
	Men		Women		Men		Women	
	Proportional reduction (in %)	95%-CI	Proportional reduction (in %)	95%-CI	Proportional reduction (in %)	95%-CI	Proportional reduction (in %)	95%-CI
Finland	6.0	(5.8–6.3)	9.0	(8.6–9.4)	37.2	(36.1–38.1)	30.0	(28.4–31.7)
Sweden	4.2	(4.0–4.4)	6.3	(6.1–6.6)	33.2	(32.1–34.2)	31.8	(30.4–33.2)
Norway	5.6	(5.4–5.9)	7.8	(7.4–8.2)	36.7	(35.1–38.3)	33.4	(31.0–35.6)
Denmark	1.9	(1.8–2.0)	5.0	(4.7–5.2)	33.2	(31.9–34.4)	30.6	(28.7–32.4)
England & Wales	3.1	(2.7–3.5)	4.3	(3.6–4.9)	31.5	(26.9–36.2)	29.6	(23.9–35.4)
Scotland	6.3	(5.1–7.4)	8.9	(7.5–10.4)	38.5	(33.6–43.2)	35.3	(28.7–41.6)
Netherlands	2.1	(1.8–2.4)	4.6	(3.8–5.5)	30.5	(26.2–34.7)	25.7	(16.2–34.0)
Belgium	5.0	(4.9–5.2)	5.5	(5.2–5.8)	34.6	(33.5–35.7)	30.7	(29.0–32.4)
France	6.0	(5.3–6.6)	6.1	(4.8–7.5)	45.0	(40.8–49.6)	29.9	(21.1–38.7)
Switzerland	4.6	(4.4–4.8)	4.7	(4.4–5.1)	30.8	(29.5–32.0)	21.3	(17.9–24.6)
Austria	2.4	(2.1–2.6)	3.4	(2.8–3.9)	34.2	(31.5–36.8)	26.0	(19.7–32.3)
Barcelona	3.7	(3.4–4.0)	4.8	(4.0–5.6)	25.8	(23.9–27.9)	19.7	(16.1–23.4)
Basque Country	5.6	(5.0–6.1)	4.2	(3.0–5.3)	22.0	(19.2–24.7)	13.1	(6.4–19.1)
Madrid	3.4	(3.1–3.8)	2.0	(1.3–2.9)	23.1	(20.6–25.8)	19.2	(13.3–24.5)
Turin	3.6	(3.2–4.0)	1.7	(0.9–2.6)	28.2	(23.9–32.5)	9.6	(1.4–17.0)
Tuscany	3.0	(2.3–3.6)	3.0	(1.8–4.1)	31.8	(25.7–37.4)	17.6	(7.4–26.4)
Hungary	10.1	(9.9–10.3)	9.0	(8.8–9.3)	54.1	(53.4–54.9)	32.0	(30.1–33.8)
Czech Republic	2.0	(1.96–2.02)	4.8	(4.7–5.0)	57.0	(56.2–57.8)	50.0	(48.0–51.9)
Poland	4.5	(4.4–4.6)	5.9	(5.7–6.1)	54.1	(53.5–54.7)	42.9	(41.8–44.1)
Lithuania	6.4	(6.1–6.8)	7.8	(7.3–8.2)	44.2	(42.9–45.6)	35.4	(33.4–37.4)
Estonia	5.4	(5.0–5.8)	7.3	(6.7–7.9)	48.6	(46.6–50.3)	41.4	(38.6–43.9)

Table 3 Absolute reduction of all-cause mortality in the cohort replacement and upward levelling scenarios, 30–79 years

Country	Cohort replacement scenario				Upward levelling scenario				Share of cohort replacement scenario on upward levelling scenario (in %)	
	Men		Women		Men		Women			
	Absolute reduction (deaths per 100,000)	95%-CI	Absolute reduction (deaths per 100,000)	95%-CI	Absolute reduction (deaths per 100,000)	95%-CI	Absolute reduction (deaths per 100,000)	95%-CI	Men	Women
Finland	60	(58–63)	42	(41–44)	371	(361–381)	142	(134–150)	16	30
Sweden	32	(30–33)	29	(28–30)	251	(242–258)	145	(139–152)	13	20
Norway	43	(41–45)	35	(33–37)	280	(267–292)	150	(139–160)	15	23
Denmark	20	(19–21)	33	(31–34)	342	(329–354)	201	(188–213)	6	16
England & Wales	27	(23–30)	24	(20–27)	267	(228–307)	162	(131–194)	10	15
Scotland	54	(43–63)	49	(42–58)	328	(286–368)	196	(160–231)	16	25
Netherlands	17	(14–18)	20	(17–24)	234	(202–267)	113	(72–150)	7	18
Belgium	45	(44–47)	26	(25–28)	311	(301–321)	146	(138–154)	14	18
France	52	(46–57)	23	(18–29)	392	(355–431)	115	(81–148)	13	20
Switzerland	31	(29–32)	17	(16–19)	205	(197–213)	78	(65–90)	15	22
Austria	23	(20–25)	17	(14–19)	329	(303–354)	129	(98–161)	7	13
Barcelona	30	(27–32)	17	(14–19)	207	(192–224)	68	(56–81)	14	25
Basque Country	46	(41–51)	14	(10–18)	182	(159–205)	45	(22–65)	25	31
Madrid	32	(30–36)	8	(5–12)	221	(196–246)	77	(53–98)	14	10
Turin	27	(24–30)	7	(4–10)	209	(177–241)	38	(6–67)	13	18
Tuscany	21	(16–25)	12	(7–16)	222	(180–262)	71	(30–106)	9	17
Hungary	182	(178–185)	77	(76–80)	973	(960–987)	275	(259–291)	19	28
Czech Republic	28.6	(27.9–28.7)	34	(33–35)	810	(799–822)	351	(337–365)	4	10
Poland	71	(69–73)	40	(39–42)	853	(844–862)	293	(285–301)	8	14
Lithuania	114	(110–122)	57	(53–60)	795	(772–820)	258	(244–273)	14	22
Estonia	118	(109–127)	66	(61–72)	1,063	(1019–1100)	376	(350–398)	11	18

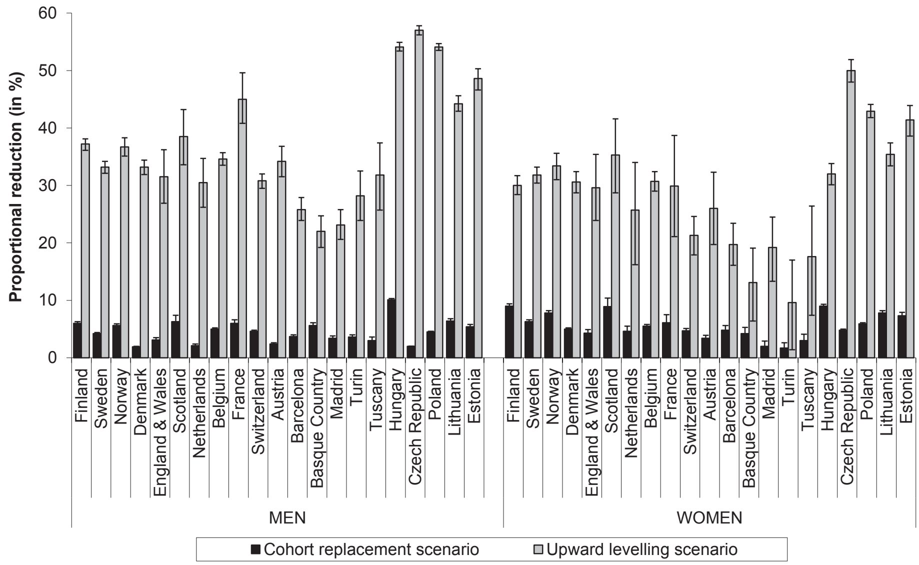

Figure 1 Percentage reduction in all-cause mortality in the cohort replacement and upward levelling scenarios, 30–79 years

according to the upward levelling scenario varies across European populations. Among men, it ranged from 20–30% in the South, over about 30% in the North and West, to 40–50% in the Central/East. Among women, the potential reduction of mortality according to the upward levelling scenario ranged from 10–20% in the South, over 20–35% in the West and 30% in the North to 30–50% in the Central/East. The maximum reduction of mortality that could be achieved among men was 57.0% in the Czech Republic followed by Hungary and Poland (both 54.1%). Among women, the highest reduction of mortality was observed in the Czech Republic (50.0%) followed by Poland (42.9%). The smallest percentage was estimated in southern European populations, especially among men in the Basque Country (22.0%) and among women in Turin (9.6%). These results are explained by the large differences across European countries in the effect of education on mortality. The effect of education on mortality is smaller in the southern European populations and much larger in central/eastern European populations (Table A3 in appendix).

Table 3 shows the absolute number of saved deaths (per 100,000 person-years) in the age group 30–79 years that may be achieved under the counterfactual scenarios in the 10–15-year time frame. For the cohort replacement scenario, the number of deaths that may be saved among men and women aged 30–79 years in the given time frame ranged from 17 to 182 deaths per 100,000 person-years among men and from 7 to 77 deaths per 100,000 person-years among women. The highest number of deaths could be saved in Hungary among both men and women. Looking at the upward levelling scenario, mortality could be reduced by up to 1,063 deaths per 100,000 person-years among men and 376 deaths per 100,000 person-years among women, both in Estonia. Table 3 also shows the proportion of the total mortality reduction associated with upward levelling that is attributable to the cohort replacement scenario. The cohort replacement scenario was estimated to achieve only part of the potential mortality decrease assessed in the upward levelling scenario. This proportion of the cohort replacement scenario on the upward levelling scenario ranged between 4% (Czech Republic) and 25% (the Basque Country) among men and between 10% (Madrid, Czech Republic) and 31% (the Basque Country) among women.

DISCUSSION

Summary of main findings

The cohort replacement scenario led to a reduction in all-cause mortality in each population observed. There were, however, important variations between countries in the magnitude of mortality reduction, depending on the current population educational distribution, the projected speed of future improvements in educational distribution, and on the mortality rate ratios between educational groups observed in each country. The potential reduction in mortality according to the cohort replacement scenario ranged from 1.9 to 10.1% for men and from 1.7 to 9.0% for women. The reduction of mortality in the upward levelling scenario ranged from 22.0 to 57.0% for men and from 9.6 to 50.0% for women. The cohort replacement scenario was estimated to achieve only part (4–25% (men) and 10–31% (women)) of the potential mortality decrease seen in the upward levelling scenario.

Limitations

The results have to be interpreted in view of some limitations. First, the assumptions inherent in the PAF methodology and the counterfactual scenarios should be discussed. The main assumption is that the observed associations between education and mortality can be interpreted as causal effects of education on mortality. As we mentioned in the introduction, while there is likely to be such a causal effect, part of the observed association may also be due to the selection of healthy individuals into higher education. Although we stratified the analyses by sex and age and therefore controlled for these variables, we did not include any other confounders, such as cognitive ability, personality or family background, when calculating mortality rate ratios because such information was not available in our data. Our results are therefore likely to overestimate the effect of education on mortality because we interpret the observed association as an approximation of the causal effect.

Second, in the cohort replacement scenario, we defined an educational structure for the youngest age group based on limited assumptions. However, as the mortality rates are low in this age group, this is not likely to strongly impact our results.

Third, our scenarios did not take into account any changes in migration, which are known to differ by education. This is likely to have impacted our results, but it is difficult to assess the magnitude of the effect, and our results should therefore be interpreted as estimates of what will happen in the absence of migration.

Fourth, we assumed that the populations size and relative risks of mortality by educational groups remained constant over time. However, this may not be true if lower educated people become a more selected group with worse health and consequently an increased mortality risk [36]. Similarly, higher educated may become a less selected group, which may raise their relative risks of mortality. We assume that new groups receiving high education also adopt the previously-observed lifestyle and the behaviour of high educated. However, this behaviour adoption may happen with different time lags and at different speeds across European countries due to different country-specific historical circumstances. Besides that, education as an indicator of social stratification may be less relevant as the proportion of tertiary educated in the population increases. It is likely that the increase in the proportion of high educated will not always match with the increase in the proportion of higher occupational opportunities. As a consequence, a certain proportion of high educated people will face over-qualification and the health returns to education should therefore presumably diminish. Indeed, over-qualification has been reported to be harmful for self-reported health [37] and mental health [38], although no association was found between over-qualification and all-cause or cardiovascular disease mortality [39]. It may also be that as the proportion of tertiary educated people increases, new stratifications appear within this group, both vertically (referring to distinct course levels or cycles, such as bachelor, master or PhD degree) and horizontally (considering the prestige of the university and of the study field) [40]. These new stratifications are likely to generate new educational inequalities in health within the high educated group. Erikson [41] found that in Sweden, university graduates having a PhD degree live longer that those having a Master's degree.

These limitations imply that our calculations are hypothetical illustrations of the effect of educational changes on mortality. The findings show the rough dimensions and orders of magnitude of what could be gained if the enormous improvements in educational expansion would continue. By illustrating the potential gains they also show what is at stake and how much potential health gains could be lost if we reduced efforts in the educational field.

Interpretation

Education is linked to health via several pathways which are not mutually exclusive. The education–health relationship may be confounded by childhood socioeconomic circumstances and/or cognitive ability and may be explained by several main factors including material conditions, social-psychological resources and healthy lifestyle [42].

Although childhood socioeconomic circumstances, such as parental socioeconomic background and material conditions during childhood, may play an important role in the final health outcomes over the life course [43], they happen before education is completed. The cognitive ability may be genetically given, however, it is enhanced through education [44]. The analytical and communication skills acquired by education promote risk assessment and decision making abilities, which in turn help to better cope with stress, to more effectively use the health care system [45, 46] or to avoid unnecessary treatments [47]. Therefore among the least educated people, lacking these skills may impair the ability to use the available health care services for prevention or clinical procedures, and in the end result in worse health outcome [48, 49].

Regarding the material conditions, such as work and economic conditions, low educated individuals are more likely to hold jobs with higher environmental and physical risks. For instance, mortality due to asbestosis, mesothelioma or silicosis, which is mostly due to occupational exposure to asbestos and silica, still largely contributes to socioeconomic inequalities in mortality in several European countries up until today [50]. Better educated people are less likely to be unemployed and face economic hardship. They have higher income and more fulfilling and rewarding jobs than less educated individuals [51]. In addition, better educated people were reported to have higher key social-psychological resources, such as sense of personal control and social support. These resources improve health through enhancing health-related behaviour and decreasing mental health problems. Finally, high educated people have a more healthy way of life, including less smoking and drinking and more physical activity.

The upward levelling scenario presents a theoretical maximum that can be achieved if the educational distribution is 'equalized' without taking into account any other factors contributing to socioeconomic inequalities in mortality. The cohort replacement scenario is an illustration of the effect of the on-going improvement in education on mortality. As expected, the potential decrease in mortality is larger under the upward levelling scenario that under the cohort replacement scenario. However, the gender pattern differs between the two scenarios and large differences in the magnitude of the reduction of mortality are observed between countries.

In the past, education was lower among women than among men. However during the past decades, education strongly increased among women and nowadays, education is similar or even higher among women, as shown by the educational distribution in the youngest age group. As a consequence, the observed improvement in educational attainment has greater impact among women in most European populations investigated. In other words, without any intervention focusing on education, women will benefit more than men from the on-going educational improvement in terms of mortality decrease. The more important on-going improvement in educational attainment among women is mirrored in the share of the cohort replacement scenario on upward levelling scenario that is much higher among women than among men in all populations but Madrid. This is also shown by the larger proportional reduction of mortality among women in the cohort replacement scenario. The gender difference, though, is not very large. This is likely to be due to the educational differences in mortality that are smaller among women, and somehow compensate the gender differences in the educational structure of the population. The importance of educational differences in mortality is clear when we look at the upward levelling scenario. Contrary to the cohort replacement scenario, the upward levelling scenario suggests a bigger scope for improvement among men than women. This may seem counterintuitive given the lower education among women at older ages where the mortality rates are high, but this is largely explained by the larger educational differences in mortality among men than among women.

Although there is a large scope for improvement in all European countries, the greatest proportional reductions of mortality for the upward levelling scenario were found in central/eastern European countries for both men and women whereas these countries exhibit great but not outstanding proportional reductions of mortality for the cohort replacement scenario. These results are the consequence of both a country-specific pattern of educational differences in mortality and a country-specific educational distribution. In these countries, the on-going increase in education is mainly a shift from low to middle educated, the percentage of high educated men remaining stable, and mortality among the middle educated group is high. So there is not much mortality gain with the on-going educational improvement. On the other hand, mortality decreased substantially under the upward levelling scenario. This is the consequence of the very large educational differences in mortality and of the low proportion of high educated in these countries. These results may be partly attributable to the communist history of compulsory education until an advanced age, which led to a large proportion of primary and secondary educated people but very few high educated. It may also be that education is still not recognized as an important factor of economic development in these countries. In contrast, the smallest theoretical potential gain in mortality was reported in the southern European populations, especially among women. These findings are observed although the educational level is similar to or even lower than in the other European populations. They are likely to mirror the smaller effect of education on mortality in these countries than, e.g. in the Nordic countries.

Finally, the gender differences in the potential for mortality decrease are large for the upward levelling scenario in all populations except in Northern Europe, England and Wales, Scotland, the Netherlands and Belgium. It therefore looks as if in the latter populations the higher education and the consequently smaller potential for educational improvement among women are balanced by larger educational differences in mortality.

Implications

The educational distribution is one of the most important sources of population heterogeneity with major social, economic, cultural and health consequences. As the educational composition of the population is a key for economic development and productivity, the future progress in education very likely affects the population development [18, 52]. Investments in education may have important side-effects on population health as better education is associated with lower mortality, better health, more migration and economic growth.

From this point of view, it is surprising that educational attainment was rarely included into population projections. Researchers have forecasted the effect of trends in selected proximal risk factors, such as smoking and obesity, on future life expectancy in the United States [53, 54]. Investigating the effect of distal factors, such as education, as in our analysis provides an improvement over those projections because distal factors involve access to diverse resources like money, knowledge, power, prestige, social support and social network [55] and are associated with mortality via diverse mechanisms. To the best of our knowledge, only one study investigated this issue by estimating the contribution of improvements in women's education on the reduction in child mortality in 175 countries over the past 40 years [22]. The authors concluded that the increase in the mean number of years of education between 1970 and 2009 had a considerable effect on mortality and could avert about 51% of deaths in children younger than 5 years.

In addition, some recent studies estimated the effect of increasing education on health outcomes other than mortality and provided evidence that the changing educational composition of the elderly population will lower the prevalence of disability in the population in the future [28, 29]. The on-going improvements in educational attainment are therefore good news for population health, and may alleviate the expected social burden of other demographic changes, such as population ageing [18, 29]. Therefore, most of the current literature likely overestimates the impact of ageing on health, including mortality.

CONCLUSIONS

The effect of on-going improvements in educational attainment on average mortality in the population should not be overlooked. The magnitude of mortality reduction depends on the combination of the current population educational structure, the projected speed of future improvements in the population educational structure and the association between education and mortality. This should be taken into account in future mortality projections.

The difference in mortality reduction observed between the upward levelling scenario and the cohort replacement scenario suggests that there is still a large potential for further health gains from educational improvements. Given the substantial benefits of increased educational attainment regarding population health, growth of human capital and economic development, this issue should be given high priority by policy makers, and the long-term benefits of educational investments should be taken into account for future public policy planning.

However, one should not forget that the educational health gradient results from important and well-documented mechanisms, such as differences in material conditions and health-related behaviours, which should also be targeted by policies and interventions. Increasing education is therefore not the only possible strategy to improve population health. This is fortunate because we will never be able to achieve a situation where everybody will be highly educated. The reason why less educated people are less healthy should be kept in mind and also tackled by policy action.

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APPENDIX

Table A1 Percentage reduction in all-cause mortality in the exptrapolation of OECD annual increase in education and upward levelling scenarios, 30–79 years

Country	OECD annual increase in education scenario				Upward levelling scenario			
	Men		Women		Men		Women	
	Proportional reduction (in %)	95%-CI	Proportional reduction (in %)	95%-CI	Proportional reduction (in %)	95%-CI	Proportional reduction (in %)	95%-CI
Finland	6.3	(6.0–6.5)	8.4	(8.1–8.8)	37.2	(36.1–38.1)	30.0	(28.4–31.7)
Sweden	4.0	(3.9–4.2)	6.2	(5.9–6.4)	33.2	(32.1–34.2)	31.8	(30.4–33.2)
Norway	5.3	(5.0–5.5)	7.3	(6.9–7.7)	36.7	(35.1–38.3)	33.4	(31.0–35.6)
Denmark	2.8	(2.6–2.9)	5.2	(4.9–5.4)	33.2	(31.9–34.4)	30.6	(28.7–32.4)
England & Wales	3.5	(3.0–4.0)	4.6	(3.8–5.3)	31.5	(26.9–36.2)	29.6	(23.9–35.4)
Scotland	6.7	(5.6–7.8)	7.9	(6.6–9.2)	38.5	(33.6–43.2)	35.3	(28.7–41.6)
Netherlands	2.4	(2.2–2.8)	4.4	(3.6–5.2)	30.5	(26.2–34.7)	25.7	(16.2–34.0)
Belgium	5.2	(5.1–5.4)	5.2	(4.9–5.5)	34.6	(33.5–35.7)	30.7	(29.0–32.4)
France	6.3	(5.6–7.0)	5.8	(4.5–7.0)	45.0	(40.8–49.6)	29.9	(21.1–38.7)
Switzerland	5.3	(5.1–5.5)	4.2	(3.9–4.5)	30.8	(29.5–32.0)	21.3	(17.9–24.6)
Austria	2.6	(2.3–2.8)	3.2	(2.7–3.8)	34.2	(31.5–36.8)	26.0	(19.7–32.3)
Barcelona	4.5	(4.1–4.8)	4.2	(3.4–4.8)	25.8	(23.9–27.9)	19.7	(16.1–23.4)
Basque Country	5.0	(4.5–5.5)	3.5	(2.4–4.6)	22.0	(19.2–24.7)	13.1	(6.4–19.1)
Madrid	3.6	(3.3–4.1)	2.1	(1.3–2.9)	23.1	(20.6–25.8)	19.2	(13.3–24.5)
Turin	4.0	(3.5–4.4)	1.7	(0.8–2.6)	28.2	(23.9–32.5)	9.6	(1.4–17.0)
Tuscany	3.7	(3.0–4.4)	3.3	(2.1–4.5)	31.8	(25.7–37.4)	17.6	(7.4–26.4)
Hungary	11.1	(10.9–11.3)	9.2	(9.0–9.5)	54.1	(53.4–54.9)	32.0	(30.1–33.8)
Czech Republic	3.1	(3.0–3.2)	5.3	(5.1–5.5)	57.0	(56.2–57.8)	50.0	(48.0–51.9)
Poland	4.9	(4.8–5.0)	6.1	(5.9–6.3)	54.1	(53.5–54.7)	42.9	(41.8–44.1)
Lithuania	6.3	(6.1–6.6)	8.0	(7.5–8.4)	44.2	(42.9–45.6)	35.4	(33.4–37.4)
Estonia	5.1	(4.7–5.5)	7.2	(6.6–7.7)	48.6	(46.6–50.3)	41.4	(38.6–43.9)

Table A2 Absolute reduction of all-cause mortality in the exptrapolation of OECD annual increase in education and upward levelling scenarios, 30–79 years

Country	OECD annual increase in education scenario				Upward levelling scenario				Share of OECD annual increase in education scenario on upward levelling scenario (in %)	
	Men		Women		Men		Women			
	Absolute reduction (deaths per 100,000)	95%-CI	Absolute reduction (deaths per 100,000)	95%-CI	Absolute reduction (deaths per 100,000)	95%-CI	Absolute reduction (deaths per 100,000)	95%-CI	Men	Women
Finland	63	(60–65)	40	(38–42)	371	(361–381)	142	(134–150)	17	28
Sweden	30	(29–32)	28	(27–39)	251	(242–258)	145	(139–152)	12	19
Norway	40	(38–42)	33	(31–35)	280	(267–292)	150	(139–160)	14	22
Denmark	29	(27–30)	34	(32–35)	342	(329–354)	201	(188–213)	8	17
England & Wales	30	(25–34)	25	(21–29)	267	(228–307)	162	(131–194)	11	15
Scotland	57	(48–66)	44	(37–51)	328	(286–368)	196	(160–231)	17	22
Netherlands	19	(17–22)	19	(16–23)	234	(202–267)	113	(72–150)	8	17
Belgium	47	(46–49)	25	(23–26)	311	(301–321)	146	(138–154)	15	17
France	55	(49–61)	22	(17–27)	392	(355–431)	115	(81–148)	14	19
Switzerland	35	(34–37)	15	(14–16)	205	(197–213)	78	(65–90)	17	19
Austria	25	(22–27)	16	(13–19)	329	(303–354)	129	(98–161)	8	12
Barcelona	36	(33–38)	14	(12–17)	207	(192–224)	68	(56–81)	17	21
Basque Country	41	(37–46)	12	(8–16)	182	(159–205)	45	(22–65)	23	27
Madrid	35	(31–39)	8	(5–12)	221	(196–246)	77	(53–98)	16	10
Turin	29	(26–33)	7	(3–10)	209	(177–241)	38	(6–67)	14	18
Tuscany	26	(21–31)	13	(8–18)	222	(180–262)	71	(30–106)	12	18
Hungary	199	(196–203)	79	(77–82)	973	(960–987)	275	(259–291)	20	29
Czech Republic	44	(43–46)	37	(36–39)	810	(799–822)	351	(337–365)	5	11
Poland	77	(76–79)	42	(40–43)	853	(844–862)	293	(285–301)	9	14
Lithuania	114	(110–119)	58	(55–61)	795	(772–820)	258	(244–273)	14	22
Estonia	112	(103–120)	65	(60–70)	1,063	(1019–1100)	376	(350–398)	11	17

Table A3 Educational distribution (in %) and mortality rate ratios according to education by country, sex and age group

Country	Education	EDUCATIONAL DISTRIBUTION (in %)								MORTALITY RATE RATIOS							
		MEN				WOMEN				MEN				WOMEN			
		30-44	45-59	60-69	70-79	30-44	45-59	60-69	70-79	30-44	45-59	60-69	70-79	30-44	45-59	60-69	70-79
Finland	low	20.1	32.6	53.7	70.4	13.9	29.7	55.0	74.0	4.27	2.35	1.82	1.55	3.49	2.05	1.59	1.50
	middle	48.8	39.5	23.7	14.1	41.1	38.8	26.6	16.3	2.27	1.76	1.50	1.26	1.69	1.32	1.25	1.22
	high	31.1	27.8	22.6	15.5	44.9	31.5	18.3	9.7	1	1	1	1	1	1	1	1
Sweden	low	15.6	28.9	45.5	55.4	12.0	23.4	45.1	62.7	3.40	2.25	1.75	1.54	2.68	2.08	1.82	1.56
	middle	63.9	49.4	37.7	31.6	58.8	48.2	37.7	28.1	1.90	1.68	1.39	1.26	1.49	1.45	1.42	1.27
	high	20.5	21.7	16.8	13.0	29.2	28.5	17.3	9.1	1	1	1	1	1	1	1	1
Norway	low	9.6	18.4	32.3	41.3	8.6	21.0	40.3	52.3	3.95	2.79	2.15	1.72	3.01	2.40	1.97	1.65
	middle	62.3	54.8	48.4	44.1	57.6	54.8	46.5	39.7	2.05	1.78	1.52	1.32	1.77	1.44	1.39	1.22
	high	28.1	26.8	19.3	14.6	33.8	24.2	13.2	8.0	1	1	1	1	1	1	1	1
Denmark	low	32.5	31.6	43.5	54.2	31.5	39.3	58.7	71.1	3.93	2.37	1.69	1.45	2.73	1.98	1.74	1.41
	middle	42.6	44.7	39.3	31.5	36.6	35.3	27.9	20.2	1.99	1.63	1.41	1.32	1.35	1.36	1.31	1.19
	high	24.9	23.7	17.2	14.4	31.9	25.5	13.3	8.8	1	1	1	1	1	1	1	1
England & Wales	low	43.3	45.1	57.2	67.1	42.9	51.1	66.1	76.2	1.95	2.12	1.59	1.56	1.80	1.37	1.77	1.63
	middle	32.9	34.1	27.8	19.8	34.5	29.1	20.6	13.6	1.62	1.54	1.16	1.13	0.98	0.88	1.24	1.16
	high	23.8	20.8	15.0	13.1	22.7	19.9	13.3	10.2	1	1	1	1	1	1	1	1
Scotland	low	20.3	35.5	56.9	63.6	20.6	39.0	59.8	67.8	4.63	2.55	1.78	1.78	3.41	1.94	1.95	1.80
	middle	46.6	34.2	21.0	16.9	47.1	33.6	23.2	17.9	2.71	1.54	1.40	1.35	1.18	1.13	1.20	1.23
	high	33.2	30.3	22.2	19.4	32.3	27.5	17.0	14.3	1	1	1	1	1	1	1	1
Netherlands	low	29.4	32.3	38.9	44.6	30.9	46.7	61.0	70.0	2.03	1.93	1.60	1.83	1.87	1.67	1.72	1.34
	middle	44.3	40.3	39.0	36.1	47.2	35.1	27.5	22.6	1.32	1.24	1.28	1.43	1.05	1.24	1.28	0.97
	high	26.2	27.4	22.1	19.2	21.9	18.1	11.5	7.4	1	1	1	1	1	1	1	1

Table A3 Educational distribution (in %) and mortality rate ratios according to education by country, sex and age group (continued)

Country	Education	EDUCATIONAL DISTRIBUTION (in %)								MORTALITY RATE RATIOS							
		MEN				WOMEN				MEN				WOMEN			
		30-44	45-59	60-69	70-79	30-44	45-59	60-69	70-79	30-44	45-59	60-69	70-79	30-44	45-59	60-69	70-79
Belgium	low	35.8	51.7	69.3	75.2	32.1	55.6	76.1	83.6	2.62	1.92	1.75	1.55	2.00	1.56	1.56	1.55
	middle	32.8	23.1	14.4	12.9	32.2	22.4	13.0	10.1	1.73	1.40	1.35	1.22	1.37	1.27	1.30	1.20
	high	31.5	25.2	16.3	11.9	35.7	22.1	10.9	6.3	1	1	1	1	1	1	1	1
France	low	24.1	33.2	51.6	68.7	26.6	43.8	67.4	81.9	3.73	2.49	1.91	2.04	3.17	1.90	1.46	1.35
	middle	53.6	48.2	36.8	22.2	47.2	38.6	24.9	13.9	2.36	1.86	1.39	1.56	1.90	1.45	1.16	1.14
	high	22.3	18.6	11.6	9.0	26.2	17.6	7.7	4.1	1	1	1	1	1	1	1	1
Switzerland	low	8.2	12.9	20.6	29.1	13.7	25.9	42.5	54.3	3.77	2.64	2.12	1.69	2.52	1.63	1.36	1.48
	middle	54.6	55.2	53.5	48.2	68.2	61.9	50.6	40.7	1.91	1.64	1.47	1.27	1.24	1.12	1.06	1.17
	high	37.3	31.9	25.9	22.7	18.1	12.2	6.9	5.0	1	1	1	1	1	1	1	1
Austria	low	13.5	19.8	32.4	37.1	24.8	38.3	60.4	66.4	2.90	2.39	1.86	1.53	2.27	1.65	1.32	1.48
	middle	68.1	62.5	53.4	50.1	60.8	52.5	35.9	30.4	1.79	1.88	1.51	1.27	1.43	1.29	1.10	1.18
	high	18.4	17.7	14.3	12.8	14.4	9.2	3.8	3.2	1	1	1	1	1	1	1	1
Barcelona	low	38.5	50.0	66.8	73.9	33.9	59.0	78.8	86.1	4.24	1.81	1.40	1.29	2.80	1.22	1.22	1.32
	middle	34.1	22.9	13.3	10.6	32.0	16.8	9.7	6.8	1.89	1.30	1.10	1.08	1.35	1.01	1.09	1.07
	high	27.4	27.0	19.9	15.5	34.1	24.2	11.5	7.1	1	1	1	1	1	1	1	1
Basque Country	low	32.6	59.4	77.7	85.3	30.9	71.7	90.0	93.4	3.19	1.66	1.27	1.19	2.40	1.28	0.96	1.18
	middle	37.9	22.3	11.0	6.7	31.8	14.0	4.8	3.1	1.62	1.20	1.15	1.03	1.61	1.16	0.91	1.04
	high	29.4	18.4	11.3	8.0	37.3	14.3	5.2	3.5	1	1	1	1	1	1	1	1
Madrid	low	39.9	57.0	71.7	79.0	39.0	68.8	84.3	89.1	3.09	1.76	1.31	1.20	1.89	1.04	1.33	1.30
	middle	31.9	20.4	12.6	9.3	30.1	15.7	8.9	6.8	1.63	1.39	1.24	1.10	1.60	1.02	1.37	1.20
	high	28.2	22.5	15.6	11.7	30.9	15.4	6.8	4.1	1	1	1	1	1	1	1	1

Table A3 Educational distribution (in %) and mortality rate ratios according to education by country, sex and age group (continued)

Country	Education	EDUCATIONAL DISTRIBUTION (in %)								MORTALITY RATE RATIOS							
		MEN				WOMEN				MEN				WOMEN			
		30-44	45-59	60-69	70-79	30-44	45-59	60-69	70-79	30-44	45-59	60-69	70-79	30-44	45-59	60-69	70-79
Turin	low	42.5	53.1	69.4	74.3	38.9	60.5	80.3	84.4	2.93	1.64	1.81	1.31	2.06	1.34	1.05	1.04
	middle	39.2	31.1	20.2	16.4	40.8	26.3	13.8	10.7	1.38	1.17	1.23	1.08	1.36	1.26	0.98	1.01
	high	18.3	15.9	10.4	9.3	20.3	13.2	5.9	4.8	1	1	1	1	1	1	1	1
Tuscany	low	45.0	52.0	71.2	76.7	35.7	55.4	78.6	83.7	4.79	2.18	1.59	1.36	2.13	1.34	1.32	1.14
	middle	39.6	31.6	18.7	14.1	45.7	29.6	15.2	11.6	2.07	1.45	1.25	1.10	1.60	1.16	1.07	0.99
	high	15.4	16.4	10.1	9.1	18.6	15.0	6.2	4.7	1	1	1	1	1	1	1	1
Hungary	low	22.8	31.8	69.6	72.3	27.8	45.4	76.8	87.8	6.83	4.81	2.50	1.92	4.25	2.45	1.55	1.26
	middle	63.7	52.9	16.8	14.7	54.9	41.4	17.5	9.2	3.00	1.79	1.40	1.12	2.04	1.46	0.98	0.81
	high	13.5	15.3	13.6	13.0	17.3	13.2	5.7	2.9	1	1	1	1	1	1	1	1
Czech Republic	low	57.1	63.6	64.6	66.3	47.6	59.6	74.7	87.0	3.75	3.62	2.95	2.40	2.71	2.49	2.22	2.01
	middle	27.9	23.3	23.5	21.5	39.9	32.1	20.6	10.6	1.69	1.81	1.57	1.36	1.47	1.55	1.65	1.60
	high	15.0	13.1	12.0	12.2	12.5	8.3	4.7	2.4	1	1	1	1	1	1	1	1
Poland	low	11.9	22.6	43.3	56.8	10.9	26.5	55.4	74.6	7.95	3.68	2.42	2.01	5.00	2.22	2.00	1.69
	middle	76.1	65.7	45.4	33.1	72.8	61.8	37.0	21.9	3.04	2.43	2.13	1.80	2.03	1.84	1.73	1.42
	high	12.0	11.6	11.3	10.1	16.3	11.6	7.6	3.5	1	1	1	1	1	1	1	1
Lithuania	low	10.9	19.8	53.6	68.0	5.1	13.2	50.2	72.2	3.97	3.12	2.05	1.66	4.73	2.85	1.84	1.55
	middle	73.5	61.7	31.0	20.4	73.1	64.9	37.0	20.5	2.21	2.02	1.51	1.36	1.80	1.55	1.34	1.31
	high	15.6	18.4	15.4	11.6	21.8	21.9	12.8	7.3	1	1	1	1	1	1	1	1
Estonia	low	12.6	31.1	50.3	59.7	6.1	19.1	45.6	63.2	6.71	3.24	2.15	1.61	6.84	3.12	2.02	1.57
	middle	70.5	50.6	33.3	27.4	70.9	60.6	40.1	28.9	3.17	2.34	1.82	1.46	2.14	1.91	1.63	1.41
	high	16.9	18.3	16.3	12.9	23.0	20.3	14.3	7.9	1	1	1	1	1	1	1	1

Table A4 Educational distribution (in %) assumed under the assumption of the cohort replacement scenario and the OECD annual increase in education scenario by country, sex and age group

Country	Education	COHORT REPLACEMENT SCENARIO								OECD ANNUAL INCREASE IN EDUCATION SCENARIO							
		MEN				WOMEN				MEN				WOMEN			
		30-44	45-59	60-69	70-79	30-44	45-59	60-69	70-79	30-44	45-59	60-69	70-79	30-44	45-59	60-69	70-79
Finland	low	7.6	20.1	32.6	53.7	0.5	13.9	29.7	55.0	9.6	20.1	32.6	53.7	6.6	13.9	29.7	55.0
	middle	58.0	48.8	39.5	23.7	41.2	41.1	38.8	26.6	48.5	48.8	39.5	23.7	32.9	41.1	38.8	26.6
	high	34.4	31.1	27.8	22.6	58.3	44.9	31.5	18.3	41.9	31.1	27.8	22.6	60.4	44.9	31.5	18.3
Sweden	low	2.3	15.6	28.9	45.5	0.6	12.0	23.4	45.1	7.7	15.6	28.9	45.5	5.9	12.0	23.4	45.1
	middle	76.0	63.9	49.4	37.7	69.5	58.8	48.2	37.7	67.4	63.9	49.4	37.7	58.6	58.8	48.2	37.7
	high	21.7	20.5	21.7	16.8	29.9	29.2	28.5	17.3	24.9	20.5	21.7	16.8	35.4	29.2	28.5	17.3
Norway	low	0.8	9.6	18.4	32.3	0.5	8.6	21.0	40.3	7.5	9.6	18.4	32.3	6.8	8.6	21.0	40.3
	middle	69.8	62.3	54.8	48.4	56.1	57.6	54.8	46.5	59.8	62.3	54.8	48.4	54.0	57.6	54.8	46.5
	high	29.4	28.1	26.8	19.3	43.4	33.8	24.2	13.2	32.6	28.1	26.8	19.3	39.2	33.8	24.2	13.2
Denmark	low	33.4	32.5	31.6	43.5	23.7	31.5	39.3	58.7	24.4	32.5	31.6	43.5	23.6	31.5	39.3	58.7
	middle	40.5	42.6	44.7	39.3	38.0	36.6	35.3	27.9	36.3	42.6	44.7	39.3	25.9	36.6	35.3	27.9
	high	26.1	24.9	23.7	17.2	38.3	31.9	25.5	13.3	39.4	24.9	23.7	17.2	50.4	31.9	25.5	13.3
England & Wales	low	41.5	43.3	45.1	57.2	34.7	42.9	51.1	66.1	28.7	43.3	45.1	57.2	28.5	42.9	51.1	66.1
	middle	31.7	32.9	34.1	27.8	39.8	34.5	29.1	20.6	33.1	32.9	34.1	27.8	35.1	34.5	29.1	20.6
	high	26.8	23.8	20.8	15.0	25.5	22.7	19.9	13.3	38.2	23.8	20.8	15.0	36.4	22.7	19.9	13.3
Scotland	low	5.1	20.3	35.5	56.9	2.1	20.6	39.0	59.8	13.4	20.3	35.5	56.9	13.6	20.6	39.0	59.8
	middle	58.9	46.6	34.2	21.0	60.7	47.1	33.6	23.2	33.4	46.6	34.2	21.0	34.6	47.1	33.6	23.2
	high	36.0	33.2	30.3	22.2	37.1	32.3	27.5	17.0	53.2	33.2	30.3	22.2	51.8	32.3	27.5	17.0
Netherlands	low	26.5	29.4	32.3	38.9	15.1	30.9	46.7	61.0	18.9	29.4	32.3	38.9	19.9	30.9	46.7	61.0
	middle	46.1	44.3	40.3	39.0	59.2	47.2	35.1	27.5	40.9	44.3	40.3	39.0	46.5	47.2	35.1	27.5
	high	27.4	26.2	27.4	22.1	25.7	21.9	18.1	11.5	40.2	26.2	27.4	22.1	33.6	21.9	18.1	11.5

Table A4 Educational distribution (in %) assumed under the assumption of the cohort replacement scenario and the OECD annual increase in education scenario by country, sex and age group (continued)

Country	Education	COHORT REPLACEMENT SCENARIO								OECD ANNUAL INCREASE IN EDUCATION SCENARIO							
		MEN				WOMEN				MEN				WOMEN			
		30-44	45-59	60-69	70-79	30-44	45-59	60-69	70-79	30-44	45-59	60-69	70-79	30-44	45-59	60-69	70-79
Belgium	low	19.9	35.8	51.7	69.3	8.6	32.1	55.6	76.1	21.0	35.8	51.7	69.3	18.8	32.1	55.6	76.1
	middle	42.3	32.8	23.1	14.4	42.1	32.2	22.4	13.0	33.4	32.8	23.1	14.4	29.5	32.2	22.4	13.0
	high	37.8	31.5	25.2	16.3	49.3	35.7	22.1	10.9	45.6	31.5	25.2	16.3	51.7	35.7	22.1	10.9
France	low	15.0	24.1	33.2	51.6	9.4	26.6	43.8	67.4	16.2	24.1	33.2	51.6	17.9	26.6	43.8	67.4
	middle	59.0	53.6	48.2	36.8	55.8	47.2	38.6	24.9	49.5	53.6	48.2	36.8	41.9	47.2	38.6	24.9
	high	26.0	22.3	18.6	11.6	34.8	26.2	17.6	7.7	34.2	22.3	18.6	11.6	40.2	26.2	17.6	7.7
Switzerland	low	3.5	8.2	12.9	20.6	1.5	13.7	25.9	42.5	6.0	8.2	12.9	20.6	10.0	13.7	25.9	42.5
	middle	53.8	54.6	55.2	53.5	74.5	68.2	61.9	50.6	27.8	54.6	55.2	53.5	57.9	68.2	61.9	50.6
	high	42.7	37.3	31.9	25.9	24.0	18.1	12.2	6.9	66.2	37.3	31.9	25.9	32.1	18.1	12.2	6.9
Austria	low	7.2	13.5	19.8	32.4	11.3	24.8	38.3	60.4	8.5	13.5	19.8	32.4	15.7	24.8	38.3	60.4
	middle	73.7	68.1	62.5	53.4	69.1	60.8	52.5	35.9	63.6	68.1	62.5	53.4	62.5	60.8	52.5	35.9
	high	19.1	18.4	17.7	14.3	19.6	14.4	9.2	3.8	27.8	18.4	17.7	14.3	21.8	14.4	9.2	3.8
Barcelona	low	27.0	38.5	50.0	66.8	8.8	33.9	59.0	78.8	24.0	38.5	50.0	66.8	21.1	33.9	59.0	78.8
	middle	45.2	34.1	22.9	13.3	47.2	32.0	16.8	9.7	26.7	34.1	22.9	13.3	17.5	32.0	16.8	9.7
	high	27.8	27.4	27.0	19.9	44.0	34.1	24.2	11.5	49.3	27.4	27.0	19.9	61.4	34.1	24.2	11.5
Basque Country	low	5.8	32.6	59.4	77.7	0.5	30.9	71.7	90.0	20.3	32.6	59.4	77.7	19.3	30.9	71.7	90.0
	middle	53.8	37.9	22.3	11.0	39.2	31.8	14.0	4.8	26.7	37.9	22.3	11.0	13.6	31.8	14.0	4.8
	high	40.4	29.4	18.4	11.3	60.3	37.3	14.3	5.2	52.9	29.4	18.4	11.3	67.2	37.3	14.3	5.2
Madrid	low	22.8	39.9	57.0	71.7	9.2	39.0	68.8	84.3	24.9	39.9	57.0	71.7	24.3	39.0	68.8	84.3
	middle	43.3	31.9	20.4	12.6	44.4	30.1	15.7	8.9	24.3	31.9	20.4	12.6	20.0	30.1	15.7	8.9
	high	33.9	28.2	22.5	15.6	46.4	30.9	15.4	6.8	50.8	28.2	22.5	15.6	55.6	30.9	15.4	6.8

Table A4 Educational distribution (in %) assumed under the assumption of the cohort replacement scenario and the OECD annual increase in education scenario by country, sex and age group (continued)

		COHORT REPLACEMENT SCENARIO								OECD ANNUAL INCREASE IN EDUCATION SCENARIO							
Country	Education	MEN				WOMEN				MEN				WOMEN			
		30-44	45-59	60-69	70-79	30-44	45-59	60-69	70-79	30-44	45-59	60-69	70-79	30-44	45-59	60-69	70-79
Turin	low	31.9	42.5	53.1	69.4	17.3	38.9	60.5	80.3	29.5	42.5	53.1	69.4	27.0	38.9	60.5	80.3
	middle	47.4	39.2	31.1	20.2	55.3	40.8	26.3	13.8	30.8	39.2	31.1	20.2	28.9	40.8	26.3	13.8
	high	20.7	18.3	15.9	10.4	27.4	20.3	13.2	5.9	39.7	18.3	15.9	10.4	44.0	20.3	13.2	5.9
Tuscany	low	38.0	45.0	52.0	71.2	16.0	35.7	55.4	78.6	31.3	45.0	52.0	71.2	24.8	35.7	55.4	78.6
	middle	45.6	39.6	31.6	18.7	61.8	45.7	29.6	15.2	35.3	39.6	31.6	18.7	34.8	45.7	29.6	15.2
	high	16.4	15.4	16.4	10.1	22.2	18.6	15.0	6.2	33.4	15.4	16.4	10.1	40.4	18.6	15.0	6.2
Hungary	low	13.8	22.8	31.8	69.6	10.2	27.8	45.4	76.8	9.3	22.8	31.8	69.6	11.3	27.8	45.4	76.8
	middle	70.9	63.7	52.9	16.8	68.4	54.9	41.4	17.5	67.1	63.7	52.9	16.8	58.4	54.9	41.4	17.5
	high	15.3	13.5	15.3	13.6	21.4	17.3	13.2	5.7	23.6	13.5	15.3	13.6	30.3	17.3	13.2	5.7
Czech Republic	low	50.6	57.1	63.6	64.6	35.6	47.6	59.6	74.7	27.7	57.1	63.6	64.6	23.1	47.6	59.6	74.7
	middle	32.5	27.9	23.3	23.5	47.7	39.9	32.1	20.6	47.5	27.9	23.3	23.5	56.2	39.9	32.1	20.6
	high	16.9	15.0	13.1	12.0	16.7	12.5	8.3	4.7	24.8	15.0	13.1	12.0	20.6	12.5	8.3	4.7
Poland	low	1.2	11.9	22.6	43.3	0.5	10.9	26.5	55.4	5.4	11.9	22.6	43.3	5.0	10.9	26.5	55.4
	middle	86.4	76.1	65.7	45.4	78.5	72.8	61.8	37.0	65.4	76.1	65.7	45.4	55.4	72.8	61.8	37.0
	high	12.4	12.0	11.6	11.3	21.0	16.3	11.6	7.6	29.2	12.0	11.6	11.3	39.6	16.3	11.6	7.6
Lithuania	low	2.0	10.9	19.8	53.6	0.5	5.1	13.2	50.2	6.8	10.9	19.8	53.6	3.2	5.1	13.2	50.2
	middle	79.6	73.5	61.7	31.0	77.8	73.1	64.9	37.0	68.2	73.5	61.7	31.0	61.9	73.1	64.9	37.0
	high	18.4	15.6	18.4	15.4	21.7	21.8	21.9	12.8	25.0	15.6	18.4	15.4	35.0	21.8	21.9	12.8
Estonia	low	0.5	12.6	31.1	50.3	0.5	6.1	19.1	45.6	7.9	12.6	31.1	50.3	3.8	6.1	19.1	45.6
	middle	81.2	70.5	50.6	33.3	73.8	70.9	60.6	40.1	65.0	70.5	50.6	33.3	59.3	70.9	60.6	40.1
	high	18.3	16.9	18.3	16.3	25.7	23.0	20.3	14.3	27.1	16.9	18.3	16.3	36.9	23.0	20.3	14.3

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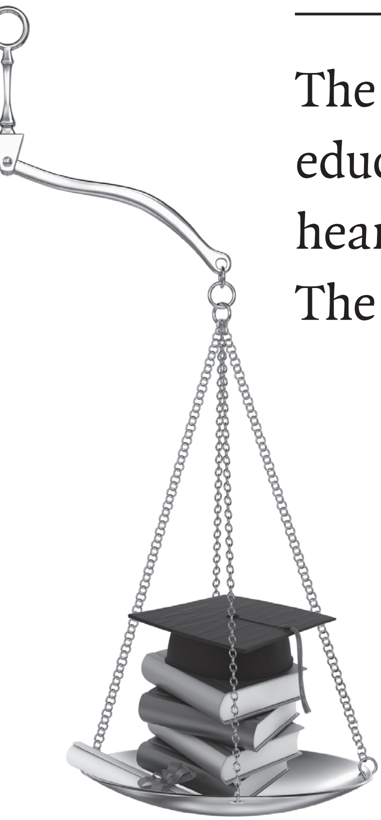

The potential for reduction of educational differences in ischaemic heart disease mortality in Europe: The role of three lifestyle risk factors

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Submitted

ABSTRACT

Background

Ischaemic heart disease (IHD) is one of the leading causes of death worldwide with a higher risk of dying among people with a lower socioeconomic status. We investigated the potential for reducing educational differences in IHD mortality in 21 European populations.

Methods

We used a method based on the Population Attributable Fraction to estimate the impact of a modified educational distribution of smoking, overweight and obesity, and physical inactivity on educational inequalities in IHD mortality among people aged 30–79. Risk factor prevalence was collected around the year 2000 and mortality data covered the early 2000s.

Results

The potential reduction of educational inequalities in IHD mortality differed by country, sex and risk factor. Smoking was the most important risk factor among men in Nordic and eastern European populations, whereas overweight and obesity was the most important among women in the South of Europe. We found only a small effect of physical inactivity on the reduction of inequalities in IHD mortality. Although the reduction in inequalities in IHD mortality may seem modest, substantial reduction in IHD mortality among the least educated can be achieved under the scenarios investigated.

Conclusions

Population-wide strategies to reduce the prevalence of risk factors such as smoking, and overweight and obesity targeted at the lower socioeconomic groups are likely to substantially contribute to the reduction of IHD mortality and inequalities in IHD mortality in Europe.

INTRODUCTION

Despite a considerable decline in ischaemic heart disease (IHD) mortality over the past decades, IHD remains one of the leading causes of mortality worldwide [1]. Socioeconomic inequalities in IHD mortality have been consistently reported with important variations in their magnitude between European countries [2]. In addition, the decrease in IHD mortality was more pronounced among people with high socioeconomic position, which resulted in widening socioeconomic inequalities in IHD mortality in many European countries during the 1980s, 1990s and 2000s [3, 4].

The major risk factors of IHD mortality include behavioural risk factors, such as e.g., tobacco consumption, physical inactivity, unhealthy diet or harmful use of alcohol; intermediate risk factors, such as e.g., overweight and obesity, hypertension and diabetes; and insufficient medical care [5]. Most of these risk factors are amenable to change and could be reduced by suitable public health interventions. There are considerable health benefits at all ages, for men and women, in stopping smoking, reducing cholesterol or blood pressure, adopting a healthy diet or increasing physical activity [6-8]. In addition, as these risk factors are more prevalent in lower socioeconomic groups, except smoking among women in southern Europe [9], their redistribution has a potential for reducing inequalities in IHD mortality.

However, although a few studies have quantified the impact of eliminating socioeconomic inequalities in risk factors distribution on socioeconomic inequalities in IHD mortality, the majority of studies is limited to a single country, especially to the United Kingdom [10, 11]. Because the socioeconomic distribution of risk factors and the average IHD mortality rates vary by country, scientific evidence limited to selected European countries hinders an effective public health policy in other parts of Europe.

The main purpose of this study was therefore to estimate to what extent educational differences in IHD mortality can potentially be reduced in 21 European populations by modifying the distribution of three lifestyle risk factors: smoking, overweight and obesity, and physical inactivity. We quantified the potential reduction in educational inequalities in IHD mortality by applying two scenarios in which the risk factor distribution according to educational level was modified.

METHODS

Data

We collected and harmonized mortality data by sex, age, cause of death and level of education for 21 European populations. The mortality data came from both longitudinal and cross-sectional country-specific datasets with one to seven years of follow-up at the beginning of the 2000s covering national (Finland, Sweden, Norway, Denmark, England and Wales, Scotland, Netherlands, Belgium, France, Switzerland, Austria, Hungary, Czech Republic, Poland, Lithuania, Estonia), regional (Madrid and the Basque Country) or urban (Barcelona, Turin and Tuscany: Florence, Leghorn, Prato) populations (Table A1 in appendix). Due to the different study designs and follow-up times, we used an adjustment method in order to obtain comparable average age at death [12]. Additionally, we collected risk factors prevalence from representative national health surveys conducted around the year 2000 in the same populations (Table A2 in appendix).

IHD was coded according to the International Classification of Diseases and defined as codes 410–414 in the 9th revision (Austria, Turin, Tuscany) and I20–I25 in the 10th revision (other countries). The socioeconomic status was measured by completed education. Educational level was classified according to the International Standard Classification of Education (ISCED) and split into three categories: less than secondary education (ISCED 0, 1, 2; 'low'), secondary education (ISCED 3, 4; 'mid') and tertiary education (ISCED 5, 6; 'high'). Individuals with unknown education were excluded from the analysis, except in Finland, Denmark and Lithuania where unknown education was classified together with low education. The share of the population with unknown education was on average less than 5%.

Risk factors

Based on sufficient evidence on an association between the risk factor and IHD mortality and on the data availability, we selected smoking, overweight and obesity, and physical inactivity as important modifiable risk factors for IHD mortality. Smoking was measured as self-reported smoking status (current, former and never smokers). The regular and occasional smokers were combined together as current smokers in order to ensure comparability across European countries which survey questions slightly differ. The RRs of IHD mortality by smoking status, sex and age group came from the Cancer Prevention Study II [13]. Overweight and obesity was measured by means of body mass index (BMI), which was calculated from self-reported weight and height. BMI was then categorized in three groups: normal weight (BMI < 25), overweight (25 =< BMI <30) and obese (BMI >= 30). BMI lower than 10 or greater than 70 was considered as missing value due to its implausibility. The RRs of IHD mortality by BMI category, sex, and age group were calculated based on single age values from a literature review [14]. Physical inactivity was derived from a variable measuring the respondent's physical activity in terms of regular sport training and physically intensive leisure time activities and was categorized in two groups: active and sedentary. The active group includes people exercising approximately twice a week or more. The RRs of IHD mortality by physical inactivity, sex and age group were taken from a systematic review and meta-analysis [15]. All RRs are presented in appendix (Table A3).

Methods

We calculated age-standardized IHD mortality rates (ASMR) for the ages 30–79 and their 95% confidence intervals (CI) directly standardized to the European Standard Population [16]. We estimated the impact of counterfactual distribution of smoking, overweight and obesity, and physical inactivity on educational differences in IHD mortality by using the measure of the Population Attributable Fraction (PAF). The PAF is defined as the proportion of disease cases or deaths which would be prevented if the exposure to the risk factor were eliminated or merely modified and was computed using the following formula [17].

$$PAF = \frac{\sum_{i=1}^{n} P_i RR_i - \sum_{i=1}^{n} P_i' RR_i}{\sum_{i=1}^{n} P_i RR_i}$$

with n the number of exposure categories (of the risk factor), P_i the proportion of population currently in the ith exposure category, P'_i the proportion of population in the ith exposure category in the scenario, and RR_i the relative mortality risk for the ith exposure category (obtained from the literature).

The analyses were conducted by country and stratified by sex, age group (30–44, 45–59, 60–69, 70–79) and educational level. Separately for men and women and by educational level, the age-specific PAFs were then combined to obtain a PAF for the age range 30–79. We calculated CIs around the PAFs by bootstrap [18]. We also calculated a European average PAF which is an arithmetic mean of the 18 country-specific estimates (for Spain and Italy, average PAF values were calculated from the regional PAFs). Separately for men and women and by educational level, the age-specific PAFs were also used to calculate new ASMRs corresponding to the mortality that would be observed after the implementation of the counterfactual scenario. Based on the original and new ASMRs, we computed mortality rate ratios (MRR) with high educated as a reference category. The potential reduction in relative inequalities in IHD mortality was expressed as a percentage change in excess mortality, using the following formula (for low educated):

$$\left(1-\frac{(MRR_{scenario}^{low}-1)}{(MRR_{original}^{low}-1)}\right)*100$$

The potential reduction in absolute inequalities in IHD mortality was expressed as a number of deaths per 100,000 person-years and calculated as the difference in rate difference before and after the implementation of the counterfactual scenarios using the following formula (for low educated):

$$(ASMR_{original}^{low} - ASMR_{original}^{high}) - (ASMR_{scenario}^{low} - ASMR_{scenario}^{high})$$

Because of space limit, we will only show results contrasting the high and low educated, which will result in an underestimation of the overall inequality reduction.

We modelled two counterfactual scenarios in which the distribution of the risk factor changed. In the first scenario called *upward levelling scenario*, we set the prevalence of the risk factor to the level currently observed among the high educated. In rare cases where the scenario would lead to a mortality increase in lower educated groups (because of reverse social gradient of risk factor prevalence) we set the PAF to zero because it is implausible that a policy intervention would aim at deteriorating health outcomes. The second scenario called *best-practice-country scenario* modelled a currently optimal situation, applying the risk factor distribution of a country that combined (one of) the lowest average risk factor prevalence with (one of) the smallest relative inequalities in the specific risk factor (without reverse social gradient in the risk factor distribution). After careful evaluation, the countries that fulfilled best the above mentioned criteria were France (men) and Finland (women) for smoking, Norway (both men and women) for overweight and obesity, and Denmark (men) and Finland (women) for physical inactivity. The prevalence of the risk factor among high educated individuals always changes in the best-practice-country scenario. It is therefore possible that by using the risk factor distribution of the 'best country' in other countries the mortality rate is reduced more among high educated than among low or mid educated and as a consequence, the relative inequalities increase. It is also possible that the mortality rate increases in a specific educational group if the risk factor distribution in this group is less 'favourable' in the best-practice country than in the specific country. This will lead to a negative PAF value. Although this is not what we aim for, we accepted negative values so that our results always show how the mortality would change if we applied the risk factor distribution of the best practice country, regardless of whether this is an improvement or a deterioration.

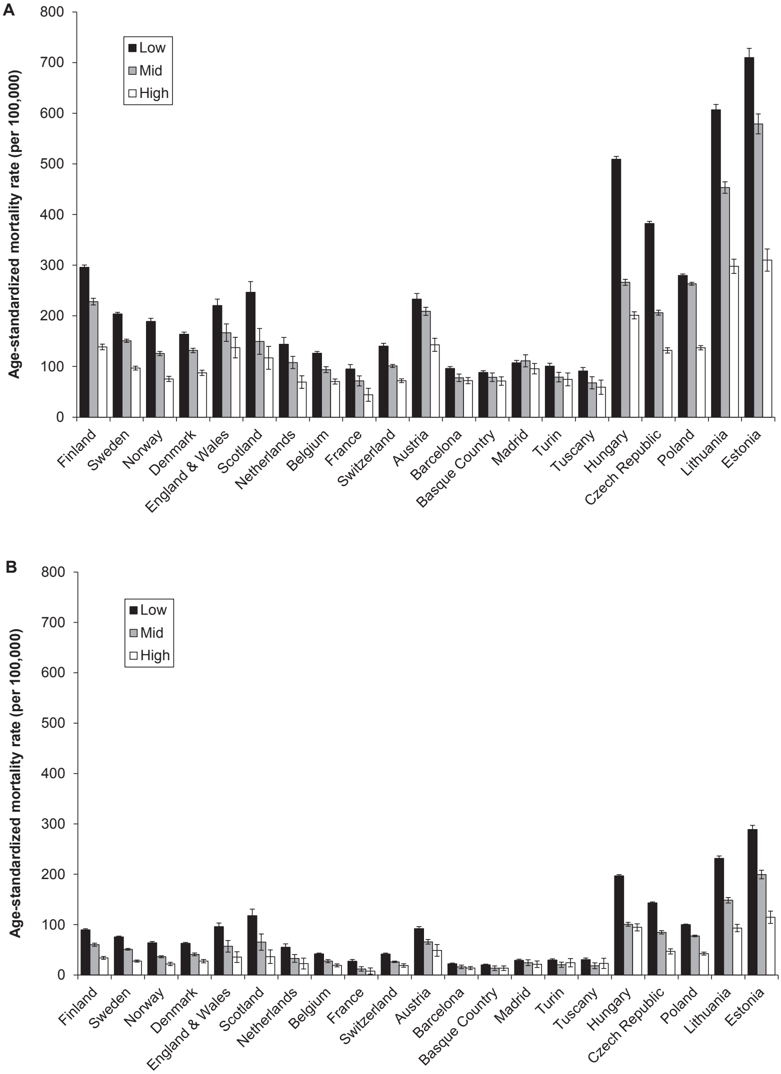

Figure 1 Age-standardized mortality rates (per 100,000 person-years) from IHD by education, country and sex, with corresponding 95% confidence intervals, 21 European populations, 30–79 years, (A) men, (B) women

RESULTS

Although we consistently observed lower IHD mortality among higher educated men and women and higher mortality rates among men than among women, the level of IHD mortality as well as educational differences in IHD mortality differed substantially across the 21 European populations studied (Figure 1, Table 2). The smallest relative and

Table 1 Population Attributable Fraction (PAF; in %) of those with a low educational level for different risk factors with 95% confidence intervals (95%-CI) by population and sex, upward levelling scenario, 30–79 years

Country	MEN						WOMEN					
	Smoking		Overweight/Obesity		Physical inactivity		Smoking		Overweight/Obesity		Physical inactivity	
	PAF	95%-CI	PAF	95%-CI	PAF	95%-CI	PAF	95%-CI	PAF	95%-CI	PAF	95%-CI
Finland	5.6	(3.9–7.5)	1.4	(1.0–1.8)	0.7	(0.5–1.2)	2.4	(1.7–4.1)	5.3	(3.1–7.5)	0.1	(0.0–1.5)
Sweden	6.4	(4.6–8.1)	3.7	(1.9–5.5)	n.a.		4.8	(3.1–6.6)	6.0	(4.3–7.7)	n.a.	
Norway	11.5	(9.2–13.5)	5.0	(2.7–7.3)	3.0	(2.0–3.6)	9.6	(7.4–11.6)	7.3	(5.0–9.6)	2.2	(1.7–3.0)
Denmark	6.3	(4.7–7.8)	5.4	(3.6–6.9)	2.9	(2.1–3.8)	3.6	(2.6–4.9)	6.3	(4.8–7.8)	4.4	(3.4–5.3)
England & Wales	8.9	(7.8–10.1)	3.3	(2.1–4.5)	n.a.		6.5	(5.2–7.8)	6.8	(5.6–8.0)	n.a.	
Scotland	9.5	(7.8–11.1)	3.8	(2.1–5.5)	n.a.		12.0	(10.4–13.7)	2.7	(1.2–4.2)	n.a.	
Netherlands	5.2	(3.7–6.6)	5.5	(4.1–6.9)	1.2	(0.5–2.0)	3.0	(2.4–3.8)	6.8	(5.5–8.1)	3.8	(3.0–4.5)
Belgium	3.0	(2.2–4.0)	4.7	(3.6–5.8)	3.1	(2.5–3.8)	0.8	(0.7–1.1)	8.3	(7.2–9.4)	6.8	(6.1–7.5)
France	3.4	(2.8–4.7)	6.7	(5.4–8.0)	n.a.		1.8	(1.4–2.1)	9.8	(8.4–11.2)	n.a.	
Switzerland	3.7	(1.8–5.8)	6.3	(4.4–8.2)	4.8	(4.0–5.8)	0.7	(0.4–1.4)	10.3	(9.0–11.6)	5.7	(5.0–6.6)
Austria	3.5	(1.9–6.2)	7.7	(5.1–10.3)	n.a.		0.5	(0.2–1.0)	10.3	(8.5–12.1)	n.a.	
Barcelona	2.6	(2.3–3.3)	3.9	(3.1–4.7)	3.1	(3.0–3.3)	0.2	(0.0–0.3)	9.2	(8.2–10.2)	2.2	(2.1–2.4)
Basque Country	3.1	(2.3–4.5)	2.1	(0.9–3.3)	3.2	(3.1–3.3)	0.7	(0.3–1.0)	9.7	(8.4–11.0)	2.4	(2.3–2.6)
Madrid	2.3	(2.1–2.9)	3.9	(3.1–4.7)	3.0	(2.9–3.2)	0.3	(0.2–0.4)	8.9	(7.9–9.9)	2.1	(1.9–2.2)
Turin	1.5	(1.3–1.9)	5.1	(4.7–5.5)	1.3	(1.1–1.4)	0.1	(0.1–0.2)	8.3	(7.9–8.7)	1.5	(1.4–1.7)
Tuscany	1.5	(1.3–1.9)	5.0	(4.6–5.4)	1.3	(1.2–1.5)	0.1	(0.0–0.2)	8.4	(8.0–8.8)	1.6	(1.4–1.7)
Hungary	n.a.		2.3	(0.6–4.0)	n.a.		n.a.		6.2	(4.7–7.7)	n.a.	
Czech Republic	9.3	(6.4–12.1)	5.8	(3.1–8.5)	0.0	(0.0–0.6)	3.0	(2.1–4.2)	8.0	(5.4–10.6)	2.0	(1.5–2.7)
Poland	10.9	(9.8–11.9)	1.4	(0.6–2.2)	n.a.		2.6	(2.0–3.2)	8.6	(7.7–9.5)	n.a.	
Lithuania	6.0	(3.6–7.2)	2.4	(0.7–4.1)	4.9	(4.0–5.9)	1.4	(0.2–2.0)	1.9	(0.1–3.7)	10.5	(9.0–11.1)
Estonia	5.9	(4.1–9.2)	0.1	(0.0–2.9)	0.9	(0.5–1.2)	2.4	(2.2–6.6)	8.5	(5.4–11.6)	2.9	(2.6–6.4)
EU average	6.1		4.1		2.4		3.3		7.3		3.8	

n.a. = not available

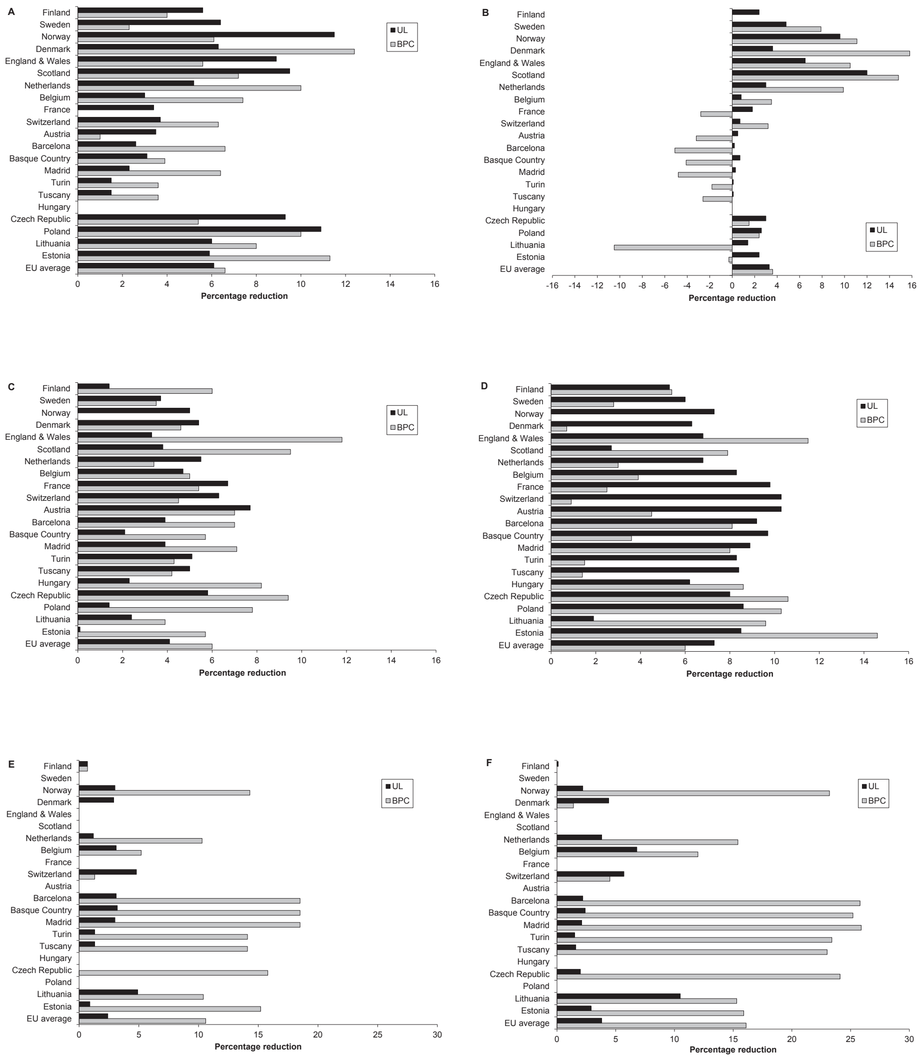

Figure 2 Percentage reduction of those with a low educational level under the upward levelling (UL) and the best-practice-country (BPC) scenario, by population and sex, 30–79 years, (A) men, smoking, (B) women, smoking, (C) men, overweight and obesity, (D) women, overweight and obesity, (E) men, physical inactivity, (F) women, physical inactivity

Chapter 8

absolute inequalities were found in the Spanish and Italian populations. Mortality rates and inequalities were largest in Eastern Europe, leading to a remarkable excess mortality among low educated in these countries.

Table 1 presents by which percentage the mortality rate among low educated may be decreased if the assumptions of the upward levelling scenario held. The PAF values varied substantially by country, gender and risk factor. The PAF ranged from 0 (for smoking among women in Turin and Tuscany, overweight and obesity among Estonian men and physical inactivity among Czech men and Finnish women) to 12% for smoking among Norwegian men and among Scottish women. Among low educated, the most beneficial for IHD mortality would be the elimination of educational differences in smoking among men and in overweight and obesity among women. From the figure 2 it is evident that both scenarios lead to different mortality reductions among low educated men and women. The decrease in mortality was more pronounced under the best-practice-country scenario than under the upward levelling scenario in many situations for all three risk factors, such as in Southern Europe for smoking among men, in Northern and Western Europe for smoking among women or in the UK and in Eastern Europe among men and women for overweight and obesity. For physical inactivity, the percentage reduction under the best-practice-country scenario was around or above 20% in several countries, especially in the South. Substantial mortality reductions were also achieved among high educated (Table A4 in appendix).

Table 2 describes the potential reduction of relative and absolute inequalities in IHD mortality. Among men, eliminating educational inequalities in smoking reduced relative inequalities in IHD mortality by more than 10% in most European populations, whereas the elimination of educational inequalities in overweight and obesity and in physical inactivity had considerable impact on relative inequalities only in southern Europe. Among women, the elimination of educational inequalities in smoking and in physical inactivity would lead to a negligible reduction in relative inequalities in IHD mortality in most populations. By contrast, eliminating inequalities in overweight and obesity could reduce relative inequalities in IHD mortality by 10% to 50% in most European populations. Although the largest percentage reductions were achieved in southern European regions, these reductions applied to low mortality rate ratio and/or to low mortality rate and did not lead to any considerable reductions in absolute terms. The reduction in absolute inequalities was largest in Eastern Europe, especially among men (e.g., among Estonian men with reduction of 42 deaths per 100,000 person-years). A substantial reduction in absolute inequalities would also be observed with an elimination of inequalities in smoking in the Nordic countries (men), England and Wales and the Netherlands (men) and Scotland (men and women).

The results did not differ considerably between the two scenarios. However, the reduction in inequalities was smaller under the best-practice-country scenario than under the upward levelling scenario, and inequalities even sometimes slightly increased, mostly for smoking among women in southern Europe.

Table 2 Original mortality rate ratios (MRR), original rate difference (RD), and potential reduction of relative (in %) and absolute (deaths per 100,000 person-years) inequalities in IHD mortality between those with high and low educational level, upward levelling (UL) and best-practice-country (BPC) scenarios, by population and sex, 30–79 years

Country	Original		Inequality decrease after implementation of the scenario											
			Smoking				Overweight/Obesity				Physical inactivity			
	MRR	RD	UL scenario		BPC scenario		UL scenario		BPC scenario		UL scenario		BPC scenario	
			rel red	abs red	rel red	abs red	rel red	abs red	rel red	abs red	rel red	abs red	rel red	abs red
MEN														
Finland	2.13	157	11	17	7	11	3	4	-17	-2	1	2	-7	-4
Sweden	2.10	107	12	13	8	7	7	8	-3	2	n.a.	n.a.	n.a.	n.a.
Norway	2.51	114	19	22	15	14	8	10	ref	ref	5	6	0	16
Denmark	1.87	76	14	10	10	13	12	9	0	4	6	5	ref	ref
England & Wales	1.60	83	22	20	18	14	9	7	-5	7	n.a.	n.a.	n.a.	n.a.
Scotland	2.11	130	18	23	12	17	7	10	-3	11	n.a.	n.a.	n.a.	n.a.
Netherlands	2.08	75	10	8	6	10	11	8	1	3	2	2	-4	7
Belgium	1.80	56	7	4	2	5	11	6	-1	3	7	4	0	3
France	2.16	51	6	3	ref	ref	13	6	3	4	n.a.	n.a.	n.a.	n.a.
Switzerland	1.95	68	8	5	4	6	13	9	2	4	10	7	4	2
Austria	1.63	90	9	8	6	4	20	18	4	8	n.a.	n.a.	n.a.	n.a.
Barcelona	1.33	24	10	3	-1	2	16	4	-7	1	12	3	0	5
Basque Country	1.24	17	16	3	0	1	11	2	-19	-1	16	3	0	3
Madrid	1.12	11	22	3	-1	1	36	4	-19	-1	28	3	-1	2
Turin	1.35	26	6	2	-3	0	20	5	0	1	5	1	-7	3
Tuscany	1.54	32	4	1	-2	1	14	5	0	1	4	1	-5	4
Hungary	2.53	308	n.a.	n.a.	n.a.	n.a.	4	12	-5	20	n.a.	n.a.	n.a.	n.a.
Czech Republic	2.90	251	14	36	12	25	9	22	2	25	0	0	-5	36
Poland	2.04	143	21	31	17	26	3	4	-9	6	n.a.	n.a.	n.a.	n.a.
Lithuania	2.04	309	12	36	9	37	5	15	-7	3	10	30	5	39
Estonia	2.29	400	10	42	5	54	0	1	-13	3	2	7	-9	48

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Table 2 Original mortality rate ratios (MRR), original rate difference (RD), and potential reduction of relative (in %) and absolute (deaths per 100,000 person-years) inequalities in IHD mortality between those with high and low educational level, upward levelling (UL) and best-practice-country (BPC) scenarios, by population and sex, 30–79 years (continued)

Country	Original		Inequality decrease after implementation of the scenario											
			Smoking				Overweight/Obesity				Physical inactivity			
	MRR	RD	UL scenario		BPC scenario		UL scenario		BPC scenario		UL scenario		BPC scenario	
			rel red	abs red	rel red	abs red	rel red	abs red	rel red	abs red	rel red	abs red	rel red	abs red
WOMEN														
Finland	2.64	56	4	2	ref	ref	9	5	-4	2	0	0	ref	ref
Sweden	2.72	48	8	4	4	4	10	5	-3	1	n.a.	n.a.	n.a.	n.a.
Norway	2.91	42	15	6	12	6	11	5	ref	ref	3	1	3	10
Denmark	2.28	35	6	2	2	6	11	4	-2	0	8	3	9	2
England & Wales	2.70	60	10	6	6	8	11	7	-1	7	n.a.	n.a.	n.a.	n.a.
Scotland	3.23	81	17	14	12	15	4	3	-8	5	n.a.	n.a.	n.a.	n.a.
Netherlands	2.44	33	5	2	-2	3	12	4	-2	1	7	2	8	6
Belgium	2.20	23	2	0	-8	0	15	4	2	1	12	3	14	4
France	3.48	19	3	1	-8	-1	14	3	3	1	n.a.	n.a.	n.a.	n.a.
Switzerland	2.21	23	1	0	-11	0	19	4	5	1	10	2	12	2
Austria	1.88	43	1	0	-6	-3	22	10	5	3	n.a.	n.a.	n.a.	n.a.
Barcelona	1.62	9	1	0	-26	-2	24	2	5	1	6	1	10	3
Basque Country	1.49	7	2	0	-26	-1	30	2	8	1	7	1	12	2
Madrid	1.37	8	1	0	-31	-2	33	3	5	1	8	1	14	3
Turin	1.21	5	0	0	-57	-2	48	3	2	0	9	0	13	2
Tuscany	1.32	7	0	0	-44	-3	35	3	1	0	7	1	6	2
Hungary	2.08	102	n.a.	n.a.	n.a.	n.a.	12	12	-3	8	n.a.	n.a.	n.a.	n.a.
Czech Republic	3.06	96	5	4	-5	0	12	12	1	11	3	3	4	24
Poland	2.35	57	5	3	-10	-1	15	9	1	6	n.a.	n.a.	n.a.	n.a.
Lithuania	2.48	138	2	3	-10	-20	3	4	-19	5	18	24	3	33
Estonia	2.52	174	4	7	1	0	14	25	-1	25	5	8	8	33

rel red = relative reduction, abs red = absolute reduction, ref = reference country, n.a. = not available

DISCUSSION

Our findings on educational inequalities in IHD mortality are in line with what has been reported previously [2]. In absolute terms, IHD mortality was extremely large in Eastern European populations leading to large inequalities. We observed the north-south gradient with IHD mortality and inequalities in IHD mortality being higher in the North and lower in the South of Europe, which is believed to be at least partly attributable to the Mediterranean diet [19].

Our findings regarding the potential for inequalities reduction revealed important country- and gender-specific patterns. The impact of smoking on IHD mortality and on educational differences in IHD mortality was larger in the North, West and East (men only) of Europe and the impact of overweight and obesity was larger in the South of Europe, especially among women. We found only a small impact of physical inactivity in most European countries, except Lithuania, which may partly be due to imprecision in the measurement of this risk factor. Although these results are consistent with the available literature on socioeconomic inequalities in these risk factors in Europe [9, 20-22], they cannot fully explain the large cross-country differences in IHD mortality.

The relatively small IHD mortality gains from the elimination or modification of the exposure to certain behavioural risk factors may be a consequence of the limited number of risk factors investigated. Although behavioural risk factors explained 53% among men and 25% among women of the relative differences between the low and high educated in IHD mortality [23], and smoking and physical inactivity were reported to be the most important health behaviours explaining educational differences in mortality [24], a large proportion of educational inequalities in IHD mortality cannot be explained by the behavioural risk factors investigated in our study. Air pollution is associated with IHD mortality [25, 26] and may partly account for our findings in Eastern Europe as both outdoor and indoor air pollution is higher in Eastern European countries than in other parts of Europe, with large inequalities in the exposure to this risk factor [27, 28]. Other risk factors, such as working conditions (both physical and psychosocial) or material circumstances [29], have been found to be major sources of health inequalities and may play an important role in the explanation of educational inequalities in IHD mortality as well.

Despite differences in study populations, measurement of socioeconomic position and method of analysis, our results are consistent with the studies investigating the role of various risk factors in socioeconomic inequalities in IHD mortality. Interventions based on smoking cessation in the UK have shown that relative inequalities in IHD mortality could be reduced by 28% among men [10], a value close to the 22%-reduction we found in England and Wales and the 18%-reduction in Scotland if all men had the same smoking prevalence as high educated men. In Denmark, among men, 8% and 21% of the excess mortality between low and high educated was attributed to smoking and BMI, respectively, whereas these figures were 6% and 14% among women. The effect of low physical activity was negligible among men and women [30]. Again, these estimates are close to our results. We found that, when inequalities in smoking and BMI are eliminated in Denmark, educational inequalities in IHD mortality could be reduced by 14% and 12% among men and by 6% and 11% among women, respectively.

The reduction of relative and absolute inequalities in IHD mortality does not extensively differ between the two scenarios investigated, especially in countries with large inequalities in IHD mortality and/or high IHD mortality. This means that the upward levelling scenario does not lead to a clear larger decrease in inequalities in IHD mortality. On the contrary, the best-practice-country scenario often showed a larger decrease in mortality among low educated than the upward levelling scenario did. The decrease was even sometimes more than double. These results mean that low educated in the best-practice country have a lower prevalence of risk factors than high educated in the studied country. Our results then point to countries where efforts should be made to decrease the risk factor prevalence among the whole population. They also suggest that focusing only on the reduction of inequalities in IHD mortality does not show the entire picture and may not be the best option to decrease health inequalities in some countries. For instance in England and Wales, the population health regarding IHD would be much more improved in all educational groups if we manage to lower the BMI to that observed in Norway, even though inequalities would remain, than if we would remove educational differences in BMI. Indeed, the mortality would decrease by 11.8% among low educated men (vs. 3.3%) and by 13.5% among high educated men (vs. no reduction). Under the best-practice-country scenario a large mortality decrease among low educated does not necessarily imply a decrease in inequalities in IHD mortality as measured with mortality rate ratio if mortality also decreased among high educated. However, the considerable reduction in IHD mortality among low educated is in itself a great achievement from a health inequalities perspective.

In this study we encountered several limitations that have to be mentioned. IHD is prone to misclassification with variation in coding practices across countries [31, 32], which may affect comparability. While IHD may be overestimated in eastern European countries, a substantial underestimation of IHD in official mortality statistics has been reported in Belgium [32] and in France, where IHD mortality could be underestimated by 27% for men and 35% for women [31]. Although the coding practice unlikely differed by socioeconomic groups, we probably over- or underestimated IHD mortality in different parts of Europe, which may have affected the absolute differences in IHD mortality between the low and high educated. Finally, in addition to IHD misclassification, the surprisingly low IHD mortality rates observed in France despite the high consumption of animal fat and increased concentration of serum cholesterol [33] may be explained by the protective effect of mild wine consumption [34].

Differences in the measurement of exposure to risk factors between countries may hamper comparability. It is likely that physical inactivity is the risk factor with the largest heterogeneity due to variation in survey questions across European populations. Self-reporting bias may also be an issue. Although self-reports may underestimate the true smoking prevalence [35], most studies, including biochemical validations, reported that self-reported smoking status was reliable with no differences by socioeconomic groups [36, 37]. People were moderately accurate in recalling their physical activity, with a tendency towards an underestimation of sedentary activities, especially among obese, an overestimation of aerobic activities, especially among men [38] and a better self-reporting among higher educated [39]. People usually underestimate their BMI, especially women, obese, elderly and higher educated [40, 41]. On the other hand, there is evidence that self-reported weight and height are remarkably accurate indicators of actual weight and height [42]. Despite these limitations we believe that the self-reporting bias is negligible.

Other limitations concern the assumptions of the PAF methodology. The relative risks used in the calculations should reflect the causal effect of the risk factors on IHD mortality. This is realistic because we used relative risks from literature reviews or large empirical studies. Due to data availability, the relative risks were assumed to be the same for all European populations investigated and for all educational groups. However, the literature suggests that when the metric of exposure is comparable, the effects of risk factors are similar across populations in different world regions [43]. In addition, there is no systematic evidence on how the impact of smoking, overweight and obesity or physical inactivity would differ by education. However, higher relative risks among those with lower education would result in higher potential for reducing mortality among low educated and educational inequalities in mortality.

Furthermore, mortality and risk factor prevalence data were collected at the same period around the year 2000 and therefore we could not take into account any time-lag between risk factor exposure and IHD mortality. The implicit time frame is that we can only expect to see a decrease in mortality after persons that have been moved from one exposure group to another have also acquired the mortality risk of this new group [44]. Regarding smoking, although one study found that the IHD risk among former smokers returned to the level of never smokers 10 to 14 years after smoking cessation [45], several other studies have shown that the biological effect of smoking on IHD was related to current use [46] and that the risk of IHD therefore became similar to the risk of never smokers within two or three years after smoking cessation [47-49]. Regular physical activity and weight loss are associated with several biological mechanisms, such as blood pressure reduction improvements in glucose control, reduction of cholesterol level or reduction of stress, anxiety and depression [8, 50], and their positive modification leads to the reduction of premature IHD mortality. Although the time-lag is not known, the association of physical activity and weight loss with these biological mechanisms suggest an immediate beneficial effect on IHD mortality.

CONCLUSIONS

Drawing general conclusions from our analysis is challenging due to the diversity of country-specific situations. Although the upward levelling scenario may not be achievable, the best-practice-country scenario is realistic. Our analysis shows that even if a modest reduction of educational inequalities in IHD mortality may be achieved under this realistic scenario, substantial reduction in the IHD mortality level among all educational groups, especially among the least educated, can be achieved in many countries. In order to tackle health inequalities in IHD mortality, policy makers should learn from countries that managed to combine low exposure to the main risk factors and small inequalities in these risk factors distribution.

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APPENDIX

Table A1 Characteristics of mortality data

Population	Type of dataset	Period	Geographic coverage	Demographic coverage
Finland	longitudinal	2001–2007	national	20% of Finns are 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% of the population
Scotland	longitudinal	2001–2006	national	5.3% representative sample of the population
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% of the population, born outside France mainland excluded
Switzerland	longitudinal	2001–2005	national	Non-Swiss nationals excluded
Austria	longitudinal	2001–2002	national	whole population
Barcelona	repeated CS	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	Florence, Leghorn, Prato	whole population
Hungary	CS unlinked	1999–2002	national	whole population
Czech Republic	CS unlinked	1999–2003	national	whole population
Poland	CS unlinked	2001–2003	national	whole population
Lithuania	longitudinal	2001–2005	national	whole population
Estonia	CS unlinked	1998–2002	national	whole population

CS = cross-sectional

Table A2 Data sources of risk factors prevalence

Country	Name of survey[a]	Years	N
Austria	European Community Household Survey, wave 7	2000	5,801
Basque Country	Health Survey of the Basque Country	2002	13,244
Belgium	Health Interview Survey 1997 + 2001	1997/2001	17,481
Czech Republic	Sample Survey of the Health Status of the Czech Population	2002	2,476
Denmark	Danish Health and Morbidity Survey 2000	2000	16,690
England & Wales	English Health Survey 2001	2001	15,767
Estonia	Finbalt Health Monitor	2002/2004	4,376
Finland	Finbalt Health Monitor	94/98/00/02/04	20,371
France	National Health Survey (Enquete Décennale Santé)[b]	2002	13,603
Italy	Health and health care utilization 1999–2000	1999/2000	118,245
Lithuania	Finbalt Health Monitor	94/98/00/02/04	11,647
Netherlands	Permanent Onderzoek Leefsituatie (POLS)	2003/2004	15,803
Poland	Second nationwide sample survey of the health status of the Polish population	2004	35,248
Scotland	Scottish Health Survey	2003	6,912
Spain	National Health Survey 2001	2001	20,748
Sweden	Swedish Survey of Living Conditions	2000/2001	11,484
Switzerland	Swiss Health Survey	2002	19,511

[a] Survey was used only when the percentage of risk factor information was lower than 20%
[b] Santé – 2003 (standard version) – (2003) [electronic file], INSEE [data producer], Centre Maurice Halbwachs (CMH) [data distributor]
N = number of respondents

Table A3 Rate ratios for the impact of selected risk factors on IHD mortality by age group and sex

Risk factor	Men				Women			
	30–44	45–59	60–69	70–79	30–44	45–59	60–69	70–79
Smoking								
current	2.80	2.80	1.51	1.51	3.08	3.08	1.60	1.60
former	1.64	1.64	1.21	1.21	1.32	1.32	1.20	1.20
never	1	1	1	1	1	1	1	1
BMI								
>=30	2.00	2.00	1.85	1.70	2.00	2.00	1.85	1.70
25–29	1.35	1.35	1.30	1.25	1.35	1.35	1.30	1.25
<25	1	1	1	1	1	1	1	1
Physical inactivity								
sedentary	1.35	1.35	1.35	1.35	1.54	1.54	1.54	1.54
active	1	1	1	1	1	1	1	1

BMI = body mass index

Source: smoking [13], BMI [14], physical inactivity [15]

Table A4 PAF (in %) by population, sex, education and risk factor among low and high educated, best-practice-country scenario, 30–79 years

Country	MEN						WOMEN					
	Smoking		Overweight/ Obesity		Physical inactivity		Smoking		Overweight/ Obesity		Physical inactivity	
	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
Finland	4.0	0.3	6.0	13.8	0.7	4.3	ref	ref	5.4	7.8	ref	ref
Sweden	2.3	-2.1	3.5	5.2	n.a.	n.a.	7.9	5.7	2.8	4.6	n.a.	n.a.
Norway	6.1	-3.4	ref	ref	14.3	14.1	11.1	3.5	ref	ref	23.2	21.5
Denmark	12.4	8.3	4.6	4.7	ref	ref	15.8	14.8	0.7	0.2	1.4	-3.6
England & Wales	5.6	-1.3	11.8	13.5	n.a.	n.a.	10.5	7.1	11.5	12.0	n.a.	n.a.
Scotland	7.2	0.9	9.5	11.0	n.a.	n.a.	14.8	7.3	7.9	12.4	n.a.	n.a.
Netherlands	10.0	7.0	3.4	3.1	10.3	12.1	9.9	10.8	3.0	4.2	15.4	11.0
Belgium	7.4	6.6	5.0	5.6	5.2	5.3	3.5	7.7	3.9	3.0	12.0	4.8
France	ref	ref	5.4	3.9	n.a.	n.a.	-2.8	2.9	2.5	0.3	n.a.	n.a.
Switzerland	6.3	4.6	4.5	3.5	1.3	-0.7	3.2	8.7	0.9	-2.1	4.5	-2.4
Austria	1.0	-1.4	7.0	5.6	n.a.	n.a.	-3.2	-0.3	4.5	2.0	n.a.	n.a.
Barcelona	6.6	6.7	7.0	8.6	18.5	18.5	-5.1	4.5	8.1	6.4	25.8	22.9
Basque C	3.9	3.9	5.7	9.0	18.5	18.4	-4.1	4.0	3.6	1.0	25.2	22.1
Madrid	6.4	6.5	7.1	8.9	18.5	18.5	-4.8	3.2	8.0	6.7	25.9	23.1
Turin	3.6	4.2	4.3	4.4	14.1	15.6	-1.8	7.3	1.5	1.2	23.4	21.6
Tuscany	3.6	4.2	4.2	5.5	14.1	15.6	-2.6	7.2	1.4	1.3	23.0	21.9
Hungary	n.a.	n.a.	8.2	10.7	n.a.	n.a.	n.a.	n.a.	8.6	10.1	n.a.	n.a.
Czech Republic	5.4	-3.0	9.4	8.3	15.8	18.6	1.5	4.6	10.6	9.8	24.1	21.9
Poland	10.0	1.6	7.8	11.7	n.a.	n.a.	2.4	7.5	10.3	9.6	n.a.	n.a.
Lithuania	8.0	3.8	3.9	7.2	10.4	8.1	-10.5	-4.3	9.6	18.8	15.3	2.2
Estonia	11.3	8.6	5.7	12.1	15.2	19.3	-0.3	-1.0	14.6	14.8	15.9	11.6
EU average	6.6	2.5	6.0	7.6	10.6	11.5	3.6	5.4	6.0	6.7	16.1	11.1

ref = reference country, n.a. = not available

9

General discussion

GENERAL DISCUSSION

This thesis presents a collection of studies focusing on educational inequalities in mortality in Europe during the 1990s and the early 2000s, with the aim of quantifying these inequalities and assessing their potential for reduction. This final chapter summarizes the main findings and discusses the answers to the research questions of this thesis. In addition, the findings are presented in light of several methodological limitations and interpreted in reference to previous studies. Finally, we consider the implications of these findings for policy strategies and future research.

MAIN FINDINGS

Answer to study questions

1) Are there differences in the reliability of cause-of-death statistics by education in European countries?

In chapter 2, we investigated educational differences in the proportion of ill-defined causes of death among subjects aged 30–79 years as one of the indicators for cause-of-death data quality. This proportion varied in the 16 European countries investigated, however, without any clear geographical pattern. This proportion was generally low among both men and women, and did not exceed 7% in any European country investigated. Our findings suggested that the proportion of ill-defined causes of death tended to be lower in countries with higher autopsy rate. The proportion of ill-defined causes of death differed statistically significantly by education in Denmark, England and Wales, Belgium, Switzerland, Italy, Hungary, Czech Republic, Poland and Estonia among men, and in Switzerland and Poland among women with the tendency of a higher proportion among low educated individuals. However, the absolute difference in the proportion of ill-defined causes between low and high educated men and women was generally less than one percentage point, with the exception of Polish men among whom the difference was 2.9%-points. Due to these small percentage differences between educational groups, a redistribution of ill-defined causes of death to some well-defined causes of death, such as ischaemic heart disease (IHD) or suicide, did not considerably affect the educational inequalities observed for these latter causes of death.

2) What is the magnitude of educational inequalities in all-cause and cause-specific mortality in Europe in a comparative perspective and has it changed over time?

Chapters 3 and 4 described the magnitude of both relative and absolute educational inequalities in all-cause and cause-specific mortality in Spain (30–74 years) and the Netherlands (30–79 years) putting these countries into a European perspective. Chapter 5 then documented trends in educational inequalities in all-cause and cause-specific mortality in a wide range of European populations between the 1990s and the 2000s among people aged 30–74 years.

The Spanish populations represented by the city of Barcelona, by the region of Madrid and by the Basque Country have substantially smaller absolute inequalities in total mortality than the other Western European populations as the result of lower average levels of mortality and smaller relative inequalities in mortality. These smaller absolute inequalities were found to be due mainly to comparatively small absolute and relative inequalities in mortality from cardiovascular disease (men) and cancer (women). However, relative inequalities in mortality from most other causes were not smaller in Spain than elsewhere and were even substantially larger for infectious disease mortality. Spain has smaller inequalities in smoking and sedentary lifestyle, due to a higher prevalence of these risk factors among higher educated individuals, whereas inequalities in obesity among women are larger than in the other European populations. Therefore, the overall situation with regard to educational inequalities in health does not appear to be more favourable in Spain than in other Western European populations. From a historical point of view, the smaller absolute and relative inequalities in mortality observed in Spain are likely to be an effect of the later socioeconomic modernization of Spain when compared with Northern Europe, delaying large-scale socioeconomic changes in society, and the epidemiologic transition. These smaller educational inequalities in mortality in Spain therefore seem to be a historical coincidence rather than the outcome of deliberate policies.

To quantify absolute and relative educational inequalities in total and cause-specific mortality in the Netherlands and compare these estimates with those in other European countries, we linked the Dutch Labour Force Survey (1998–2002) with death records (1998–2007) via an encoded unique personal number. We reported large absolute educational inequalities in mortality and showed that their magnitude and cause-specific patterning were similar to those observed in other countries of North-Western Europe. The relative risk of dying was two times higher among people with primary education when compared with tertiary educated. This difference in total mortality led to a gap in partial life expectancy between ages 30 and 79 years of 3.4 and 2.4 years among men and women, respectively. The contributions to this gap were mainly driven by cardiovascular diseases and cancer. No inequalities in mortality were found for colorectal cancer, prostate cancer and female breast cancer. On the contrary, absolute and relative inequalities in lung cancer mortality were found to be substantially larger in the Netherlands than in other countries of North-Western Europe, particularly among men. The contribution of lung cancer to the gap between primary and tertiary educated people was 20% among men and 16% among women, suggesting an important contribution of smoking to educational inequalities in mortality in the Netherlands. This is consistent with the high smoking prevalence rates reported in the Netherlands during the last decades.

In chapter 5, we focused on trends in relative and absolute educational inequalities in total and cause-specific mortality in 13 European countries between the 1990s and the 2000s. We reported an increase in relative inequalities in most populations in the North, West and East of Europe, but not in the South. The increase in the relative inequalities was mostly due to smaller proportional reductions in mortality among the lower than the higher educated. In the case of Lithuania and Estonia, mortality rose among the lower educated, due to conditions related to smoking (lung cancer, women only) and excessive alcohol consumption (liver cirrhosis and external causes), whereas it declined among the higher educated. This fact very likely contributed to the increasing difference between the South, characterized by smaller relative inequalities, and the East of Europe, characterized by large relative inequalities, since the 1990s. In absolute terms, however, we observed a larger mortality decline among the lower educated in many countries in the North, West and South of Europe, due mainly to larger absolute reductions in mortality from cardiovascular disease and cancer (men only). It suggests that changes in health-related behaviours (e.g., smoking, diet, physical activity) and in health care interventions (e.g., hypertension detection and treatment, thrombolytic therapy) must have been larger among the low educated.

3) What is the potential for reducing educational inequalities in mortality in Europe?

Chapters 6, 7 and 8 discussed the potential health gains and inequality reductions due to different policies and interventions. All estimations were obtained using a methodology based on the Population Attributable Fraction (PAF).

Chapter 6 presented the methodology used as well as illustrative calculations. For illustrative purposes, we investigated how changes in the educational distribution of smoking, alcohol consumption, lack of physical activity, and overweight and obesity may impact educational inequalities in mortality in three European countries (Belgium, Norway and Czech Republic). We applied a scenario implying that the prevalence of the four risk factors is reduced to the level currently seen among high educated. We found that socioeconomic inequalities in all-cause mortality could potentially be reduced for both men and women by a redistribution of risk factors by education. Additionally, we found that the PAF methodology and the conventional regression yielded similar results.

Chapter 7 provided an innovative approach for assessing the effect of the on-going improvement in the educational structure on mortality for people aged 30–79 years. The educational distribution is one of the most important sources of population heterogeneity with major social, economic, cultural and health consequences, and as such it is a key for economic development and productivity. Hence, based on two scenarios we estimated the impact of the projected increase in higher education on mortality in 21 European populations. The first scenario represented the improvement in the future distribution of educational attainment as expected on the basis of cohort replacement. The second scenario represented the levelling up situation when everyone has obtained tertiary education. The effect of these counterfactual scenarios on mortality was estimated with a 10–15-year time horizon. We observed important variations between countries in the magnitude of mortality reduction, depending on the current educational distribution, on the projected speed of future improvements in the educational distribution, and on the mortality rate ratios between educational groups observed in each country. The potential reduction in mortality ranged from 1.9 to 10.1% among men and 1.7 to 9.0% among women according to the cohort replacement scenario and from 22.0 to 57.0% among men and from 9.6 to 50.0% among women according to the upward levelling scenario. In addition, the cohort replacement scenario was estimated to achieve only part of the potential mortality decrease seen in the upward levelling scenario (4–25% for men and 10–31% for women). Despite the large scope for mortality reduction in all European countries, the greatest theoretical potential gain in mortality was found in eastern European countries for both men and women whereas the smallest theoretical potential gain in mortality was observed in southern European populations. As shown in this chapter, the on-going improvements in educational attainment may have important positive side-effects on mortality.

In chapter 8, we estimated the potential reduction in educational inequalities in IHD mortality in 21 European populations by modifying the educational distribution of smoking, overweight and obesity, and physical inactivity. We investigated two redistribution scenarios. In the upward levelling scenario, the risk factor prevalence was changed to the level currently observed among the high educated in each country. In the best-practice-country scenario, the risk factor prevalence was changed to the level observed in the best practice country, which was selected as the country with the lowest average risk factor prevalence combined with the smallest relative inequalities in the specific risk factor. These scenarios showed that the reduction of inequalities in IHD mortality varied by country, sex and risk factor. Under the upward levelling scenario, the maximal potential reduction of relative inequalities in IHD mortality between low and high educated amounted up to 22% for smoking, 36% for overweight and obesity, and 28% for physical inactivity among men and to 17% for smoking, 48% for overweight and obesity, and 18% for physical inactivity among women. Although the decrease in inequalities in IHD mortality was slightly smaller under the best-practice-country scenario, the mortality reduction among low educated was much more important in most of the countries under this scenario than under the upward levelling scenario.

METHODOLOGICAL CONSIDERATIONS

Several specific data limitations relevant for some studies included in this thesis, such as certification and coding of causes of death, differences in data design and differences in population coverage, have been addressed in previous chapters. In addition to these limitations, we would like to discuss two general methodological issues in more detail in this part of the thesis. First, the attention will be given to the causality between education and mortality. Second, we will discuss the PAF methodology.

Causal relationship between education and mortality

Educational inequalities in mortality are widely documented in the literature. However, while many studies reflect on the association between education and mortality in general, only few of them address a causal relation. Indeed, most of the epidemiological studies are observational rather than experimental. Observing an association does not necessarily mean that there is a causal relationship because the observed association may be due to chance, bias or confounding. Causality is one of the main assumptions of the PAF methodology used in this thesis. The assumption of causal relationship between education and mortality may be problematic for the educational scenario (chapter 7) because we are interested in the effect of a social exposure (i.e. education) rather than a biological one and we will address this issue in more detail below. However, when calculating the contribution of a proximate risk factor, such as smoking, BMI or physical inactivity to mortality (chapters 6 and 8), we do not have to assume a causal effect of education on mortality because education serves here merely as a stratifier for the specific lifestyle risk factors. We even do not have to assume a causal relationship between education and the specific lifestyle risk factors because smoking, overweight/obesity and physical inactivity have a negative effect on mortality regardless of educational level.

We now review the assumption of causal relationship between education and mortality. In order to determine whether an observed association between education and mortality represents a causal relationship, a number of criteria have been proposed. Bradford Hill´s criteria are widely used in epidemiology for assessing whether an observed association is likely to be causal [1]. According to Bradford Hill, a relation between two variables can be causal if it fulfils nine criteria: strength of the association, consistency, specificity, temporality, biological gradient, plausibility, coherence, experiment, and analogy.

It can easily be seen that several of these criteria are fulfilled. The literature consistently reports a strong association between education and mortality, with a gradient. Most people achieve their highest educational level early in life, and education therefore precedes the occurrence of most conditions leading to mortality. Education can plausibly be linked to mortality via several mechanisms including cognitive ability, living and working conditions, psychosocial resources and lifestyle determinants.

The criterion "experiment", however, needs more in-depth discussion. An experiment corresponds to a set of observations, conducted under controlled circumstances, in which the scientist manipulates the conditions to ascertain what effect such manipulation has on the observation [2]. However, experiments on human beings are often difficult to perform, particularly in social epidemiology. Randomized experiments, in which education is randomly assigned across individuals, and which would solve the self-selection problem, are practically impossible. Natural or quasi-experimental methods, however, can be used instead. Exploiting changes in the economic environment or in government policy, natural experiments allow an evaluation of changes in education that occur regardless of the will or action of the observed individuals, e.g. school reforms changing the minimum school leaving age. Various statistical methods, such as difference-in-difference analysis, fixed effects models, regression discontinuity, instrumental variables, propensity score matching and interrupted time series, can be used to evaluate natural experiments [3-6].

It is difficult to estimate what percentage of the observed educational inequalities in mortality is due to a causal effect. Although such a quantification has never been assessed, recent studies exploiting natural experiments in which changes in educational level were exogenously imposed have shown that education may have a causal effect on mortality [7-13]. The majority of the studies used school reforms or compulsory schooling laws and assessed their effect in a regression discontinuity design. It has been reported that an additional year of schooling increased life expectancy at age of 35 by 1.7 years [11] or reduced the probability of dying by 1.1 percentage points for men and by 0.8–0.9 percentage points for women [13]. Lager and Torssander [10] have shown that a one-year increase in compulsory schooling was associated with a 4% lower risk of all-cause mortality after the age of 40. In addition, the increase in education can have an important side-effect on health outcomes, such as disability [14, 15]. Even though the estimated effects of the increased compulsory schooling age on mortality in those studies can probably not assess the impact of further increases in educational attainment nowadays, they serve as valuable examples of evidence for causal relationship between education and mortality.

Population attributable fraction methodology

The Population Attributable Fraction (PAF) estimates the proportion of a population health outcome that is attributable to a particular exposure, i.e. the proportion by which a population health outcome would be reduced if the exposure to a particular risk factor were completely eliminated [16-18]. The PAF is closely related to another measure, the Potential Impact Fraction (PIF), which estimates the proportion by which a population health outcome would be reduced if the exposure to a particular risk factor were only partially eliminated. These two measures are very similar and we therefore only used the term PAF in this thesis.

The PAF methodology was used in two different ways. In chapter 7, we investigated how changes in the educational distribution impacted mortality; in this analysis, the risk factor investigated was education. In chapter 8, we investigated how changes in the distribution of smoking, BMI and physical inactivity impacted mortality. The analyses were conducted by educational groups, so that we could in a second step assess how these changes impacted educational differences in mortality.

We implemented this methodology in an Excel tool that offered PAF calculations for selected risk factors. In the Excel tool, all necessary data for the calculations were stored by country, sex, age groups, educational category, and cause of death. The necessary input data for the PAF calculations comprised 1) risk factors prevalence by country, age group and sex, 2) rate ratios (RRs) for the impact of risk factors on total and cause-specific mortality by age group and sex, and 3) all-cause or cause-specific mortality rates by country, age groups and sex.

Although the PAF calculations are relatively simple, there are several strong assumptions behind the PAF methodology. One of the main assumptions is, again, causality. There should be a causal relationship between the risk factor investigated and the health outcome in order to be able to interpret the calculated mortality reduction as being attributable to the risk factor change [19]. In the previous section, we already discussed this assumption for the association between education and mortality; here, we will focus on the specific risk factors. The causality assumption also implies that the RRs for the impact of the risk factor on mortality reflect the causal effect. This might be problematic because the observed association can be a mix of causal effects with the effects of selection bias or confounding. Moreover, when investigating the effect of health behaviours, we assumed that the RRs of the risk factors were the same for all countries investigated and for all educational groups. These limitations have been discussed in the previous chapters, and we believe that the use of RRs from large meta-analyses probably largely overcomes these problems.

Next to these important assumptions, it is also essential that the prevalence of the risk factors accurately reflects the relevant exposure, which may be hampered by differences in data collection, data classification or survey non-response between the European countries. Indeed, a European study comparing smoking prevalence between three morbidity data sources showed that the magnitude of inequalities in smoking prevalence depended on the survey used [20]. Its results suggested that the National Health Interview Surveys were the most reliable sources of information. These National Health Interview Surveys were used in our analyses.

Furthermore, the risk factor prevalence must be measured at a point in time which is consistent with the causal effect of the risk factors on mortality. In other words, any time lag between the risk factors exposure and the effect on mortality should be taken into account when collecting data on risk factors exposure. This may not always have been the case, as we collected risk factors data from around the year 2000 and mortality data from the early 2000s. These limitations have been addressed in chapter 8.

Finally, a last assumption is about the time frame. The expected reductions in mortality will only occur after a person has moved from one exposure group to another, and has also acquired the mortality risk of this new exposure group [21]. In our calculations, we have not specified the time dimension of the changes in mortality and mortality inequalities, because it is in general unknown how long it takes before a person acquires the new mortality risk after moving to the new exposure group. This should be kept in mind when interpreting the results.

Despite these limitations, the PAF approach offers several advantages. In chapter 6, we showed the similarity of the results between the PAF methodology and a conventional multivariate regression analysis. One of the main advantages of the PAF approach over a conventional regression analysis is the lesser demand on data collection. Whereas a conventional regression analysis necessitates a dataset including both risk factors exposure and outcome for the same individuals, the PAF approach can combine data from different sources. Such individual level data comprising information on cause-specific mortality, socioeconomic status and risk factors, are often not available. Due to this lack of relevant datasets, the results presented in chapter 8 could not have been obtained with regression analysis. Another major advantage is that the PAF approach can easily address many scenarios where the prevalence of the risk factors is changed to any possible value in a straightforward way, while comparable regression results can only be obtained using a complex regression framework.

The PAF approach, however, implies the investigation of simple risk factors and no possibility to include interactions. Many diseases have multiple risk factors acting simultaneously [22]. As a result of multicausality, the PAF calculations for multiple risk factors cannot be obtained by simple addition of each risk factor PAF, as the latter overlap [23]. Under specific conditions, the joint effect of more than one risk factor can be estimated to assess the proportion of mortality that can be avoided by reducing exposure to all these risk factors. There are two key assumptions when using this approach [22]. First, the exposure to the different risk factors is uncorrelated. Second, the hazardous effect of one risk factor is not mediated through the other risk factors. We did not use this joint-effect-approach in this thesis. Due to the strong assumptions of the multicausality, we focused only on the single effect of one risk factor. Nevertheless, it should be kept in mind that the lifestyle risk factors, such as e.g., overweight and obesity, and physical inactivity are correlated.

Based on the simplicity of the calculations, the easy interpretability and the similarity with regression models, the PAF measure is a useful tool for policy makers to develop effective health policies. Although we reported results only for a limited number of scenarios, the tool we developed in our project offers more opportunities for intervention settings going beyond the upward levelling or the best-practice-country scenario.

INTERPRETATION OF FINDINGS

This thesis explores educational inequalities in mortality based on cross-country comparative studies. We mentioned the quality of cause-of-death data, estimated the magnitude of educational inequalities in mortality, assessed trends in these inequalities and provided a couple of examples for policies to reduce these inequalities. Although we used different datasets and applied different methodologies in several studies of this thesis, educational inequalities in mortality were present in all European populations investigated. Moreover, there were some systematic variations in the magnitude of these inequalities confirming a north-south gradient of these inequalities and an east-west gap in mortality and in educational inequalities in mortality, which have been previously found in the literature. These two phenomena will now be elaborated in more detail.

North-South gradient in educational inequalities in mortality

A north-south gradient in educational inequalities in mortality has been reported for a long time in the literature with smaller educational inequalities in cardiovascular and total mortality in the southern European populations compared with other European populations [24-27]. Our findings are consistent with this gradient. In chapter 8, we showed that the lowest mortality rates from ischaemic heart disease could be found in the Basque Country among women and that the Spanish and Italian populations, in general, had the smallest relative inequalities in mortality from ischaemic heart disease. In chapter 5, we also documented that not only the educational inequalities in mortality were smaller in southern Europe but also trends over time in these inequalities were more favourable in the South than elsewhere in Europe. Indeed, we found no increase in relative inequalities in premature mortality in the South of Europe between the 1990s and the 2000s, while we did observe an increase in these inequalities in most populations in the North, West and East of Europe. Similar findings were already reported for earlier time-periods, both for total and cause-specific mortality [28]. More specifically, the north-south gradient in relative and absolute inequalities in mortality from ischaemic heart disease within Europe has been reported previously [26, 29, 30]. Our findings for the most recent period were also confirmed by recent national data for Spain [31] and Italy [32].

In chapter 3, we performed an in-depth investigation of the cause-specific pattern explaining the small educational inequalities in one Southern European country, Spain, based on data from three Spanish regional and urban populations. We found that Spain had considerably smaller absolute inequalities in total mortality than other Western European populations due to a combination of lower average mortality level and smaller relative inequalities in mortality, especially from cardiovascular diseases among men and cancer among women. Relative inequalities in most other causes were not smaller in Spain than elsewhere and even larger for respiratory and infectious disease mortality. These findings are in line with a recent study using national data for Spain, which also reported the strongest educational gradient for mortality from HIV disease [31].

As shown in this thesis and reported in previous literature, the north-south gradient in socioeconomic inequalities in mortality in Europe is largely a consequence of cardiovascular diseases being of greater importance in the North of Europe [28]. Socioeconomic inequalities in cardiovascular risk factors are therefore likely to be of major importance in explaining these geographical patterns [33]. North-south variations in the magnitude of socioeconomic differences in smoking, alcohol consumption, overweight and obesity, vegetable consumption or physical activity have been reported to largely contribute to the differences in socioeconomic inequalities in mortality between the North and the South of Europe. For smoking, a north-south gradient has been documented with larger socioeconomic differences in smoking in northern countries [34-36], as a consequence of differences in timing of the smoking epidemic. Northern European countries are considered to be in stage 4 of this epidemic, characterized by a decrease in smoking rates for both men and women and smoking being a habit of lower socioeconomic groups. Southern European countries are thought to be in stage 3 of this epidemic, which is depicted by a decline in smoking among men, especially among higher educated men, but an increase in smoking among women [34]. The north-south gradient in smoking can then possibly be explained by a time-lag of adoption of unhealthy and then healthy behaviour between the North and South of Europe [37].

On the other hand, educational inequalities in overweight and obesity were largest in Southern Europe, especially among women [38], among whom these inequalities seemed to be more pronounced in Spain than in Italy [39]. This is a striking finding in view of the smaller educational inequalities in energy intake in these countries due to the adherence to the Mediterranean diet. For instance, fruit and vegetable consumption was more common among high educated men and women in northern Europe whereas in southern European countries, educational differences in fruit and vegetable consumption were small or non-existent [35, 40]. One possible explanation for these larger educational inequalities in overweight and obesity among southern European women may be the education-related differences in labour force participation, with larger differences between high and low educated women in the proportion having a job [41]. The educational inequalities in labour force participation may further be linked to the educational inequalities in overweight and obesity via differences in parity, differences in leisure time physical activity or differences in sociocultural environment, with a stronger emphasis on thinness and healthy diet among highly educated women in Southern Europe [42].

In addition to differences in educational inequalities in exposure to risk factors, the north-south gradient may also partly be explained by differences in the meaning of education itself. In chapter 7, we estimated the smallest theoretical potential gain in mortality when increasing education in the southern European populations, especially among women. These findings were observed although the educational level was similar to or even lower than in other European populations. This result is likely to mirror the smaller effect of education on mortality in these countries than, e.g. in the Nordic countries. The southern European countries experienced dramatic changes in the 1970s when dictatorial regimes were replaced by democratic ones in Portugal, Spain and Greece. Major political changes occurred in Italy as well [43]. These political changes likely delayed two major historical processes, namely large-scale socioeconomic modernization and the epidemiologic transition [44]. Socioeconomic modernization is a process of societal changes, such as rising prosperity, industrialization, urbanization and expansion of mass education, that is also characterized by an increasing importance of educational qualifications for occupational careers [45-47]. Due to this later socioeconomic modernization of societies in southern Europe, educational attainment may be less relevant as a measure of socioeconomic position in the South compared with the North of Europe.

We consistently reported smaller educational inequalities in Italy and Spain. However, due to the lack of data in other southern European populations, such as Portugal and Greece, we do not know if the results can be generalized to the entire southern Europe. Nevertheless, recent calculations of life expectancy by education provided by Eurostat showed that small inequalities could also be found in Malta [48]. In addition, the international literature reported a similar pattern in overweight and obesity in Portugal and in smoking in Portugal and Greece [36, 38]. If this evidence suggests the existence of a 'South Europe pattern', a closer look at the literature and at this thesis' findings for Italy and Spain also reveals some differences at the cause-specific level within this 'South Europe pattern'. First, although all countries are at a delayed stage of the smoking epidemic when compared with the other Western European countries, there are some differences within the Southern European countries. Thus, it has been stated that Portugal lagged behind Italy and Spain in the smoking epidemic [34]. Moreover, although we showed a reverse social gradient for lung cancer mortality among people aged 30–74 in both Spain and Italy, a recent EURO-GBD-SE study describing these inequalities by age groups clearly showed that Spanish men and women lagged behind Italians in the diffusion of the smoking epidemic [49]. Second, some specific causes of death may exhibit large inequalities in one country due to a specific context, as observed in Spain with the large educational inequalities in infectious diseases, likely due to the AIDS epidemic (chapter 3). This finding was confirmed by a recent study based on Spanish national data [31]. This has not been found for Italy neither in our analysis nor in the international literature. Finally, if our trend analysis showed a reduction in absolute inequalities in Spain and Italy, the decrease was much more pronounced in Turin than in the Spanish populations both among men and women.

In chapter 5, we found that trends over time in educational inequalities in mortality between the 1990s and the 2000s were more favourable in the South than elsewhere in Europe. An important question is how this North-South gradient will change in the coming years. However, the future trends are uncertain given the economic crisis, which hit most severely the southern European countries. Due to a lack of up-to-date morbidity and mortality data it is difficult to estimate the immediate effects of the economic crisis on population health. However, the consequences of the economic crisis, such as budgetary restrictions of health care or an increase in unemployment rates may have an important impact on health outcomes [50]. These effects are likely to be more pronounced among the most deprived groups of the population. Unemployment is associated with adverse health outcomes [51], and it has been reported that the increasing unemployment rate in the southern European countries was connected with rises in suicide and in mental disorders in Spain and Greece [50, 52, 53]. Additionally to these health problems, outbreaks of infectious diseases are becoming more common, as observed for instance with the HIV outbreaks in Greece due to increasing prostitution [53]. On the other hand, it has been hypothesised that recession may improve health behaviours by several mechanisms. Unemployed people can spend more time in leisure time physical activity, and the most deprived people may decrease their tobacco and alcohol consumption and consumption of unhealthy food due to a lack of financial resources. Finally, a fall in the number of deaths from road traffic accidents can be observed as a consequence of traffic decrease [50].

East-West divide in mortality

The east-west divide in mortality is characterized by high mortality rates in eastern European countries leading to a mortality gap between the western and eastern part of Europe [54]. Central and Eastern European (CEE) countries were included in the analyses in chapters 2, 5, 6, 7 and 8 of this thesis. The analyses of all these chapters consistently showed excessive premature mortality for total and cause-specific mortality, especially mortality from ischaemic heart disease. Additionally, CEE countries showed large educational inequalities in all-cause and cause-specific mortality. The east-west divide in mortality is then combined with an east-west gap in educational inequalities in mortality, which is particularly remarkable in absolute terms and among men. Recent studies on lifespan variation also showed that larger educational inequalities in mortality observed in CEE countries were due to large between-individual variations in age at death among lower educated people [55, 56]. Our results confirm findings from previous international literature reporting an east-west gap in mortality as well as in educational inequalities in mortality [27, 57-60]. In addition, we demonstrated that the east-west gap in educational inequalities in mortality has worsened during the last two decades. Indeed, contrary to the other European countries, a considerable increase in absolute inequalities in total mortality was reported in CEE countries between the 1990s and 2000s, which was largely explained by a disadvantaged position of low educated in these countries when compared with the rest of Europe. Cardiovascular diseases and external causes were found to substantially contribute to this increase in absolute inequalities.

The international literature offers some explanations for the excessive mortality in CEE countries. The contribution of medical care to the east-west gap plays a role but is unlikely to be the main explanation [54]. Air pollution may contribute to the increased mortality in the eastern part of Europe [61, 62] as the most polluted European areas can be found in the Czech Republic, Poland and former East Germany [54, 63]. Apart from these likely limited contributions, it has been argued that health behaviours, such as smoking, alcohol consumption, diet and physical exercise, and psychosocial factors were the most important factors creating the east-west gap in mortality as these risk factors are less favourable in the eastern part of Europe compared with the western European countries [54, 63, 64]. Based on a survey among young adults in eastern and western Europe, Steptoe and Wardle [63] found differences in the prevalence of regular exercise, alcohol consumption, fat and salt consumption, or using sunscreen protection between the two European parts. The authors also observed that Eastern European people were less likely to have adequate knowledge of the risk factors, such as smoking, exercise and diet, which may explain their higher exposure to these risk factors. In addition, Eastern Europeans were less likely to use seat-belts when driving, which likely contributes to the observed excess mortality from external causes, such as traffic accidents. Other studies found remarkable differences in the level of depression and the perceptions of social support between the East and the West of Europe [65, 66], with a much less favourable situation in Eastern Europe. Depression and lack of social support have been reported to have an impact on health behaviours [67], which can partly explain the higher prevalence of unhealthy behaviours among eastern European men and women.

According to the evidence in the literature, not only is the average exposure to the risk factors less favourable in the CEE countries, but educational inequalities in the exposure to these risk factors are also large, with particularly contrasting pattern between Baltic and Central Europe. Although not many studies focusing on educational inequalities in exposure to the risk factors in CEE countries are available, the existing literature points to large educational differences in exposure to the lifestyle risk factors, such as smoking, alcohol consumption or overweight and obesity in CEE countries. For instance, substantially larger relative educational inequalities in heavy episodic drinking and alcohol-related problems were found among men in the Czech Republic and Hungary compared to men in other European countries [68]. If relative educational inequalities in overweight and obesity were comparable or even smaller in Hungary than in other European countries [39], larger absolute educational inequalities in overweight (women) and in obesity (men and women) were observed in Hungary compared to western European countries. This is likely the consequence of a generally higher prevalence of overweight and obesity in Hungary [39]. In light of these differences in health behaviour and psychosocial stress between eastern and western part of Europe reported in the international literature, it is not surprising that cardiovascular diseases and external causes are the major contributors to the east-west gap in mortality and in educational inequalities in mortality [39, 54, 63, 65, 67, 68].

We used education as a measure of socioeconomic position. International literature confirms the large differences between eastern and western European countries regarding educational differences in mortality; it is not clear, however, if education has the same meaning in the East as in the West. Although education was provided free of charge during communism in order to eliminate differences in financial access to education, the educational trajectories of individuals depended on socioeconomic position, employment and political loyalty of their parents and therefore were not primarily driven by skills and abilities of each individual [69, 70]. The main focus on heavy industry in the socialist societies emphasized technical and vocational programs [69-71]. The promotion of manual jobs and the orientation on vocational programs under the communist regime led to a high proportion of secondary educated in CEE countries. However, secondary education was highly stratified offering lower vocational, secondary general and upper vocational programs and leading to strong social inequalities within this level of education [71]. Individuals from lower socioeconomic groups selected themselves into lower vocational programs without any possibility for entering later a higher education, whereas individuals from advantaged socioeconomic groups attended more often upper secondary general or upper secondary vocational programs providing access to higher education as well as to better occupational opportunities [71]. As some manual jobs were more rewarded than intellectual ones, and the returns to education were low in CEE countries under communism, people had low motivation to invest in higher education [69, 71, 72]. Apart from this educational focus, the communist countries were well-known for their small income differences due to wage levelling [73]. Due to the absence of financial compensation for higher education, only a selective group of people seeing high education as a cultural value or as a source of social prestige pursued studies at universities [70]. This explains the specific educational distribution in CEE countries, with a high proportion of middle educated (upper secondary education) and a small proportion of high educated (tertiary education). This may also explain the surprisingly low mortality level among high educated compared to their lower educated counterparts in CEE countries, leading to huge educational inequalities in mortality. Finally, the specificity of the secondary educational level in CEE countries led to difficulties in recoding CEE countries' diplomas into ISCED categories, which represents an unavoidable limitation of our European comparisons.

After the collapse of communism, expansion and differentiation of tertiary education have proceeded at a high speed in many CEE countries. However, the quality of providers and the role of market-based financing of higher education substantially varied across countries depending on the national history and institutional context of each country [71]. For instance, two different approaches of educational reform can be found in the Czech Republic and Poland. While the low public expenditures on tertiary education hindered reforming the system of tertiary education and increasing the number of educational opportunities in the Czech Republic [69, 73], the smooth privatisation of higher education in Poland was a successful process [70]. Nevertheless, neither the liberal approach in Poland nor the conservative approach in the Czech Republic succeeded in avoiding three major problems of the reform of the educational system, i.e. difficulties in measuring the quality of teaching and research; the information asymmetry in the higher education market; and a shortage of academic staff [70]. How these educational reforms will affect the east-west differences in mortality and in educational inequalities in mortality remains a task for future research.

In chapter 7, we found that the potential for mortality reduction with an increase in education was larger in Eastern Europe compared with Western Europe. It is therefore of major importance that these countries succeed in their educational reform by providing higher education to and improving health of all socioeconomic groups of the population. The increase in education induced by the educational reform will, however, affect mortality only after several decades, when people who graduated after the collapse of communism will reach their 50s. In the meantime, there will be very modest reduction in mortality due to education increase as illustrated by the cohort replacement scenario (chapter 7). This scenario indeed showed that among adult population aged above 30 years around the year 2000 – the vast majority of whom completed their education under the communist educational system – no clear increase in education was observed with decreasing age. Available evidence shows that the social selectivity of educational attainment both at secondary and tertiary education was pronounced in CEE countries still after the collapse of communism, which suggests that large educational inequalities in mortality will remain [71]. Additionally, in view of the different directions of current changes in education policy in CEE countries, we can expect larger variations of educational inequalities in mortality between the countries of central and eastern Europe in the future.

POLICY AND RESEARCH IMPLICATIONS AND RECOMMENDATIONS

Policy implications and recommendations

The investigation of educational inequalities in mortality and the assessment of their potential reduction are not possible without high quality epidemiologic data including information on education. To successfully monitor these inequalities, authorities responsible for public health policy should assure availability of such high quality data. In this thesis, we encountered some deficiencies in data, such as unlinked cross-sectional designs and small sample sizes. Furthermore, for several European countries data were available for a few regions only (in Italy and Spain) or data by education were not available at all (e.g. Portugal, Greece or Ireland). The poor quality of socioeconomic information included in death certificates and the restrictive legislation concerning the linkage of death registries with censuses are the main barriers for monitoring socio-economic differences in mortality in the southern European countries [74], although recently studies have been published using national datasets in Italy [32] and Spain [31]. Additionally, the stricter legislation in many European countries makes the use of census data more complex than several years ago. These data problems hinder the comparability of educational inequalities in mortality between countries and over time. Health authorities should therefore put more efforts in data collection according to the European standards in order to achieve comparability at the international level, and should also ensure accessibility to these data for research purposes.

We demonstrated that there is a substantial scope for mortality reduction based on on-going improvements in educational attainment. From this perspective, policy makers should invest and improve education for the whole population. Indeed, under the assumption of a causal relationship between education and mortality, raising education for everybody to the highest level will diminish mortality. Thus, it is important to invest in education for the entire population and remove the barriers of education accessibility, e.g. due to high tuition fees.

Nevertheless, despite the beneficial effects of education on health, a high level of education can also have negative impacts on health when the educational qualification does not match with the occupational achievements and earnings expectations. This phenomenon is known as over-qualification. Over-qualification is associated with frustration and less satisfaction at work [75] as well as declining self-reported health [76] and mental health [77]. As we reported in this thesis, the on-going improvements in educational attainment likely have important positive side-effects on mortality and population health. However, the full beneficial effect of education will be achieved only if there are enough employment opportunities and if the achieved education meets the occupational needs. Policy makers should therefore not only invest in education but at the same time also monitor the needs of the labour market, create new job opportunities matching the increased proportion of higher educated people in society and/or create new study programmes needed in view of technological progress in society.

The complete levelling up of education and its perfect matching with the occupational opportunities are of course utopian solutions, rather than practically feasible solutions. Therefore, as long as not everybody has the same high level of education, there will be a need for policies and interventions that reduce educational inequalities in mortality through risk factor modifications. We have reported that changes in the prevalence of major lifestyle risk factors, such as smoking, overweight and obesity, and physical inactivity, can have an important impact on mortality and educational inequalities in mortality in European populations. Evidence-based health policies based on primary and secondary prevention have been developed in Europe, although with different degrees of successful implementation in the European countries [78-80]. The success of health policy implementation very likely depends on country-specific financial resources, functioning institutions, effective government and competent public health workforce [80]. Tobacco control policies, such as price increases, restrictions on smoking in public and advertising bans, have been implemented in several western European countries, e.g. England and Wales or Sweden. This reduced the prevalence of smoking [79, 80] and contributed to decreasing mortality from ischaemic heart disease [81]. Alcohol control policies, such as accessibility restrictions, price increases and marketing control, were designed to reduce excessive alcohol consumption. These policies were successful for instance in France [79]. The decrease in alcohol consumption consequently contributed to the decline in mortality from liver cirrhosis [82].

Lower education has been reported to be associated with higher prevalence of harmful behaviour, e.g. higher tobacco and alcohol consumption, poorer eating habits, excessive body weight or inadequate physical exercise [83-88]. From this point of view and as shown in this thesis, reducing exposure to lifestyle risk factors seems to be an important entry point for reducing educational inequalities in mortality. Indeed, as the potential health gains are larger among low educated people, raising health status of these people may not only reduce educational inequalities in mortality but also improve average population health. However, despite the major successes of health policies that tackle harmful behaviour, these policies are not equally effective in different socioeconomic groups and are often more effective in the most privileged groups, which remains an important barrier for reducing socioeconomic inequalities in mortality. Health promotion campaigns discouraging smoking or excessive drinking or encouraging healthy diet and physical exercise are not sufficient if we want to decrease inequalities in these risk factors. Health policies should target disadvantaged individuals, e.g. lower educated people, by controlling their risk factor exposure, by protecting them against the negative effects of the risk factor exposure and by addressing specific barriers to behaviour change [89].

For instance, it has been shown that all educational groups have equal will quitting smoking, however, lower educated people do not succeed as frequently as their higher educated counterparts [90]. This suggests that there are restrictions which limit the individual choice of risky behaviour among low educated people, such as financial resources, low social support, neuroticism, and low perceived control [90]. Interventions like free or cheap prescriptions for nicotine replacement therapy, smoking restrictions in the workplace, or raising tobacco taxes may have positive effects among lower educated people. One of the most successful strategies, however, i.e. raising the price of tobacco, penalises smokers from the most disadvantaged groups who are not able to stop their addiction [91]. Although the financial hardship forces people to cut expenses on cigarettes and stop smoking, the stress of living in deprivation coped with through smoking hinders smoking cessation [84]. Material barriers do not only affect smoking cessation behaviour but also eating habits and participation in physical activity. Investments in programs emphasizing physical activity which does not depend on attendance at expensive facilities or programs creating safe and accessible environment for physical activity may be potentially more effective interventions to promote activity among low educated individuals. Effective health policies regarding nutrition should reduce material barriers low educated people face to purchase more healthy food for a reasonable price, for instance by promoting the installation of groceries or the consumption of fruits and vegetables at school in deprived areas.

In general, health promotion policies seem to overlook several material and psychosocial restrictions people face. Additional interventions that focus on the childhood conditions which may partly generate these material and psychosocial restrictions may contribute to the decrease of socioeconomic differences in health as suggested for physical inactivity [86]. As structural and economic determinants of health-related behaviour are mainly beyond individual control, it is an important part of health policy to intervene on these determinants in order to reduce risky behaviour among low educated individuals.

The heterogeneity of the findings of this thesis across European countries highlights the fact that there is no single common strategy in Europe that would effectively decrease educational differences in mortality. Policy makers should therefore first identify the most important entry-points for interventions specific to their particular country, in particular in reference to the country-specific stage of the smoking or the obesity epidemic [92, 93]. Interventions focusing on decreasing smoking prevalence will likely have important effects on reducing educational inequalities in mortality in the Nordic and western European countries. On the other hand, southern European populations will probably benefit the most from interventions focusing on obesity reduction, especially among women. However, policy makers should not only evaluate the current risk factor distribution, they should also be aware of future trends. For instance, current smoking habits do not look like a threat in southern European populations, which may send a misleading message to public health policy makers. In the near future, smoking inequalities will most likely emerge in southern Europe as the smoking epidemic progresses [93]. Thus, awareness of long-run consequences of changing risk factors distribution is essential for successful policy interventions.

Finally, tackling merely lifestyle risk factors would contribute to decrease educational differences in mortality but not eliminate these inequalities. Although the main focus of this thesis was on lifestyle risk factors, health authorities should also be aware of potential health gains from improvements in material and working conditions as well as psychosocial well-being of the population, in particular among the least educated. These determinants are likely to also play an important role in reducing educational inequalities in mortality.

Research implications and recommendations

We focused on education as a measure of socioeconomic status, and it is not known if the conclusions described in the previous chapters, would hold for other measures of socioeconomic position, e.g. occupational class or income. However, a recent study on trends in life expectancy by income in Finland showed that the increase in disparity was more extreme when using income instead of occupational class or education [94]. This is likely because income identifies economically more deprived population groups more clearly than other measures of the socioeconomic position. Future research should therefore focus on other measures of the socioeconomic position. However, these measures are in many cases not available or difficult to gather for certain groups of the population, e.g. students, housewives, unemployed or retired people. More attention should therefore be given to data collection and statistical techniques dealing with missing values in order to elude these problems.

We concentrated on the contribution of lifestyle factors to educational inequalities in mortality in this thesis. However, only part of these inequalities can be explained by these factors. Future studies should also focus on environmental, material and psychosocial determinants and assess their contribution to educational differences in mortality.

Finally, it is also important to explore in more detail the processes leading to health related behaviour by investigating the role of determinants like intelligence, social norms, social support or perceived control. A better understanding of these mechanisms would not only shed light on the mechanisms generating educational inequalities in health related behaviour, but is also necessary to underpin the development of more effective interventions to reduce health inequalities.

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Summary

SUMMARY

Education is an important indicator of socioeconomic position. The association between education and health has been widely documented and there is now an extensive body of literature on educational inequalities in all-cause and cause-specific mortality in Europe. These cross-country comparisons have been an important source of information for understanding the mechanisms that generate these inequalities. However, unanswered questions still remain and this thesis aims at answering some of them. For instance, there is not much evidence regarding the quality of the cause-of-death data used in these European studies. Second, although many studies investigated educational inequalities in mortality in Europe, some countries were not included in these comparisons (e.g. the Netherlands) and there is a shortage of comprehensive studies focusing on trends over time in socioeconomic inequalities in a larger amount of European countries. Third, the smaller socioeconomic inequalities in mortality consistently reported in Southern Europe remained largely unexplored in a comprehensive and comparative framework. Finally, even though findings from international literature suggested a great scope for potential reduction of socioeconomic inequalities in mortality, studies quantifying the potential health gains and inequality reductions due to different interventions are scarce and mostly limited to a single or a small number of countries.

To address these questions, we used aggregated mortality and morbidity data collected in the framework of two large European projects – Eurothine and EURO-GBD-SE – and individual mortality data based on two data sources provided by Statistics Netherlands, namely death records in the Netherlands and the Dutch Labour Force Survey. We limited our analyses to adult population aged 30–74 or 30–79 years. This data collection provided a unique source for exploring educational inequalities in all-cause and cause-specific mortality in Europe.

In the first part of this thesis, including chapter 2, we investigated the quality of cause-of-death data by studying educational differences in the proportion of ill-defined causes of death among subjects aged 30–79 years in 16 European countries. This proportion was generally low among both men and women, and did not exceed 7% in any European country investigated. Our findings suggested that the proportion of ill-defined causes of death tended to be lower in countries with higher autopsy rate. The proportion of ill-defined causes of death differed statistically by education in Denmark, England and Wales, Belgium, Switzerland, Italy, Hungary, Czech Republic, Poland and Estonia among men, and in Switzerland and Poland among women with the tendency of a higher proportion among low educated individuals. Despite some statistically significant difference, the absolute difference in the proportion of ill-defined causes between low and high educated men and women was generally less than one percentage point, with the exception of Polish men among whom the difference was 2.9%-points. Due to these small percentage differences between educational groups, a redistribution of ill-defined causes of death to some well-defined causes of deaths, such as ischaemic heart disease (IHD) or suicide, did not considerably affect the educational inequalities observed for these latter causes of death.

In the second part of this thesis, comprising chapters 3 to 5, we expanded the current knowledge on the magnitude of and the trends in educational inequalities in all-cause and cause-specific mortality in Europe.

In chapter 3, we explored the substantially smaller absolute inequalities in total mortality consistently observed in Spain compared to the other Western European populations. Based on three Spanish populations (city of Barcelona, region of Madrid and the Basque Country), we showed that these smaller absolute educational inequalities in total mortality were the result of lower average levels of mortality and smaller relative inequalities in mortality. These smaller absolute inequalities were found to be due mainly to comparatively small absolute and relative inequalities in mortality from cardiovascular disease (men) and cancer (women). In contrast, relative inequalities in mortality from most other causes were not smaller in Spain than elsewhere and were even substantially larger for infectious disease mortality. It has been further shown that Spain has smaller inequalities in smoking and sedentary lifestyle, due to a higher prevalence of these risk factors among higher educated individuals, whereas inequalities in obesity among women are larger than in the other European populations. Regarding the cause-specific mortality patterns and the risk factors distribution in Spain, the smaller educational inequalities in mortality does not seem to be an outcome of deliberate policies. They are rather a historical coincidence suggesting widening of these inequalities in the future.

In chapter 4, we evaluated for the first time the magnitude of educational inequalities in all-cause and cause-specific mortality in the Netherlands and compared the findings with the estimates in other European countries. Using a linkage of the Dutch Labour Force Survey (1998–2002) with death records (1998–2007) via an encoded unique personal number in the Netherlands we reported large absolute educational inequalities in mortality and showed that their magnitude and cause-specific patterning were similar to those observed in other countries of North-Western Europe. The relative risk of dying was two times higher among people with primary education when compared with tertiary educated. This difference in total mortality led to a gap in partial life expectancy between ages 30 and 79 years of 3.4 and 2.4 years among men and women, respectively. The contributions to this gap were mainly driven by cardiovascular diseases and cancer, especially by lung cancer, which mortality differences in both absolute and relative terms were found to be substantially larger in the Netherlands than in other countries of North-Western Europe, particularly among men. The contribution of lung cancer to the gap between primary and tertiary educated people was 20% among men and 16% among women, suggesting an important contribution of smoking to educational inequalities in mortality in the Netherlands. This is consistent with the high smoking prevalence rates reported in the Netherlands during the last decades.

In chapter 5, we documented trends in relative and absolute educational inequalities in total and cause-specific mortality in 13 European countries between the 1990s and the 2000s. We observed an increase in relative inequalities in most populations in the North, West and East of Europe, but not in the South. The increase in the relative inequalities was mostly due to smaller proportional reductions in mortality among the lower than the higher educated, with exception of Lithuania and Estonia where mortality rose among the lower educated, due to conditions related to smoking (lung cancer, women only) and excessive alcohol consumption (liver cirrhosis and external causes), whereas it declined among the higher educated. This fact very likely contributed to the increasing difference between the South, characterized by smaller relative inequalities, and the East of Europe, characterized by large relative inequalities, since the 1990s. In absolute terms, however, we observed a larger mortality decline among the lower educated in many countries in the North, West and South of Europe, due mainly to larger absolute reductions in mortality from cardiovascular disease and cancer (men only). These findings suggested larger changes in health-related behaviours (e.g., smoking, diet, physical activity) and in health care interventions (e.g., hypertension detection and treatment, thrombolytic therapy) among the low educated.

Finally in the third part of this thesis, containing chapters 6 to 8, we discussed the potential health gains and inequality reductions due to different policies and interventions. We used an Excel tool specially developed for the estimation of the potential reductions of educational inequalities in mortality. This Excel tool was based on the Population Attributable Fraction (PAF) methodology.

The methodology is presented based on a couple of illustrative calculations (chapter 6). For the illustration purpose, we investigated how changes in the educational distribution of smoking, alcohol consumption, lack of physical activity, and overweight and obesity may impact educational inequalities in mortality in Belgium, Norway and Czech Republic. We applied a scenario implying that the prevalence of the four risk factors is reduced to the level currently seen among high educated. We found that socioeconomic inequalities in all-cause mortality could potentially be reduced for both men and women by a redistribution of risk factors by education. Additionally, we found that the PAF methodology and the conventional regression yielded similar results. Subsequently, we applied this methodology to two different research questions.

In chapter 7, we provided an innovative approach for assessing the effect of the on-going improvement in the educational structure on mortality for people aged 30–79 years. Based on two scenarios we estimated the impact of the projected increase in higher education on mortality in 21 European populations. The first scenario represented the improvement in the future distribution of educational attainment as expected on the basis of cohort replacement. The second scenario represented the levelling up situation when everyone has obtained tertiary education. The effect of these counterfactual scenarios on mortality was estimated with a 10–15-year time horizon. We observed important variations between countries in the magnitude of mortality reduction, depending on the current educational distribution, on the projected speed of future improvements in the educational distribution, and on the mortality rate ratios between educational groups observed in each country. The potential reduction in mortality ranged from 1.9 to 10.1% among men and 1.7 to 9.0% among women according to the cohort replacement scenario and from 22.0 to 57.0% among men and from 9.6 to 50.0% among women according to the upward levelling scenario. In addition, the cohort replacement scenario was estimated to achieve only part of the potential mortality decrease seen in the upward levelling scenario (4–25% for men and 10–31% for women). Despite the large scope for mortality reduction in all European countries, the greatest theoretical potential gain in mortality was found in eastern European countries for both men and women whereas the smallest theoretical potential gain in mortality was observed in southern European populations. The on-going improvements in educational attainment may have important positive side-effects on mortality.

In chapter 8, we estimated the potential reduction in educational inequalities in IHD mortality in 21 European populations by modifying the educational distribution of smoking, overweight and obesity, and physical inactivity. We investigated two redistribution scenarios: upward levelling scenario and best-practice-country scenario. In the upward levelling scenario, the risk factor prevalence was changed to the level currently observed among the high educated in each country. In the best-practice-country scenario, the risk factor prevalence was changed to the level observed in the best practice country, which was selected as the country with the lowest average risk factor prevalence combined with the smallest relative inequalities in the specific risk factor. These scenarios showed that the reduction of inequalities in IHD mortality varied by country, sex and risk factor. Under the upward levelling scenario, the maximal potential reduction of relative inequalities in IHD mortality between low and high educated amounted up to 22% for smoking, 36% for overweight and obesity, and 28% for physical inactivity among men and to 17% for smoking, 48% for overweight and obesity, and 18% for physical inactivity among women. Although the decrease in inequalities in IHD mortality was slightly smaller under the best-practice-country scenario, the mortality reduction among low educated was much more important in most of the countries under this scenario than under the upward levelling scenario.

Based on these findings, we demonstrated that there are large variations in educational inequalities in mortality and that there is a substantial scope for mortality reduction based either on on-going improvements in educational attainment or on modification of risk factors distribution by education. From this perspective, policy makers should invest and improve education for the whole population. However, the full beneficial effect of education will be achieved only if there are enough employment opportunities and if the achieved education meets the occupational needs. Policy makers should therefore invest in education and create new job opportunities at the same time. The complete levelling up of education and its perfect matching with the occupational opportunities are of course utopian solutions, rather than practically feasible solutions. Therefore, as long as not everybody has the same high level of education, there will be a need for policies and interventions that reduce educational inequalities in mortality through risk factor modifications. Nevertheless, the heterogeneity of the findings in this thesis across European countries highlights the fact that there is no single common strategy in Europe that would effectively decrease educational differences in mortality.

Samenvatting

SAMENVATTING

Opleidingsniveau is een belangrijke indicator van sociaaleconomische status. De associatie tussen opleidingsniveau en gezondheid is inmiddels op grote schaal gedocumenteerd en er is een uitgebreide hoeveelheid literatuur beschikbaar over ongelijkheden in totale en oorzaakspecifieke sterfte in Europa, voor personen met een verschillend opleidingsniveau. Studies tussen verschillende landen hebben veel informatie opgeleverd om de mechanismen te begrijpen die de sociaaleconomische ongelijkheden veroorzaken. Desalniettemin is er nog een aantal onbeantwoorde vragen. Dit proefschrift heeft als doel een aantal van deze vragen te beantwoorden. Ten eerste is er bijvoorbeeld weinig bewijs voor de kwaliteit van de doodsoorzaakspecifieke data die in deze Europese studies worden gebruikt. Ten tweede, ondanks dat veel studies de ongelijkheden in sterfte naar opleidingsniveau in Europa hebben onderzocht, ontbreken sommige Europese landen (bijvoorbeeld Nederland) in deze vergelijkingen. Daarnaast is er een gebrek aan omvangrijke studies die aandacht besteden aan trends in sociaaleconomische verschillen in een groter aantal Europese landen. Ten derde worden de consistent gerapporteerde kleinere sociaaleconomische verschillen in sterfte in Zuid-Europese landen grotendeels buiten beschouwing gelaten in een omvangrijk en vergelijkend raamwerk. Tot slot suggereren bevindingen in de internationale literatuur een grote reikwijdte van potentiële vermindering in de sociaaleconomische ongelijkheden in sterfte. Studies die de potentiële gezondheidswinst van verschillende interventies kwantificeren zijn echter schaars en voornamelijk gelimiteerd tot slechts één land of een beperkt aantal landen.

Om bovenstaande vragen te beantwoorden hebben we gebruikt gemaakt van geaggregeerde mortaliteit- en morbiditeitdata, welke zijn verzameld in het kader van twee grote Europese projecten – Eurothine en EURO-GBD-SE – en individuele sterftegegevens gebaseerd op twee databronnen van het Centraal Bureau voor de Statistiek – sterfteregistratie in Nederland en de Enquête Beroepsbevolking. We hebben onze analyses beperkt tot de volwassen populatie tussen de 30 en 74 of tussen de 30 en 79 jaar oud. Deze dataverzameling bood de unieke kans om de ongelijkheden in totale en oorzaakspecifieke sterfte naar opleidingsniveau in Europa te verkennen.

In het eerste deel van dit proefschrift, hoofdstuk 2, hebben we de kwaliteit van doodsoorzaakspecifieke gegevens onderzocht. Hiervoor bestudeerden we verschillen naar opleidingsniveau in de proportie van de sterftecijfers door onvolkomen gedefinieerde doodsoorzaken (in tegenstelling tot goed gedefinieerde doodsoorzaken) bij volwassenen tussen de 30 en 79 jaar in zestien Europese landen. Deze proportie was over het algemeen laag onder zowel mannen als vrouwen en kwam bij geen enkel Europees land dat werd onderzocht boven de 7% uit. Onze bevindingen suggereerden dat de proportie van de sterfgevallen door onvolkomen gedefinieerde doodsoorzaken lager was in landen met een hogere autopsiegraad. De proportie van deze sterfgevallen verschilde significant per opleidingsniveau voor mannen in Denemarken, Engeland en Wales, België, Zwitserland, Italië, Hongarije, Tsjechië, Polen en Estland, en voor vrouwen in Zwitserland en Polen. Hierbij was er een tendens voor een hogere proportie onder lager opgeleide individuen. Ondanks een enkel statistiek significant verschil, was het absolute verschil in de proportie van de sterfgevallen door onvolkomen gedefinieerde doodsoorzaken tussen laag en hoog opgeleide mannen en vrouwen over het algemeen minder dan één procent punt, met de uitzondering van Poolse mannen onder wie het verschil 2,9 procent punt was. Vanwege de kleine percentuele verschillen tussen de opleidingscategorieën, bleek een herdistributie van de sterfgevallen door onvolkomen gedefinieerde doodsoorzaken naar de sterfgevallen door andere, goed gedefinieerde doodsoorzaken, zoals bijvoorbeeld ischemische hartziekte of zelfmoord, geen aanzienlijk gevolg te hebben voor de ongelijkheden in sterfte naar opleidingsniveau voor deze laatste groep doodsoorzaken.

In het tweede deel van dit proefschrift, hoofdstuk 3 tot en met 5, hebben we de kennis over de omvang van en de trends in de ongelijkheden naar opleidingsniveau in totale en oorzaakspecifieke sterfte in Europa uitgebreid.

In hoofdstuk 3 exploreren we de kleinere absolute ongelijkheden in de totale sterfte die consistent wordt geobserveerd in Spanje ten opzichte van de andere West-Europese landen. Op basis van gegevens uit drie Spaanse populaties (de stad Barcelona, de regio van Madrid en Baskenland) lieten we zien dat deze kleinere absolute ongelijkheden in de totale sterfte naar opleidingsniveau het resultaat zijn van een lager gemiddeld niveau van mortaliteit en kleinere relatieve ongelijkheden in mortaliteit. Deze kleinere absolute ongelijkheden bleken met name een gevolg van kleine absolute en relatieve ongelijkheden in mortaliteit door cardiovasculaire ziekten (voor mannen) en kanker (voor vrouwen). Relatieve ongelijkheden in sterfte naar de meeste andere doodsoorzaken waren niet kleiner in Spanje dan in de andere landen. Ze waren zelfs substantieel groter voor mortaliteit door infectieziekten. Verder is aangetoond dat Spanje kleinere ongelijkheden heeft wat betreft roken en het hebben van een zittende leefstijl. Dit komt door een hogere prevalentie van deze risicofactoren onder hoger opgeleide individuen. De ongelijkheden voor obesitas zijn daarentegen onder Spaanse vrouwen groter dan in de andere Europese populaties. Met betrekking tot de oorzaakspecifieke sterftepatronen en de distributie van risicofactoren in Spanje bleken de kleinere ongelijkheden in sterfte naar opleidingsniveau geen gevolg te zijn van specifiek beleid. Deze kleinere ongelijkheden lijken eerder een historisch toeval te zijn en daarom is een toename van deze ongelijkheden in de toekomst waarschijnlijk.

In hoofdstuk 4 hebben we als eerste de omvang van ongelijkheden in totale en oorzaakspecifieke sterfte naar opleidingsniveau in Nederland geëvalueerd en onze bevindingen vergeleken met de schattingen uit andere Europese landen. We gebruikten hiervoor een koppeling tussen de Enquête Beroepsbevolking (1998-2002) en sterfte-registratie (1998-2007) via een gecodeerd uniek persoonsnummer. We observeerden grote absolute ongelijkheden in sterfte naar opleidingsniveau en lieten zien dat de omvang en oorzaakspecifieke patronen hetzelfde waren als die geobserveerd in andere Noordwest-Europese landen. Het relatieve risico op overlijden was tweemaal zo hoog onder mensen met basisonderwijs ten opzichte van mensen met hoger beroeps en/of universitair onderwijs. Het verschil in totale sterfte leidde tot een verschil in partiële levensverwachting van respectievelijk 3,4 en 2,4 jaar voor mannen en vrouwen in de leeftijd tussen 30 en 79 jaar. Dit verschil is met name te danken aan verschillen in sterfte door cardiovasculaire ziekten en kanker, in het bijzonder longkanker, waar de sterfteverschillen in zowel absolute als relatieve termen substantieel groter waren in Nederland dan in andere Noordwest-Europese landen (met name onder mannen). Longkanker droeg voor 20% voor mannen en voor 16% voor vrouwen bij aan het verschil in sterfte tussen personen met basisonderwijs en hoger beroepsonderwijs en/of een universitaire opleiding. Dit suggereert dat roken een belangrijke bijdrage levert aan de ongelijkheden in sterfte naar opleidingsniveau binnen Nederland. Deze bevinding lijkt consistent met de hoge prevalenties van roken die de afgelopen jaren in Nederland zijn gerapporteerd.

In hoofdstuk 5 hebben we de trends gedocumenteerd in relatieve en absolute ongelijkheden in totale en oorzaakspecifieke sterfte naar opleidingsniveau tussen 1990 en 2000 in dertien Europese landen. We observeerden een toename in relatieve ongelijkheden in de meeste populaties in Noord-, West- en Oost-Europa, maar we observeerden geen toename in Zuid-Europa. De toename in relatieve ongelijkheden werd met name veroorzaakt door de kleinere proportionele afnames in sterfte onder personen met een lage opleiding ten opzichte van personen met een hoge opleiding. Een uitzondering waren de landen Litouwen en Estland, waar de sterfte steeg onder de lager opgeleide bevolking. Deze stijging werd veroorzaakt door condities gerelateerd aan roken (longkanker bij vrouwen) en extreme alcohol consumptie (levercirrose en uitwendige oorzaken zoals ongelukken). Onder de hoogopgeleide bevolking daalde de sterfte aan deze doodsoorzaken. Deze feiten hebben hoogstwaarschijnlijk bijgedragen aan de toename in verschillen tussen het zuiden van Europa, met kenmerkende kleine relatieve ongelijkheden, en het oosten van Europa, met kenmerkende grote relatieve ongelijkheden, sinds de negentiger jaren. In absolute termen zagen we in veel landen in Noord-, West- en Zuid-Europa een grotere afname in sterfte onder de lager opgeleiden, met name veroorzaakt door grotere absolute dalingen in sterfte door cardiovasculaire ziekten en kanker (alleen mannen). Deze bevindingen suggereren dat er onder lager opgeleiden grotere veranderingen waren in gezondheidgerelateerde gedragingen (bijvoorbeeld roken, voeding en fysieke activiteit) en gezondheidszorginterventies (bijvoorbeeld signalering en behandeling van hypertensie, behandeling van trombose).

Tot slot bespreken we in het derde deel van dit proefschrift, hoofdstuk 6 tot en met 8, de potentiële gezondheidswinst en afname in ongelijkheden door beleid en interventies. We hebben hiervoor een Excel tool gebruikt die specifiek is ontwikkeld voor het schatten van mogelijke afnames in verschillen in sterfte naar opleidingsniveau. Deze Excel tool is gebaseerd op de *Population Attributable Fraction* (PAF) methodologie.

De PAF methodologie wordt gepresenteerd aan de hand van een aantal voorbeeld berekeningen (hoofdstuk 6). Ter verduidelijking van de tool, onderzochten we hoe veranderingen in de opleidingsniveauspecifieke verdeling van roken, alcohol consumptie, gebrek aan fysieke activiteit en overgewicht en obesitas een invloed hebben op ongelijkheden in sterfte naar opleidingsniveau in België, Noorwegen en Tsjechië. We pasten een scenario toe waarin de prevalentie van de vier risico factoren gereduceerd werd naar het niveau dat momenteel van toepassing is voor de hoogopgeleide bevolking. We vonden dat de sociaaleconomische ongelijkheden in totale sterfte mogelijk konden worden verlaagd door een herdistributie van de risicofactoren per opleidingsniveau. Dit resultaat vonden we voor zowel mannen als vrouwen. Aanvullend vonden we dat de PAF methodologie en de conventionele regressie tot vergelijkbare resultaten leidden. Vervolgens hebben we deze methodologie toegepast om twee verschillende onderzoeksvragen te beantwoorden welke zijn besproken in hoofdstuk 7 en 8.

In hoofdstuk 7 bekeken we, met een innovatieve aanpak, de effecten van de continue verbetering in het onderwijssysteem op de sterfte van mannen en vrouwen in de leeftijd tussen 30 en 79 jaar. Op basis van twee scenario's hebben we de invloed van een geprojecteerde toename in hoger onderwijs op sterfte in 21 Europese populaties geschat. Het eerste scenario is representatief voor een verbetering in de verdeling van het behaalde opleidingsniveau in de toekomst, zoals kan worden verwacht op basis van cohort vervanging. Het tweede scenario is representatief voor de situatie waarin iedereen een hoog opleidingsniveau heeft behaald, namelijk een *upward levelling* scenario. Het effect van deze *counterfactual* scenario's op sterfte werd geschat met een tijdpad van 10–15 jaar. We observeerden belangrijke verschillen tussen landen wat betreft de omvang van de reductie in sterfte (afhankelijk van de verdeling van het huidige opleidingsniveau in de landen), de geprojecteerde snelheid van toekomstige verbeteringen in de verdeling van opleidingsniveau en de ratio van sterftecijfers tussen de opleidingsgroepen in elk land. De potentiële afname in sterfte lag met het cohort vervangingsscenario tussen de 1,9% en 10,1% voor mannen en 1,7% en 9,0% voor vrouwen. Voor het *upward levelling* scenario lag de potentiele afname tussen de 22,0% en 57,0% voor mannen en tussen de 9,6% en 50,0% voor vrouwen. In aanvulling hierop werd ingeschat dat het cohort vervangingsscenario naar schatting slechts een deel van de afname van sterfte in het potentiële *upward levelling* scenario kon behalen (4–25% voor mannen en 10–31% voor vrouwen). Ondanks de brede omvang van potentiële sterftereductie in alle Europese landen, werd de grootste theoretische winst voor sterfte gevonden voor zowel mannen als vrouwen in Oost-Europese landen, terwijl de kleinste theoretische winst werd geobserveerd in de Zuid-Europese populaties. De continue verbeteringen in het behaalde opleidingsniveau zou belangrijke positieve bijeffecten kunnen hebben op sterfte.

In hoofdstuk 8 schatten we de potentiele afname in ongelijkheden in sterfte door ischemische hartziekten naar opleidingsniveau in 21 Europese landen door het veranderen van de verdeling van roken, overgewicht en obesitas en fysieke activiteit naar opleidingsniveau. We onderzochten twee herdistributie scenario's: een *upward levelling* (UL) scenario en een *best-practice-country* (BPC) scenario. In het UL scenario werd de prevalentie van de risicofactor aangepast naar het huidige niveau voor de hoogopgeleiden in elk land. In het BPC scenario werd de prevalentie van de risicofactor aangepast naar het niveau van het BPC. Het BPC was het land met de gemiddeld laagste waarde voor de risicofactor in combinatie met de kleinste relatieve ongelijkheden voor deze risicofactor. Deze scenario's lieten zien dat de afname in ongelijkheden in sterfte aan ischemische hartziekten varieerden per land, geslacht en risicofactor. Voor het UL scenario was de maximale reductie voor relatieve ongelijkheden in sterfte aan ischemische hartziekten voor mannen tussen laag- en hoogopgeleiden 22% voor roken, 36% voor overgewicht en obesitas en 28% voor fysieke activiteit. Voor vrouwen waren de reducties 17% voor roken, 48% voor overgewicht en obesitas en 18% voor fysieke activiteit. De afname in ongelijkheden in sterfte aan ischemische hartziekten waren enigszins kleiner bij het BPC scenario, echter bij dit scenario was de afname in sterfte onder laag opgeleiden veel belangrijker in de meeste landen dan het geval was in het UL scenario.

Op basis van onze bevindingen kunnen we stellen dat er grote variaties bestaan in opleidingsniveau en ongelijkheden in sterfte naar opleidingsniveau in Europa. Door continue verbeteringen in de behaalde opleiding of verandering van de verdeling van risicofactoren bestaat een substantiële kans om een verkleining van sterfteverschillen te realiseren. Vanuit dit perspectief zouden beleidsmakers moeten investeren in het onderwijssysteem en onderwijs voor de hele populatie moeten verbeteren. Echter, het volledige positieve effect van opleiding kan enkel worden bereikt als er voldoende mogelijkheden zijn tot werk en als de behaalde opleiding aansluit bij de beroepen in de maatschappij. Beleidsmakers zouden daarom moeten investeren in educatie en tegelijkertijd nieuwe banen moeten creëren. Een volledige opschaling van educatie en een perfecte matching met beschikbaarheid van banen is uiteraard een utopische oplossing en geen praktisch haalbare oplossing. Zolang als niet iedereen hetzelfde opleidingsniveau heeft zal er behoefte zijn aan beleid en interventies gericht op het verminderen van ongelijkheden in sterfte naar opleidingsniveau door het veranderen van risicofactoren. Dit proefschrift benadrukt, door de heterogeniteit in de bevindingen tussen de Europese landen, dat er geen universele strategie is die in Europa effectief verschillen in sterfte naar opleidingsniveau kan verkleinen.

EURO-GBD-SE project partners

EURO-GBD-SE PROJECT PARTNERS

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A big thank you will also have to go to my office mates Tessa and Jitske. You were always kind and very supportive. I was one of the few foreigners at the department at that time and I was completely lost in all the information available to me in Dutch only. Thank you very much for your patience, for conversing with me in English, for translating Dutch for me and for giving me information that I missed because I did not understand. (Good news, I do understand now!) You made the hard beginning much easier. Tessa, I am happy we still keep in touch, even though you do not work at MGZ anymore.

I would also like to thank Amy, Nikki, Vivian and Luuk who shared the office with me after we had moved to another building. I am happy that I could practice my Dutch with you. Amy, thank you for the Dutch translation of the summary section. Nikki and Luuk, thank you very much for your kindness, advice and emotional support during some difficult moments.

Thank you to all other MGZ colleagues as well for creating a friendly environment. Bart and Istvan, thank you for your advice regarding the remote access data. Lifang, thank you for your delicious Chinese food and for inviting me to play badminton. Marcel, thank you for the nice chats in the evenings when we both stayed late working on our PhD theses. Mariëlle, Rianne, Yannan, Giorgia, Anne, Tiago, Kevin and Joost deserve a special mention as well. I enjoyed a lot of our chats over dinners or drinks, picnics in the park or PubQuiz in the Irish pub.

Dear Karolina, I am glad I met you at the Dutch course. Thanks to you, I met other great people like Katharina, Rachel, Joris and Alex. We had a lot of fun together during birthday parties, bowling, Sinterklaas games or in the Irish pub. We should go soon eating sushi again. Alex, I love your Brazilian humour, you always made me laugh. I hope you will organize another boat trip in Amsterdam when you celebrate your 25^{th} (again!) birthday.

Special big thanks go to John and Laurens. I know you did not have it easy with me. You know my ups and downs the best. Words can never express how grateful I am for your friendships. Thank you for always being there for me and for all the hugs when I needed them. You will always have a place in my heart.

I would also like to thank my Czech friend Lucie who I met in Rotterdam. I am happy we could spend a year together travelling around the Netherlands to discover the beauty of this country. The numerous trips on Saturdays were a great balance to the hard work.

Dear Olga, you are the best example that true friendship knows no distance. You have been supporting me since we first met at university in Prague. Although hundreds of kilometres separate us, you were always available for an advice, help or just a talk.

Finally, I would like to thank my family for helping me get through the difficult time. Mum and Dad, thank you for all your love, support and encouragement not to give up. Without you, I would not be here now. Thank you!

About the author

ABOUT THE AUTHOR

Ivana Kulhánová was born on the 21st of February 1982 in Vlašim, Czech Republic. After completing secondary school at the Gymnázium Benešov, Czech Republic in 2001, she started studying Demography and Economics at the Charles University in Prague, Czech Republic. During 2004–2005, she spent one and half years in Germany studying Business Administration at the University of Applied Sciences in Aachen for two semesters and Mathematics at the RWTH Aachen University for one semester. After returning from Germany, Ivana obtained her Bachelor's degree in Demography and Economics at the Charles University in Prague in 2005 and she continued with the Master´s studies in Demography at the same university.

In 2006, she followed courses in demography and economic geography at the University of Rome "La Sapienza", Italy for one semester as an exchange student. In the same year, she received a scholarship from the German Academic Exchange Service to pursue university education in Germany and consequently, she enrolled in Master´s studies in Demography at the University of Rostock, Germany. During her studies, she worked for five months as a student assistant at the Laboratory of Demographic Data of the Max Planck Institute for Demographic Research in Rostock where she was involved in data harmonization for the Human Life-Table Database. In 2008, she obtained her Master of Science degree in Demography from the University of Rostock. After her graduation, she stayed for another six months at the Max Planck Institute for Demographic Research in Rostock attending advanced courses in demography and statistics within the framework of the International Max Planck Research School for Demography.

In 2009, Ivana was selected as one of the Blue Book trainees of the European Commission for a five-month internship. She was placed in the Population Unit at Eurostat in Luxembourg where she supported the analyses of the 2008-based regional population projections (EUROPOP2008) for the EU-27 Member States, Norway and Switzerland. After returning from Luxembourg, she completed her Master´s studies at the Charles University in Prague. After her graduation, she moved back to Germany attending two-month preparatory courses in statistics, mathematics, computer programming, and demographic measures and models within the framework of the European Doctoral School of Demography at the Max Planck Institute for Demographic Research in Rostock. Later that year, she moved to Sweden and enrolled in a research Master programme in Demography at the Lund University where she obtained her third Master of Science degree in Demography in 2010.

In the same year, she was appointed Junior Researcher at the Department of Public Health of the Erasmus Medical Center in Rotterdam, the Netherlands. Here, she was involved in the large European research project – EURO-GBD-SE – with the main goal of quantifying the potential for reduction of socioeconomic inequalities in health based on policies and interventions on socioeconomic determinants as well as on specific risk factors. Her research work resulted in this PhD thesis. Currently, she works as a researcher at the Department of Public Health of the Erasmus Medical Center in Rotterdam on another European project called Demetriq, which aims at developing methodologies to reduce inequalities in the determinants of health.

List of publications

LIST OF PUBLICATIONS

In this thesis

Kulhánová I, Menvielle G, Bopp M, Borrell C, Deboosere P, Eikemo TA, Hoffmann R, Leinsalu M, Martikainen P, Regidor E, Rodríguez-Sanz M, Rychtaříková J, Wojtyniak B, Mackenbach JP. Socieconomic differences in the use of ill-defined causes of death in 16 European countries. *(submitted)*

Kulhánová I, Bacigalupe A, Eikemo TA, Borrell C, Regidor E, Esnaola S, Mackenbach JP, the Eurothine consortium. Why does Spain have smaller inequalities in mortality? An exploration of potential explanations. *European Journal of Public Health.* 2014;24:370-377.

Kulhánová I, Hoffmann R, Eikemo TA, Menvielle G, Mackenbach JP. Educational inequalities in mortality by cause of death: first national data for the Netherlands. *International Journal of Public Health.* 2014;59:687-696.

Mackenbach JP, **Kulhánová I**, Menvielle G, Bopp M, Borrell C, Costa G, Deboosere P, Esnaola S, Kalediene R, Kovács K, Leinsalu M, Martikainen P, Regidor E, Rodríguez-Sanz M, Strand BH, Hoffmann R, Eikemo TA, Östergren O, Lundberg O, for the Eurothine and the EURO-GBD-SE consortiums. Trends in inequalities in premature mortality: a study of 3.2 million deaths in 13 European countries. *Journal of Epidemiology and Community Health.* 2014 Jun 25. doi: 10.1136/jech-2014-204319.

Hoffmann R, Eikemo TA, **Kulhánová I**, Dahl E, Deboosere P, Dzúrová D, van Oyen H, Rychtaříková J, Strand BH, Mackenbach JP. The potential impact of a social redistribution of specific risk factors on socioeconomic inequalities in mortality: illustration of a method based on population attributable fractions. *Journal of Epidemiology and Community Health.* 2013;67:56-62.

Kulhánová I, Hoffmann R, Menvielle G, Looman CWN, Eikemo TA, Bopp M, Borrell C, Deboosere P, Leinsalu M, Martikainen P, Rychtaříková J, Wojtyniak B, Judge K, Mackenbach JP, for the EURO-GBD-SE Consortium. Assessing the potential impact of increased participation in higher education on mortality: Evidence from 21 European populations. *Social Science & Medicine.* 2014;117:142-149.

Kulhánová I, Menvielle G, Hoffmann R, Eikemo TA, Kulik MC, Toch-Marquardt M, Deboosere P, Leinsalu M, Lundberg O, Regidor E, Looman CWN, Mackenbach JP, for the EURO-GBD-SE Consortium. The potential for reduction of educational differences in ischaemic heart disease mortality in Europe: The role of three lifestyle risk factors. *(submitted)*

Other publications

Eikemo TA, Hoffmann R, Kulik MC, **Kulhánová I**, Toch-Marquardt M, Menvielle G, Looman CWN, Jasilionis D, Martikainen P, Lundberg O, Mackenbach JP, for the EURO-GBD-SE Consortium. How can inequalities in mortality be reduced? A quantitative analysis of 6 risk factors in 21 European populations. *PLoS One.* 2014;9:e110952.

Kulhánová I, Hoffmann R, Eikemo TA, Menvielle G, Mackebach JP. Sociaal-economische verschillen in sterfte naar doodsoorzaak. Eerste Nederlandse gegevens. *Nederlands Tijdschrift voor Geneeskunde.* 2014;158:A8188.

Toch-Marquardt M, Menvielle G, Eikemo TA, **Kulhánová I**, Kulik MC, Bopp M, Esnaola S, Jasilionis D, Mäki N, Martikainen P, Regidor E, Lundberg D, Mackenbach JP. Occupational class inequalities in all-cause and cause-specific mortality among middle-aged men in 14 European populations during the early 2000s. *PLoS One.* 2014;9:e108072.

Mackenbach JP, **Kulhánová I**, Bopp M, Deboosere P, Eikemo TA, Hoffmann R, Kulik MC, Leinsalu M, Martikainen P, Menvielle G, Regidor E, Wojtyniak B, Östergren O, Lundberg O, for the EURO-GBD-SE Consortium. 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. *Social Science & Medicine.* 2014 May 22.
doi: 10.1016/j.socscimed.2014.05.021

Kulik MC, Menvielle G, Eikemo TA, Bopp M, Jasilionis D, **Kulhánová I**, Leinsalu M, Martikainen P, Östergren O, Mackenbach JP, for the EURO-GBD-SE Consortium. Educational inequalities in three smoking-related causes of death in 18 European populations. *Nicotine & Tobacco Research.* 2014;16:507-518.

Kulik MC, Hoffmann R, Judge K, Looman C, Menvielle G, **Kulhánová I**, Toch M, Östergren O, Martikainen P, Borrell C, Rodríguez-Sanz M, Bopp M, Leinsalu M, Jasilionis D, Eikemo TA, Mackenbach JP. Smoking and the potential for reduction of inequalities in mortality in Europe. *European Journal of Epidemiology.* 2013;28:959-971.

Eikemo TA, Hoffmann R, **Kulhánová I**, Kulik MC, Toch M, Mackenbach JP. EURO-GBD-SE Final Report, Chapter 1: General introduction to the EURO-GBD-SE project. Available at: http://www.euro-gbd-se.eu/fileadmin/euro-gbd-se/public-files/EURO-GBD-SE_Final_report.pdf

Eikemo TA, Hoffmann R, **Kulhánová I**, Kulik MC, Toch M, Mackenbach JP. EURO-GBD-SE Final Report, Chapter 2: Approach followed in the EURO-GBD-SE project. Available at: http://www.euro-gbd-se.eu/fileadmin/euro-gbd-se/public-files/EURO-GBD-SE_Final_report.pdf

Hoffmann R, Eikemo TA, **Kulhánová I**, Mackenbach JP & the EURO-GBD-SE Consortium. EURO-GBD-SE Final Report, Chapter 3: Development of methods to assess the potential for reduction of health inequalities. Available at: http://www.euro-gbd-se.eu/fileadmin/euro-gbdse/public-files/EURO-GBD-SE_Final_report.pdf

Lundberg O, Östergren O, Menvielle G, **Kulhánová I**, Eikemo TA, Mackenbach JP & the EURO-GBD-SE Consortium. EURO-GBD-SE Final Report, Chapter 5.1: Inequalities in mortality across Europe: An international comparative study. Available at: http://www.euro-gbd-se.eu/fileadmin/euro-gbd-se/public-files/EURO-GBD-SE_Final_report.pdf

Vandenheede H, Deboosere P, Espelt A, Bopp M, Borrell C, Costa G, Eikemo TA, Gnavi R, Hoffmann R, **Kulhánová I**, Kulik MC, Leinsalu M, Martikainen P, Menvielle G, Rodríguez-Sanz M, Rychtaříková J, Mackenbach JP, for the EURO-GBD-SE consortium. Educational inequalities in diabetes mortality across Europe in the 2000s: the interaction with gender. *(submitted)*

Hoffmann R, Eikemo TA, **Kulhánová I**, Kulik MC, Looman CWN, Menvielle G, Deboosere P, Martikainen P, Regidor E, Mackenbach JP. Obesity and the potential reduction of inequalities in mortality: Evidence from 21 European populations. *(submitted)*

Publications

PhD portfolio

PHD PORTFOLIO

Summary of PhD training and teaching

PhD student	Ivana Kulhánová	PhD period	2010–2014
Erasmus MC	Department of Public Health	Promotor	Prof.dr. Johan P. Mackenbach
		Supervisor	Dr. Gwenn Menvielle

	Year	Workload (ECTS)
1. PhD training		
Research skills		
English Biomedical Writing and Communication	2011–2012	4.0
NIHES courses, Rotterdam, the Netherlands		
Medical Demography	2013	1.1
Biostatistics for Clinicians	2013	0.7
Regression Analysis for Clinicians	2013	0.7
Survival Analysis for Clinicians	2013	0.7
Causal Inference	2013	0.7
Pharmaco-epidemiology	2013	0.7
Topics in Meta-analysis	2012	0.7
Introduction to Global Public Health	2012	0.7
Methods of Public Health Research	2012	0.7
History of Epidemiologic Ideas	2012	0.7
Principles of Epidemiologic Data-analysis	2011	0.7
Methods of Health Services Research	2011	0.7
Primary and Secondary Prevention Research	2011	0.7
Health Economics	2011	0.7
Methodologic Topics in Epidemiologic Research	2010	1.4
Summer School, Bielefeld University, Germany		
Infectious Disease Epidemiology	2011	3.0
Presentations		
Assessing the potential impact of increased participation in higher education on mortality: Evidence from 21 European populations, MMDV meeting, Rotterdam, the Netherlands	2013	1.0

Educational inequalities in mortality in the Netherlands, European Population Conference, Stockholm, Sweden	2012	1.0
The potential for reduction of mortality attributable to low education: Evidence from 20 European populations, EURO-GBD-SE Consortium and Steering Committee meeting, Rotterdam, the Netherlands	2012	1.0
Educational inequalities in mortality in the Netherlands, Research meeting, Department of Public Health, Erasmus MC, Rotterdam, the Netherlands	2011	1.0
Measurement of fruit and vegetable consumption within EURO-GBD-SE project, MMDV meeting, Rotterdam, the Netherlands	2011	1.0
Sources of relative risks for risk factors within EURO-GBD-SE project and coverage of causes of death, EURO-GBD-SE Steering Committee meeting, Turin, Italy	2011	1.0
Causes of death within EURO-GBD-SE project, EURO-GBD-SE Steering Committee meeting, Paris, France	2011	1.0
Educational inequalities in mortality, workshop on "Smaller mortality inequalities in the Basque Country and other southern European populations? Exploring potential explanations", Bilbao, Spain	2010	1.0
On the causal relationship between education and health, EURO-GBD-SE Steering Committee meeting, Stockholm, Sweden	2010	1.0
Effectiveness of health care system in countries in transition, PopFest Population Studies Conference, St. Andrews, Scotland, UK	2010	1.0
Trends in avoidable mortality in the Central and Eastern European countries, Annual Meeting of Population Association of America, Dallas, Texas, USA	2010	1.0

International conferences

European Population Conference, Stockholm, Sweden	2012	0.5
European Population Conference, Vienna, Austria	2010	0.5
PopFest Population Studies Conference, St. Andrews, Scotland, UK	2010	0.5
Annual Meeting of Population Association of America, Dallas, Texas, USA	2010	0.5

Seminar and workshops

Research seminars of the Department of Public Health, Erasmus MC, Rotterdam, the Netherlands	2010–2013	2.0
NETSPAR symposium, Health expenditures a cause of increasing life expectancy? Rotterdam, the Netherlands	2012	0.3
EURO-GBD-SE Consortium meeting, Rotterdam, the Netherlands	2012	0.5
NETSPAR symposium, Projecting future life expectancy: an interdisciplinary perspective, Rotterdam, the Netherlands	2011	0.3
EURO-GBD-SE Steering Committee meeting, Turin, Italy	2011	0.5
Jaegtvolden seminar, Social inequalities in health – research status and new challenges, Trondheim, Norway	2011	1.0
EURO-GBD-SE Steering Committee meeting, Paris, France	2011	0.5
Workshop: Smaller mortality inequalities in the Basque Country and other southern European populations? Exploring potential explanations, Bilbao, Spain	2010	0.5

SHARELIFE launch, Brussels, Belgium	2010	0.5
EURO-GBD-SE Steering Committee meeting, Stockholm, Sweden	2010	0.5
Rostocker Ring Inaugural Conference, Rostock, Germany	2010	0.5
Joint Eurostat/UNECE Work Session on Demographic Projections, Lisbon, Portugal	2010	0.5
EURO-GBD-SE Consortium meeting, Rotterdam, the Netherlands	2010	0.5
2. Teaching		
Lecture on "PAF and health inequalities" within the NIHES course "Public Health Research: Analysis of Determinants", Erasmus MC, Rotterdam	2014	0.5
Supervising medical students, Theme 3.C4 Community projects	2013	1.0
Project 1: Gezond en Vitaal leven: Obesitas in de Turkse en Marokkaanse gemeenschap in Rotterdam		
Project 2: Niet Aangeboren Hersenaandoeningen		
3. Other activities		
Member of Organizing Committee of PhD day 2014 "Your PhD Profile for Success!"	2014	0.2

NIHES = Netherlands Institute for Health Sciences
MMDV = 'Medische en Maatschappelijke Determinanten van Volksgezondheid' research line
NETSPAR = Network for Studies on Pensions, Aging and Retirement
UNECE = United Nations Economic Commission for Europe