OECD*publishing*

Please cite this paper as:

Mackenbach, J. *et al.* (2015), “Measuring Educational Inequalities in Mortality Statistics”, *OECD Statistics Working Papers*, 2015/08, OECD Publishing, Paris.
http://dx.doi.org/10.1787/5jrqppx182zs-en

OECD Statistics Working Papers
2015/08

Measuring Educational Inequalities in Mortality Statistics

Johan P. Mackenbach, Gwenn Menvielle, Domantas Jasilionis, Rianne de Gelder

OECD

Unclassified **STD/DOC(2015)8**

Organisation de Coopération et de Développement Économiques
Organisation for Economic Co-operation and Development

English - Or. English

STATISTICS DIRECTORATE

STD/DOC(2015)8
Unclassified

MEASURING EDUCATIONAL INEQUALITIES IN MORTALITY

STATISTICS DIRECTORATE

STD WORKING PAPER No 66

This working paper has been prepared by Johan P. Mackenbach, Gwenn Menvielle, Domantas Jasilionis, and Rianne de Gelder.

English - Or. English

MEASURING EDUCATIONAL INEQUALITIES IN MORTALITY

Johan P. Mackenbach, Gwenn Menvielle, Domantas Jasilionis, and Rianne de Gelder

OECD STATISTICS WORKING PAPER SERIES

The OECD Statistics Working Paper Series – managed by the OECD Statistics Directorate – is designed to make available in a timely fashion and to a wider readership selected studies prepared by OECD staff or by outside consultants working on OECD projects. The papers included are of a technical, methodological or statistical policy nature and relate to statistical work relevant to the Organisation. The Working Papers are generally available only in their original language – English or French – with a summary in the other.

OECD Working Papers should not be reported as representing the official views of the OECD or of its member countries. The opinions expressed and arguments employed are those of the author.

Working Papers describe preliminary results or research in progress by the author and are published to stimulate discussion on a broad range of issues on which the OECD works. Comments on Working Papers are welcomed, and may be sent to the Statistics Directorate, OECD, 2 rue André-Pascal, 75775 Paris Cedex 16, France.

The release of this working paper has been authorised by Martine Durand, OECD Chief Statistician and Director of the OECD Statistics Directorate.

Notes

This document and any map included herein are without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

Israel

The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

www.oecd.org/std/publicationsdocuments/workingpapers/

ACKNOWLEDGEMENTS

The authors wish to thank Marco Mira d'Ercole and Fabrice Murtin (OECD Statistics Directorate) for their comments on a previous version of this paper.

Several illustrations included in this paper were taken from data collected as part of the "Developing methodologies to reduce inequalities in the determinants of health" (DEMETRIQ) project. This study was supported by a grant (FP7-CP-FP grant no. 278511) from the European Commission Research and Innovation Directorate General. The authors thank the European Commission for this support, and the members of the DEMETRIQ consortium for their assistance in preparing this dataset.

ABSTRACT

All OECD countries are faced with substantial inequalities in health status between socioeconomic groups within their populations. One aspect of these inequalities for which data are routinely available in many countries is inequalities in mortality by level of education: people with a lower level of education typically have considerably higher death rates and lower life expectancy than people with a higher level of education. The OECD recently started a project to generate measures of the distributions of ages at death by educational level, gender and cause of death for as many countries as possible. This working paper aims to highlight the most important methodological issues to be faced when trying to create valid statistics on mortality by level of education, and to highlight how different methodologies may affect results and comparisons. Topics covered include study designs (e.g. use of cross-sectional census-unlinked versus longitudinal census-linked data), data harmonization issues (e.g. use of a common educational classification scheme), and data analysis issues (e.g. choice of a summary measure of inequalities in mortality). The paper ends with a number of recommendations for data analysts.

RESUME

On observe dans tous les pays de l'OCDE des inégalités considérables entre les différents groupes socioéconomiques de leur population du point de vue de l'état de santé. Ces inégalités, pour lesquelles des données sont régulièrement disponibles dans de nombreux pays, se manifestent notamment par une mortalité différente selon le niveau d'études : en effet, les individus ayant un faible niveau d'instruction enregistrent généralement des taux de mortalité beaucoup plus élevés et ont une espérance de vie plus courte que ceux ayant suivi de plus longues études. L'OCDE a récemment lancé un projet visant à élaborer des indicateurs de la répartition de l'âge au décès par niveau d'études, par sexe et par cause du décès dans le plus grand nombre de pays possible. Ce document mets en évidence les principales difficultés d'ordre méthodologique que l'on rencontre lorsque l'on tente d'établir des statistiques valables sur la mortalité par niveau d'études, et à montrer comment des méthodologies différentes risquent d'avoir un impact sur les résultats et les comparaisons. Parmi les thèmes abordés figurent la conception des études (par exemple l'exploitation de données transversales non liées au recensement ou à l'inverse de données longitudinales extraites du recensement), la question de l'harmonisation des données (par exemple l'utilisation d'un dispositif commun de classification de l'éducation), et celle relative à l'analyse des données (par exemple le choix d'un indicateur synthétique des inégalités en matière de mortalité). Le document se termine par un certain nombre de recommandations à l'intention des responsables de l'analyse des données.

TABLE OF CONTENTS

Tables

Figures

Boxes

1. Introduction

1. At the start of the 21st century, all OECD countries are faced with substantial inequalities in health status within their populations. People with a lower level of education, a lower occupational class, or a lower level of income tend to die at a younger age, and to have, within their shorter lives, a higher prevalence of many different health problems (Commission on Social Determinants of Health, 2008; Mackenbach, 2006). This leads to large differences between socioeconomic groups in life expectancy, as well as in healthy life-expectancy (Bronnum-Hansen and Baadsgaard, 2012; Deboosere et al. 2009; Palosuo et al., 2012; Steingrimdottir et al., 2012). Socio-economic inequalities in health conditions not only represent a great challenge for public health, but also involve a significant loss in social and economic welfare. For instance, it has been estimated that, for the EU as a whole, health inequalities lead to more than 700,000 excess deaths per year, and to 33 million extra cases of ill health, as compared to the hypothetical situation in which everyone would have the mortality and morbidity rates of the high educated. These health losses account for 20% of the total costs of healthcare and 15% of the total costs of social security benefits (Mackenbach, Meerding and Kunst, 2011).

2. In response, many countries have made a reduction of health inequalities one of the priorities of their health and social policies, with some of them even setting quantitative targets for reducing these inequalities. A target to reduce health inequalities by 25% was introduced by the World Health Organization in 1985, and renewed in 1998 (WHO, 1999); several European countries, such as England, Finland and Lithuania, have adopted national targets for the reduction of socio-economic inequalities in mortality (Bauld, Day and Judge, 2008). In order to be able to monitor progress in reducing health inequalities, many countries now produce regularly updated statistics on mortality and (less often) morbidity by one or more breakdowns reflecting people's socio-economic position. At the international level, Eurostat, the statistical agency of the European Union, has included life expectancy by level of education among the standard measures of population health it collects from the EU's member states (OECD, 2014). Although this represents an important step forward, availability of data for international benchmarking remains limited.

3. Recognizing the importance of generating more comparable data on inequalities in mortality by socio-economic position for as many countries as possible, the OECD recently started a project to generate measures of the distributions of ages at death by educational level, gender and cause of death for as many countries as possible. This working paper aims to highlight the most important methodological issues to be faced when trying to create valid statistics on mortality by level of education, and to highlight how different methodologies may affect results and comparisons. The paper is structured as follows. Section 2 briefly highlights the main reasons why this is important. Section 3 describes the two main study set-ups that can be used to relate population numbers to numbers of deaths by educational attainment, whereas section 4 provides guidance with regard to the necessary harmonization of data coming from different countries. Section 5 describes how the data can be analysed to obtain informative measures of educational inequalities in mortality. Finally, section 6 summarizes our main recommendations.

2. Why is measuring educational inequalities in mortality important?

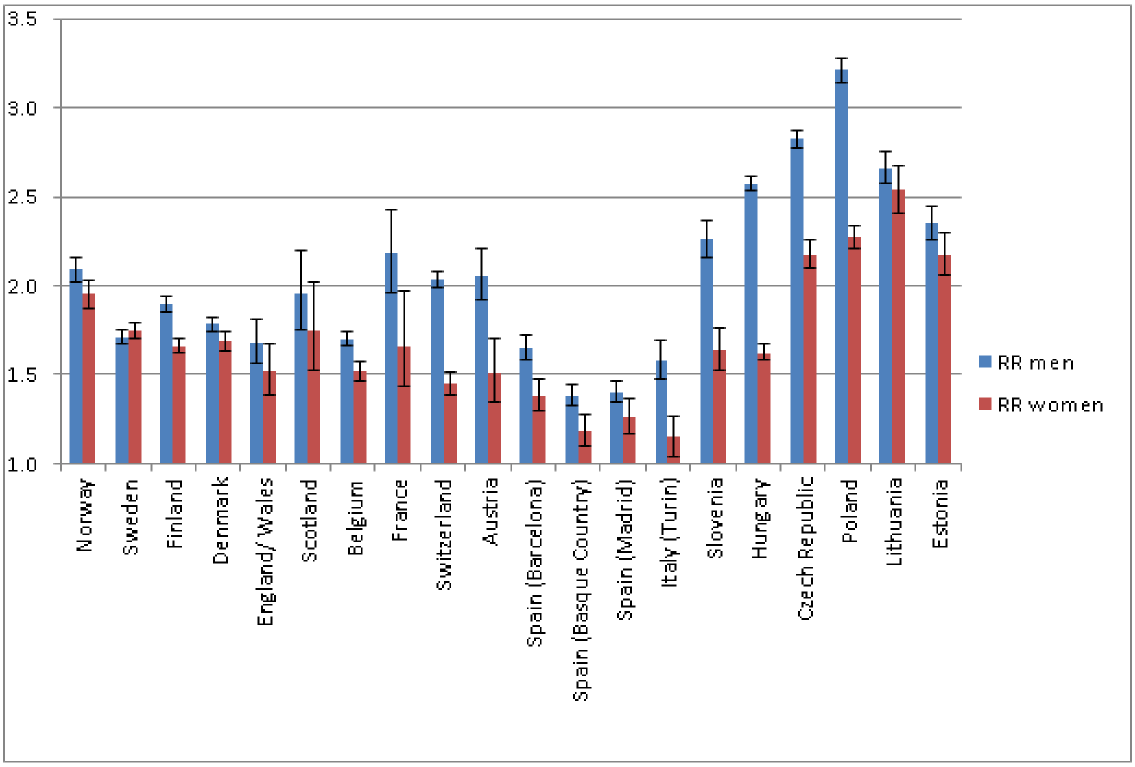
4. Individuals differ enormously in their age at death: some new-borns die on their first day of life, whereas other people reach their 100th birthday or beyond. These between-individual variations in life-span have many causes, including genetics, health-related behaviours, environmental conditions, health care utilization and chance. The role of a person's socioeconomic position can be seen as structuring these specific determinants of mortality into patterns whereby groups placed lower in the social hierarchy face consistently higher mortality risks than groups with a more advantaged position. Although variations in mortality by socioeconomic position account for only a modest part of all the between-individual variations in life-span (van Raalte et al., 2011), they have a special relevance because they point to

opportunities for intervention (e.g. to 'level up' people with a lower socioeconomic position and thereby not only improve their situation but also improve average population health), and are often perceived as unfair (Whitehead, 1992); Whitehead, 2007). Data on inequalities in mortality and length of life (still the most widely available measures of health status) are therefore useful additions to other types of information on inequalities within populations, such as inequalities in income and wealth (OECD, 2012).

5. The usefulness of international comparisons of health inequalities has clearly been demonstrated by a series of European studies (Mackenbach et al. 1997; Mackenbach et al. 2008). Figure 1 shows that throughout Europe, for both men and women, mortality is higher among those with less education. The magnitude of these inequalities varies substantially. For example, in Sweden, the ratio of mortality rates by educational attainment is around 1.7 for men, indicating that mortality among those with primary and lower secondary education only is more than one-and-a-half times as high as that among people with postsecondary education. In Poland, on the other hand, the inequalities are considerably larger: among men, mortality differs by a factor of more than 3 between the two groups. Education-related inequalities in mortality are below the European average in all Southern European countries and above average in most countries in Central-eastern and Baltic regions. Similar patterns are seen for occupation-related inequalities in mortality among middle-aged men (Mackenbach et al. 2008; Toch-Marquardt et al., 2014). The explanation of these remarkable patterns is beyond the scope of this paper, but has been extensively discussed in the literature (Mackenbach et al, 1997; Mackenbach et al,2008; Mackenbach, 2012).

Figure 1. Inequalities in all-cause mortality across people with different educational attainment in 20 European countries or regions, by gender, 2000-2005

Ratios of mortality rates with their 95% Confidence Intervals



Note: Ratios of mortality rates are adjusted for age. These Rate Ratios compare the mortality rate among those with primary and lower secondary education only, to the mortality rate among those with postsecondary education.
Source: DEMETRIQ dataset (www.demetriq.eu).

6. Although the explanation of these inequalities in mortality is beyond the scope of this paper, a brief comment is necessary to put these data into context. During the past decade, great progress has been made in unravelling the determinants of health inequalities in high-income countries.

- Because of the occurrence of 'social mobility', and the partial dependence of social mobility on a person's health and health-related characteristics, self-selection of people with good health into higher socio-economic groups, and of people with bad health into lower socio-economic groups, is one of the mechanisms generating health inequalities (Macyntire, 1997; Bartley and Plewis, 1997).

- Causal mechanisms, via which a lower socio-economic position leads to worse health by raising the prevalence of specific determinants of morbidity or mortality, also play an important role (Lleras-Muney, 2002; Lager and Torssander, 2012). Research has shown that material, psycho-social, behavioural and health care-related factors all play a role (Marmot, 2003; van Oort et al, 2005). One of the factors that is most consistently found to contribute to the explanation of inequalities in mortality is smoking (Marmot Caavelars et al., 2000; Mackenbach et al., 2004; Kulik et al., 2013).

- Ultimately, however, it is the social forces underlying social stratification which cause health inequalities. The persistence of health inequalities in different time-periods and different national conditions suggests that a high socio-economic status provides "flexible resources", such as knowledge, money, power, and prestige, which can be used to avoid disease risks or to minimize the consequences of disease once it occurs (Link and Phelan, 1995; Mackenbach et al., 2015).

Although, in principle, these considerations apply to health inequalities by education, occupational class and income, the relative importance of the various contributing mechanisms and factors differs between socio-economic indicators.

7. Mortality differences between socio-economic groups have widened considerably in many high-income countries during the last four decades (Mackenbach et al. 2003; Krieger et al., 2008; Shkolnikov et al., 2012). For relative inequalities, i.e. inequalities measured as a ratio of the mortality rates in lower as compared to higher socioeconomic groups, this widening has been observed in all countries with available data. On the other hand, absolute inequalities, i.e. inequalities measured as a difference of the mortality rates comparing lower and higher socioeconomic groups, have shown a more variable picture, declining in some countries and increasing in others. For example, among Finnish men the Rate Ratio comparing the low and high educated increased from 1.97 in the early 1990s to 2.08 in the early 2000s, while the Rate Difference declined from 639 to 564 deaths per 100,000 (Mackenbach et al., 2015). In most Western European countries, the widening of relative inequalities is the result of a difference between socioeconomic groups in the speed of mortality decline. While mortality declined in all socio-economic groups, the decline has been faster, in percentage terms, in the higher socioeconomic groups than in the lower ones. These faster mortality declines in higher socioeconomic groups were in turn mostly due to faster mortality declines for cardiovascular diseases and diseases amenable to medical intervention (Mackenbach et al., 2015). The widening of the gap in death rates has been particularly strong in Central and Eastern Europe, due to a dramatic rise of mortality in lower socioeconomic groups, probably as a result of economic and social developments following the political changes around 1990 (Leinsalu et al., 2009). Reports from the United States indicate that mortality in lower socioeconomic groups may have increased there as well (Krieger et al., 2008; Montez and Zajacova, 2013).

8. The main reason for focusing on level of education (as opposed to occupational class or income level) as indicator of socio-economic position is data availability: the number of countries for which mortality can be differentiated by level of education is substantially larger than the number of countries for

which mortality can be differentiated by occupational class or income level (Mackenbach, 2006). In addition, the level of education has other advantages over other indicators of socioeconomic position. First, it is easier to measure on a routine basis, and usually has less missing values than e.g. income, which in many countries is regarded as a more sensitive variable. Second, education is relevant for both men and women regardless of their employment status, in contrast to occupation which is often difficult to ascertain for the unemployed, students, housewives, retired people and people in unpaid, illegal or voluntary jobs. Third, formal educational attainment is usually completed in early adulthood and remains fixed throughout remaining life; therefore, contrary to other socio-economic indicators such as occupation or income, reverse causality (ill-health leading to low socioeconomic position, instead of vice versa) is likely to be less important (Galobardes, Lynch and Smith, 2007). These advantages often outweigh the main disadvantage of education as an indicator of socioeconomic position: although education is a reasonably good predictor of a person's occupational class and income, at higher ages it gradually loses its discriminatory power with regard to socioeconomic (dis)advantage; this is because access to higher education was considerably lower in older birth cohorts than it is now, and many older people with primary or lower secondary education have obtained middle or even higher socioeconomic positions during their lives.

3. Relating mortality to education: study designs

3.1. Basic data lay-out

9. The minimum data requirements for an analysis of mortality by level of education are illustrated in Table 1. Both data on a numerator (i.e. the number of deaths that have occurred within a given population within a given time-period) and on a denominator (i.e. the total amount of person-time in which these deaths occurred) will be necessary, and both need to be categorized by age (as an important determinant of mortality for which adjustment will need to be made in the analysis); gender (as an important stratifying variable); and level of education. Table 1 illustrates this for total (or all-cause) mortality, but separate columns can be added for deaths from specific causes. If adjustment for other variables than age (e.g., ethnicity) is necessary, or if an analysis stratified by other characteristics than sex (e.g. region) is seen to be desirable, numerator and denominator data must also be categorized by these other variables.

Table 1. Minimum data necessary for analysis of educational inequalities in mortality: Turin, Italy, 2001-2006

Sex	Age group	Education	Number of person years	Number of deaths
…..	……	…..	…..	…..
men	55-59	low	79873	572
men	55-59	middle	37140	189
men	55-59	high	19501	85
women	55-59	low	104905	347
women	55-59	middle	30458	99
women	55-59	high	15486	38
men	60-64	low	86561	956
men	60-64	middle	30112	218
men	60-64	high	15766	85
women	60-64	low	115801	607
women	60-64	middle	24303	118
women	60-64	high	10684	43
men	65-69	low	93462	1621
men	65-69	middle	23752	285
men	65-69	high	11928	125
women	65-69	low	128489	975
women	65-69	middle	18956	136
women	65-69	high	7895	63
…..	…..	…..	…..	…..

Source: DEMETRIQ dataset (www.demetriq.eu).

10. In practice, countries use one of two basic set-ups for obtaining data like those in Table 1: a "cross-sectional census-unlinked design" or a "longitudinal census-linked design". These two approaches are described below.

3.2. Cross-sectional design

11. The "cross-sectional" or "census-unlinked" design is based on independent tabulations of education-specific data from death and census records. This design is called "unlinked" because educational information on the deaths is not obtained through linkage to the census, as in the case of the longitudinal design described in Section 3.3, but from data reported on the death certificate. In this approach, numbers of deaths by sex, age, and educational category are usually aggregated for several (usually two to five) years around the census date. For example, for a census held in the middle of 2001, deaths for 3 years (2000-2002) or five years (1999-2003) around the census date can be aggregated. This implies that the cross-sectional approach uses two different sources of information on people's education. The educational information on the deaths is based on reports by proxy informants, such as relatives or officials, whereas the educational information on the person-years at risk is based on information given by the individual him-/herself. This often leads to a bias in education-specific death rates. In the literature, this bias is called numerator-denominator bias (Smith, Blane and Bartley, 1994). It occurs when the education reported by the individual at the time of the census differs from the information on education provided after his/her death by proxy informants, e.g. because proxy informants are not well informed or are inclined to overestimate the level of education of the deceased (this is sometimes called the "promoting the dead" phenomenon), or because the questions on education on the death certificate are imprecisely formulated.

12. Studies examining the validity of information on education in death records are rare (as they require linkages between death records and individual records in the census or other sources of information on education like household surveys) and often based on relatively small numbers of death certificates. Evidence from these studies is also mixed (Sorlie and Johnson, 1996 ; Rostron, Boies and Arias, 2010). They typically found evidence of both overestimation and underestimation of education in death records and suggest that there may be substantial differences in the direction and magnitude of the bias between countries and over time within one country. Because very few countries have data generated by both the cross-sectional census-unlinked and longitudinal census-linked approach, there is very limited empirical evidence on the actual direction of the bias. One exception is Lithuania, for which both longitudinal and cross-sectional data are available. In a study of educational inequalities in mortality in the years 2001-2004, a significant misreporting of education in death records was found for both males and females, with both overstatement and understatement of education occurring in a substantial number of cases. Even though only three broad educational categories were used in the study, the agreement rates between death and census records ranged from 66-67% for the lowest educational category to 83-84% for the upper secondary educational category (Jasilionis et al., 2009). The reporting bias resulted in an overestimation of mortality in the lowest education group and an underestimation of mortality in the highest education group; as a consequence, inequalities in mortality between low and high educated persons were significantly overestimated in the cross-sectional unlinked data (Table 2). Misreporting of education on death records was more common among the elderly, among women, among non-married people and among urban residents, and was more frequent for external, alcohol-related or ill-defined causes of death. Fortunately, although this reporting bias led to incorrect estimation of the magnitude of inequality, it did not affect the general conclusion of substantially higher mortality in the lower than the higher educational groups (Shkolnikov et al. 2007 ; Jasilionis, Shkolnikov and Andreev, 2009).

Table 2. Differences between a cross-sectional (unlinked) and a longitudinal (linked) design when estimating inequalities in mortality by education, Lithuania around 2000

	Men		Women	
	Age-adjusted mortality rate (unlinked)	Age-adjusted mortality rate (linked)	Age-adjusted mortality rate (unlinked)	Age-adjusted mortality rate (linked)
Educational categories	2000-02	2001-04	2000-02	2001-04
Higher	629	726	254	286
Upper secondary	1312	1359	420	440
Lower than secondary or less	2371	2125	949	802
Rate Difference (low minus high)	1742	1399	695	516
Rate Ratio (low divided by high)	3.77	2.93	3.73	2.80

Source : Jasilionis et al., 2009

13. Despite serious data quality issues, in many countries cross-sectional unlinked data remain the only source of information available about inequalities in mortality. When these data are used, their validity should be carefully assessed by means of sensitivity analyses and plausibility checks. These checks may include a visual inspection of age-specific mortality curves by education group allowing to identify unusual age patterns (such as unexpected mortality declines at old age) or mortality cross-overs (e.g.

mortality in the low education group suddenly becoming lower than in the high education groups). As the evidence from validity studies shows, particular attention should be paid to older age groups as well as to certain causes of death (such as ill-defined or alcohol-related causes). If unusual age-patterns suggest distortions attributable to numerator-denominator bias, several solutions can be applied to (at least partly) diminish the effects of this bias.[1]

3.2. Longitudinal design

14. The optimal way of generating the data in Table 1 is by conducting a longitudinal mortality follow-up after a population census, in which the population has been enumerated and classified by sex, age and level of education. Many countries have regular population censuses that allow a linkage to administrative certificates referring to deaths occurring in the years after the census, e.g. by the use of personal identification numbers. This approach avoids numerator-denominator bias, because the educational information on both the deceased (numerator) and on the person-years at risk (denominator) derive from self-reported information in the census.[2] Not all countries have regular population censuses, but some have alternative ways of collecting information on population composition by level of education, e.g. by regularly conducting surveys among large representative samples of the population (Kulhanova et al., 2014). When the population surveyed can be followed up for mortality, such surveys can also generate the required information. However, because of gaps in population coverage (e.g. institutionalized people are often excluded), survey non-response (e.g. ill people are more likely not to participate) and smaller numbers, the validity and reliability of the information may be less than that of census-linked mortality follow-up studies.

15. Mortality follow-up after a census (or after a survey) requires linkage between the census or survey records and the death registry. The optimal method, which is common in the Nordic countries, is to use unique personal identification numbers. The use of such personal identification numbers can provide high rates of linkage, and makes a false linkage between census records and vital events almost entirely impossible (Shkolnikov et al. 2007). However, not all countries include personal identification numbers in their census and death records, while in other countries statistical offices may confront legal constraints that prevent them from using census information for other uses. In these cases, linkage will then have to be made using other characteristics common to both datasets, e.g. combinations of sex, date of birth, address, family name, etc. Although many such combinations will lead to the identification of a unique person, duplicates may occur, and errors in registering these data will also reduce the reliability of the linkage. There may also be some deaths among people who did not respond to the census, e.g. because they were abroad at that time. If after the linkage has been performed, a substantial number of death records (say, >5%) is left that could not be linked to a corresponding census record, mortality rates will be underestimated, and a correction factor needs to be applied. For instance, in a study of mortality by education in Madrid, linkage to the census was achieved in only 80% of the death records. Therefore, the observed mortality rates were multiplied by a correction factor equal to 1/0.8=1.25). If possible, these correction factors must be broken down by sex and age group.

---

1 First, the most problematic parts of the data may be excluded from the analyses by calculating mortality and inequality measures for narrower age intervals. Omitting data for older ages was shown to reduce the overestimation of mortality difference between the lowest and highest education groups among Lithuanian women (Shkolnikov et al., 2007). Second, education-specific mortality rates at older ages may be corrected by applying well-known mathematical models for age-specific mortality, such as Gompertz-Makeham or logistic models (Thatcher, Kannisto and Vaupel, 1999; Vallin and Caselli, 2006).

2 An even more reliable way of obtaining educational information on deaths and person-years is by linkage to educational registers covering the whole population, but these are only available in a few Nordic countries.

3.4. Computation of person-years at risk

16. While the calculation of the number of deaths is usually straightforward, both in the cross-sectional and longitudinal designs, the calculation of the person-years from which these deaths originate can be complex, particularly in the longitudinal design. In datasets based on a cross-sectional design, the number of person-years can be estimated by multiplying the population size at the census around which the numbers of deaths have been counted (e.g. the census population in 2011, when the deaths considered are those occurring in the 3-year period 2010-2012) by the length of the observation period (3 years, in this example), for each sex, age and educational level. In datasets based on a longitudinal design, the calculation of person-years at risk is more complex because the census only provides the number of people at the beginning of the observation period, and does not directly give us the number of person-years of observation. The number of years during which those present at census were at risk of dying in this case is not necessarily equal to the length of the time-period during which the deaths have been counted, because emigration and mortality gradually remove people from the population at risk.

17. In datasets based on a longitudinal design, the number of person-years at risk can be computed in two ways. The preferred method is to calculate, for each individual and each year of the follow-up period, an individual's contribution of person-time until the end of the year, death or emigration. A simpler and less accurate method is to calculate for each year of the follow-up period the average number of persons alive by age, sex and level of education, as $(P_0 + P_1) / 2$, where P_0 and P_1 refer to the number of subjects alive at, respectively, the beginning and the end of the follow-up year. This simple method assumes that migration and mortality rates are constant over the year. In both methods, the person-years at risk are then aggregated into numbers of person-years by sex, age, and education.

18. Depending on the study-design, one should also consider whether emigration and immigration should be into account when calculating the number of person-years at risk.[3] Unfortunately this information is not available in many countries. This may be an issue in countries with high emigration or immigration rates. In such countries, if emigration is not accounted for, this may lead to an overestimation of the number of person-years at risk and an underestimation of the mortality rates. Conversely, if immigration is not accounted for, this may lead to an underestimation of the number of person-years at risk and to an overestimation of the mortality rates. Sensitivity analyses can be performed to assess the risk of bias.

3.5. Allocating deaths and person-years to an age-band

19. Deaths and person-years at risk should be allocated to a correct age-band for the analysis. In datasets based on a cross-sectional design this is again straightforward, but in datasets based on a longitudinal design this is often more complex, because a considerable amount of time may pass between the census and death. For this type of dataset, there are two possibilities for allocating person-years at risk and deaths to an age-band. The first possibility is to allocate both to the "current" age-band, i.e. the age-band applying at the time of being at risk to death or at the time of dying. For deaths, this implies that they must be classified by age-at-death. For person-years exposed to the risk of dying, a calculation example is given in Box 1. In the rest of the document we will refer to this method as the 'age-at-death' format. This corresponds to the method commonly used in demographic studies, which is based on the Lexis diagram (Preston, Heuveline and Guillot, 2000). When the 'age-at-death' format is used, the results of the analysis

---

3 It should be noted that it is not necessary to account for immigration in datasets based on a census-linked longitudinal design because only people who answered the census at baseline are followed up for mortality. However, in case of substantial immigration the results of the mortality follow-up can no longer be generalized to the total population, and discrepancies may occur between the mortality rates calculated in the census-linked dataset and the mortality rates calculated in official national statistics.

can be interpreted in a straightforward way. For example, when the data apply to the age-range 30-79 years, the results will give us educational inequalities in mortality among people aged 30-79.

Box 2. Example of how to attribute person-years at risk to the correct age-group in a longitudinal census-linked study

Let's consider a population with a census at 1 January 1990 and at 1 January 2000 and mortality follow-up from 1990 until the end of 2000. We are interested in calculating a mortality rate for the period 1 January 1990 to 31 December 2000. For each combination of age, sex and educational level, the number of people exposed to the risk of dying is computed at the time of the census in 1990.

Let's consider 3 situations for the period 1990 – 2000. (The same method would apply to any period). Persons A, B and C are born on 1 January; person D is born on 1 July.

- **Person A is aged 68 at 1990 census and alive at the end of the period, in 2000.** Person A will contribute 2 years of person years to age band 65-69, then 5 years to age band 70-74 and then 3 years to age band 75-79.

- **Person B is aged 68 at 1990 census and dies in 1995, after 5.5 years of follow-up.** Person B dies in 1995 at age 73. The death will be assigned to the age band 70-75. Person B will hence contribute for 2 years of person years to age band 65-69, and for 3.5 years to age band 70-74.

- **Person C is aged 68 at 1990 census and dies in 1991, after 1 year of follow-up.** Person C dies in 1991 at age 69. The death will be assigned to the age band 65-70. Person C will hence contribute to 1 year of person years to age band 65-69.

- **Person D is aged 68 at 1990 census and alive at the end of the period, in 2000.** Person D will contribute 1.5 years of person years to age band 65-69, then 5 years to age band 70-74 and then 3.5 years to age band 75-79.

The table below summarizes how data should be structured for these 3 situations.

	Age band	Number of subject at census 1990	Person years during follow-up	Deaths during follow-up
PERSON A	65-69	1	2	
	70-74		5	
	75-79		3	
PERSON B	65-69	1	2	
	70-74		3.5	1
PERSON C	65-69	1	1	1
PERSON D	65-69	1	1.5	
	70-74		5	
	75-79		3.5	

20. The second possibility for allocating person-years at risk and deaths to an age-band in datasets based on a longitudinal census-linked design is to allocate deaths and person-years at risk of dying to the baseline age-band, i.e. the age as recorded in the census. This method is sometimes inevitable; indeed, in some longitudinal datasets information on age for both person-years and deaths is only available at the baseline date. In this method, person-years are classified according to the age-band that applied at census date, and do not 'grow older' during follow-up. Similarly, if a person dies during the follow-up period, the death will have to be allocated to his/her age-band at baseline date, no matter the age of this person when he/she died. In the rest of the document we will refer to this method as the 'age-at-baseline' format. When

the ‘age-at-baseline’ format is used, the results of the analysis are to be interpreted in terms of mortality inequalities observed in a birth cohort. For example, if the census was held in 2000 and the data apply to the age-range 30-79 years, the results will give us educational inequalities in mortality among people born between 1921 and 1970 (i.e. among people aged 30-79 in the year 2000). Deaths will actually occur in a wider age-range than 30-79; for instance, if the follow-up period is 10 years, deaths and person-years at risk will cover the 30-89 years age-range.

21. In datasets based on a longitudinal census-linked design, the ‘age-at-death’ format is the preferred way of allocating person-years at risk and deaths to an age-band. An advantage of this method is that data from different countries will be comparable even if the length of follow-up differs between countries. Datasets prepared according to the ‘age-at-baseline’ format will not lead to comparable results if the length of follow-up differs between countries, because the age-range covered depends on the length of the follow-up. Also, results based on data in the ‘age-at-death’ format are not directly comparable with results based on data in the ‘age-at-baseline’ format, because the average age of persons in a dataset in the ‘age-at-baseline’ format is lower than that in a dataset in the ‘age-at-death’ format: the longer the follow-up period, the larger the difference. For example, in a dataset with 3 years of follow-up, those recorded as having age 30-34 at baseline are in reality 30-37 years old during follow-up, whereas in a dataset with six years of follow-up they are in reality 30-40 years old during follow-up. In addition, the older the age-band, the larger the difference between the two formats is, since adult death risks exponentially increase with age. An adjustment procedure has been developed that corrects for this ’age-at-baseline bias’ (see below).

4. Data collection: harmonization issues

4.1. Delimitation of study-population

22. Ideally, data should refer to complete national populations. However, some datasets exclude certain subgroups of the population, such as recent immigrants (in the case of population censuses) or the institutionalized population (in the case of surveys). Restrictions of the study population may hamper the generalization of the study results to the whole national population, because excluded groups may differ from the general population in their average mortality risk and/or in the magnitude of their inequalities in mortality. Unfortunately, there is little empirical evidence on the impact of such restrictions. In Switzerland, foreign nationals are excluded from national data on inequalities in mortality by education. A study showed that foreign nationals, as compared to Swiss nationals, had a 15% lower mortality rate on average (Regidor et al., 2001). Because foreign nationals (19% of the Swiss population, in 2014) tend to have a lower educational level than Swiss nationals, their exclusion was estimated to have led to a 2% overestimation of educational inequalities in mortality (Bopp et al., 2014).[4] It is, however, impossible to generalize from this study to other situations, because the impact of restrictions of the study population may vary by country, nature and size of the excluded subgroup, cause of death, etc. When full harmonization is impossible, sensitivity analyses using a reasonable range of assumptions can be conducted to gauge the potential impact of exclusion of a particular subgroup from the analysis.

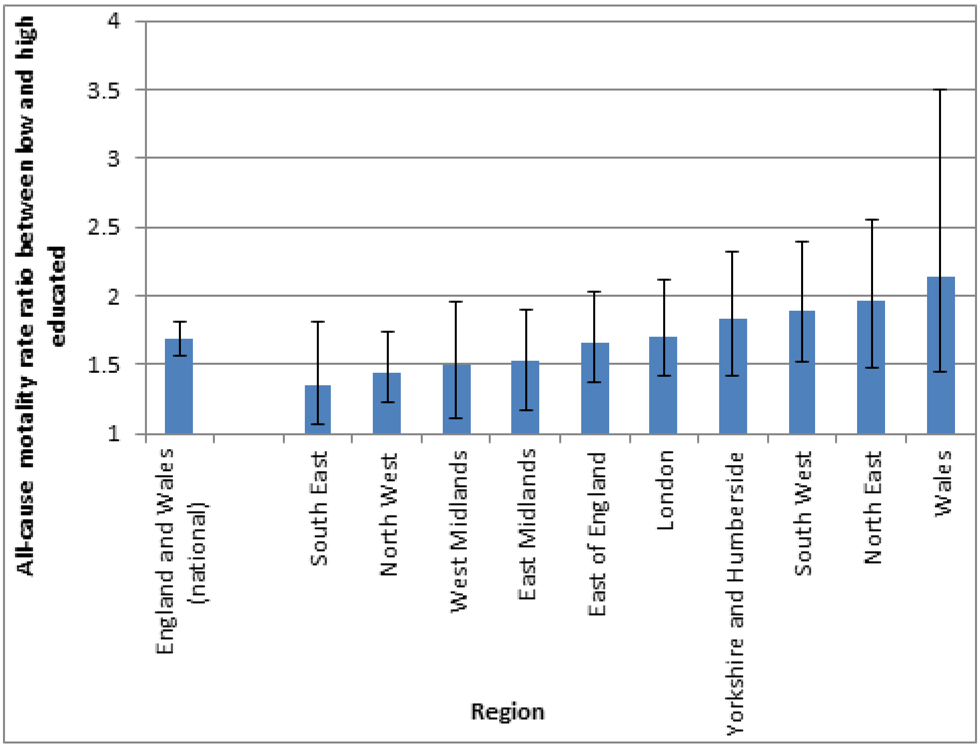
23. Some datasets on mortality by education only cover the population of a specific region, as in the case of Spain (where data used to be available for Madrid, Barcelona and the Basque Country only) and

4 Conservatively assuming that all foreign nationals have a low education, their exclusion from national data could have led to a 2% overestimation of the mortality rate among the low educated in Switzerland. This was calculated by multiplying the mortality rate in Switzerland in 1990-1995 (i.e. 1488/100,000 PYR) by the hazard ratio of all-cause mortality among foreign nationals (i.e. 0.85) and the fraction of foreign nationals in Switzerland (i.e. 19%), and adding this to the mortality rate among low educated multiplied by the fraction of Swiss nationals (i.e. 81%). As a consequence, relative inequalities are also overestimated by 2% (Bopp et al. 2014).

Italy (where good quality data used to be available for Turin and Tuscany only) (Mackenbach et al., 2008).[5] Such restrictions may again hamper the generalization of the study results to the whole national population, because these regions may differ from the national population in their average mortality risk and/or in the magnitude of their inequalities in mortality. Although indirect evidence is available suggesting that there is no substantial bias in these cases (Regidor et al. 2011; Marinacci et al. 2013; Federico et al., 2013), a direct comparison between regional and national data in England and Wales suggests that in England and Wales the magnitude of inequalities in mortality between low and high educated may differ between regions (Figure 2). As full harmonization will be impossible when only data from certain regions are available, sensitivity analyses using a reasonable range of assumptions should be conducted to gauge the potential impact of a particular geographical delimitation on the results of the analysis.

Figure 2. Comparison between inequalities in all-cause mortality in England and Wales at the national level with those observed in various geographic regions within England and Wales, men

Rate ratios



Source: DEMETRIQ dataset (www.demetriq.eu).

4.2. Time

24. As the magnitude of (absolute and relative) inequalities in mortality changes over time, comparisons between countries should preferably be made for the same point in time. For example, many studies have shown that relative inequalities have been and are still widening over time (see Section 2). This implies that, when two countries are being compared with data applying to somewhat different

5 Recently, national data based on mortality follow-up after a census have become available (Marinacci et al., 2013).

periods in time (e.g. 2005 for Country A and 2010 for Country B), it will be difficult to draw firm conclusions about the differences between the two countries in the magnitude of their relative inequalities in mortality (as health inequalities in Country A may have increased when observed in 2010). If this cannot be avoided, it will again be useful to conduct sensitivity analyses using whatever information is available on time-trends in inequalities in mortality to gauge the potential impact of these differences in timing on the results of the analysis.

25. When inequalities change over time, the length of the period over which mortality rates have been measured will also become important. For example, in a longitudinal dataset mortality measured over 10 years after the census will include more recent data than mortality measured during the first 5 years after a census. If inequalities have gone up over time, the 10-year follow-up period will give higher estimates for inequalities in mortality than the 5-year follow-up period. Table 3 illustrates this for the case of Norway. Between 1970 and 1980, the rate ratio measured over a 5-year follow-up period increased from 1.37 to 1.47, and the rate ratio measured over 10 years of follow up was 1.42 (in effect, close to the arithmetic average of the two 5-year periods). Similar differences are seen in the following decades. Therefore, if data from Norway are compared with data from other countries it is important to make sure that data from all countries either come from (the same) 5-year follow-up period, or from (the same) 10-year follow-up period. If this is impossible, sensitivity analyses should be conducted to determine whether differences in follow-up periods may have affected the results of the comparison.

Table 3. Comparison of relative inequalities in mortality by education between a 5- and 10-years follow-up period. Norway, men

Follow-up period	Rate ratio 5 years follow-up	Rate ratio 10 years follow-up
Nov 1970 - Oct 1975	1.37	1.42
Nov 1975 - Dec 1980	1.47	
Nov 1980 - Oct 1985	1.51	1.58
Nov 1985 - Dec 1990	1.65	
Nov 1990 - Oct 1995	1.75	1.88
Nov 1995 - Dec 2001	1.96	
Nov 2001 - Oct 2006	2.09	2.13
Nov 2006 - Dec 2009	2.15	

Source: DEMETRIQ dataset (www.demetriq.eu)

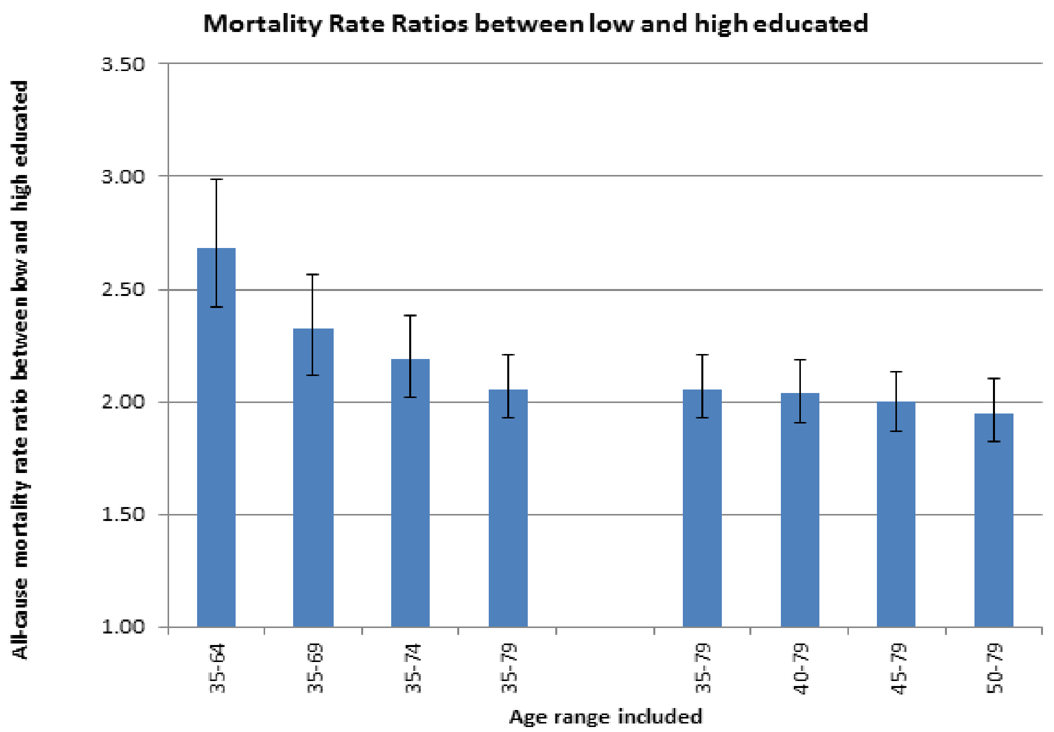
4.3. Age of the person

26. The usefulness of education as an indicator of socioeconomic position depends on a person's age. Due to compulsory schooling laws, most persons before the age of 18 will not have finished their education; similarly, between the age of 18 and 25 (or even 30) many persons may still be enrolled in programmes of (higher) education. After the age of 25 or 30 years, most people's level of education remains fixed throughout remaining life. However, at higher ages education gradually loses its discriminatory power, because older people were born in a time when most people only attended primary

school, and obtaining a higher level of education was very rare. This implies that it is often better to restrict analyses of inequalities in mortality by education to a limited age-range, e.g. 30-75 or 35-79.

27. The age-range chosen will affect the magnitude of inequalities in mortality, because inequalities in mortality differ by age. More specifically, absolute inequalities as measured for example by Rate Differences between educational groups, tend to increase with age, because the average mortality rates increases with age; conversely, relative inequalities as measured for example by Rate Ratios, generally decrease with increasing age (Huisman et al., 2005). For comparative purposes it is therefore important to harmonize the age-range of the populations to be compared. Figure 3 shows the effect of choosing different age-ranges on the magnitude of absolute and relative inequalities in all-cause mortality in the case of Austria. For example, when mortality is restricted to 35-64 years, the Rate Ratio is considerably higher than when mortality covers the wider age-range 35-79 years, which is dominated by the larger number of deaths among older people. Note, however, that patterns of increasing or decreasing inequalities by age may differ by cause of death (Huisman et al., 2005).

Figure 3. Effect of different age-ranges on the magnitude of all-cause mortality by education, Austria in 2001-2002



Source: DEMETRIQ dataset (www.demetriq.eu).

28. In Section 3.5 we mentioned the fact that some datasets based on the longitudinal design follow an 'age-at-baseline' instead of an 'age-at-death' format. When comparisons are made between data collected according to these two different formats, harmonization can be achieved with a specially designed adjustment procedure (Ostergren, Menvielle and Lundberg, 2012). By applying this method to data collected according to the 'age-at-baseline' format, reliable estimates can be calculated that can be compared with estimates based on the other format. Table 4 shows the impact of applying the adjustment procedure. In Sweden, mortality data are available in both classification formats: 'age-at-baseline' and 'age-at-death'. The ratio of mortality rates between the two data formats before adjustment is around 1.3, showing that mortality is relatively overestimated in the 'age-at-baseline' format; after adjustment the ratio

is close to 1.0, showing the efficacy of the adjustment procedure. Measures of inequality (such as the Rate difference and the Rate Ratio) are also affected by the 'age-at-baseline bias', although less strongly than the mortality rates: the Rate Difference is relatively overestimated, and the Rate Ratio relatively underestimated in the 'age-at-baseline' format. The difference between the two formats again disappears when the correction procedure is applied.

Table 4 Age-standardized all-cause mortality rates by educational group in datasets classified according to age at baseline and age at death, before and after correction with the Ostergren method, Sweden, people aged 35-74

			'Age at baseline' classification (A)	'Age at death' classification (B)	Ratio A/B	'Age at baseline' classification, corrected by Ostergren method (A*)	Ratio A*/B
Men	Mortality rate (per 100,000 PYR)	Low	1067.5	847.6	1.3	835.0	1.0
		Mid	852.3	644.0	1.3	635.0	1.0
		High	617.5	445.5	1.4	457.8	1.0
	RD		450.0	402.1	1.1	379.5	0.9
	RR		1.7	1.9	0.9	1.8	0.9
Women	Mortality rate (per 100,000 PYR)	Low	675.6	548.2	1.2	539.4	1.0
		Mid	518.4	395.7	1.3	399.1	1.0
		High	377.8	278.5	1.4	284.3	1.0
	RD		297.9	269.7	1.1	257.3	1.0
	RR		1.8	2.0	0.9	1.9	1.0

Note: Absolute Rate Differences (RD) were calculated by subtracting the standardized mortality rate among the high educated from the standardized mortality rate among the low educated. Relative Rate Ratios (RR) were calculated by dividing the standardized mortality rate among the low educated by the standardized mortality rate among the high educated. The STATA program needed to correct data that are classified according to age at baseline is available from Erasmus MC on request.

Source: DEMETRIQ dataset (www.demetriq.eu)

4.4. Educational categories

29. Educational systems differ significantly between European countries, and may also change substantially over time within a country. In cross-country comparisons of socio-economic inequalities using education as indicator, it is therefore important that educational level is appropriately harmonized. Ideally, the measurement of educational level should be the same in all countries that are analysed. This implies, for instance, that it is always measured in terms of the highest level of education that was *attended* by a person, or the highest level that was *completed* by obtaining a diploma, rather than according to one

criterion in one country and according to the other criterion in another country. The categorization of educational class should also ideally be the same across countries and over time. The International Standard Classification of Education (ISCED) provides a scheme with which reasonably comparable educational categories can be obtained (UNESCO, 1997). The ISCED-97 scheme broadly defines the following levels, and provides guidance on which national school types correspond with these levels:

0 Pre-primary education
1 Primary education or first stage of basic education
2 Lower secondary education or second stage of basic education
3 Upper secondary education
4 Post-secondary non-tertiary education
5 First stage of tertiary education
6 Second stage of tertiary education

30. Because comparability issues are not completely solved by the application of the ISCED-97 scheme to national data on education (Schneider and Kogan, 2008), we recommend to group the ISCED-97 levels into three larger categories that define ‘low’, ‘middle’ and ‘high’ education (for instance by grouping ISCED levels 0, 1 and 2 into ‘low’ education; ISCED levels 3 and 4 into ‘middle’ education; and ISCED levels 5 and 6 into ‘high’ education). Using fewer and broader educational categories will also overcome other problems, such as inaccuracies in assigning people to a more specific category. However, some issues of comparability may still remain, particularly if comparisons over time are being made. An example is England and Wales, where secondary education has only been used as a separate category in census data in recent years, whereas previously it had been grouped with lower levels of education instead. In such cases, it is recommended to perform sensitivity analyses with different categorizations of educational level.

31. The comparability of data on deaths and population numbers by education over time is also likely to be affected by educational reforms, which have occurred in many countries. Educational reforms may change entry requirements, durations, entry ages and examination standards for the different levels of education, which all affect comparability over time. Furthermore, for outdated qualifications, which many senior citizens in many countries continue to use, there may not always be ‘official’ guidelines on how to code them into the ISCED-97 education scheme; in these cases, these older educational categories may have been grouped in a response category with the current qualification they are (officially) considered to be equivalent to, even though the cumulative duration, entry requirement and/or content of studies might vary substantially (Schneider and Kogan, 2008). In several Central and Eastern European countries, for instance, it is uncertain whether persons classified as having completed vocational education in the census should be classified as ISCED 3c or ISCED 2. The ISCED-97 scheme would suggest to classify them as ISCED 3c, thus as ‘middle’ level education, but for older persons, vocational education in many Central and Eastern European countries was part of the compulsory education, suggesting that ‘ISCED 2’ or ‘low’ level of education would be more appropriate. Table 5 shows the impact of classifying vocational education as ‘low’ or as ‘middle’ level on trends in all-cause mortality rates in the case of Hungary. Because the mortality rates of the group with vocational education are relatively low, inequalities between the ‘low’ and ‘high’ educated group are considerably smaller if vocational education is grouped with the ‘low’ than when it is grouped with the ‘middle’ educated. The first option probably gives a more realistic view of inequalities in mortality in Hungary than the second option.

Table 5 Comparison of inequalities in age-standardized all-cause mortality between educational groups classified in two different ways, Hungary, men in 1999-2002

	Vocational education grouped with 'low' education		Vocational education grouped with 'middle' education	
Educational level	ASMR	95% C.I.	ASMR	95% C.I.
Low	2623.7	(2614.2 - 2638.5)	3026.5	(3013.5 - 3044.8)
Middle	1469.5	(1449.4 - 1484.2)	1467.0	(1452.3 - 1483.5)
High	1020.4	(1003.3 - 1033.3)	1020.4	(1005.6 - 1033.9)
Inequality measure				
Absolute rate difference	1603.4	(1585.2 - 1622.2)	2006.1	(1988.6 - 2028.1)
Relative rate ratio	2.6	(2.5 - 2.6)	3.0	(2.9 - 3.0)

ASMR: Age-standardized mortality rate. 95% C.I.: 95% confidence interval.

Source: DEMETRIQ dataset (www.demetriq.eu).

32. A more general issue with regard to comparability of health inequality estimates between countries and over time originates from the expansion of higher education that has occurred over the last half century, with some differences in pace and timing, in all developed countries. As a consequence, both the size and composition of this formerly privileged group has changed dramatically – from a small and highly selective group, to a large and almost universally accessible group. At the same time, the lowest education groups decreased substantially in size and became increasingly selective in terms of cognitive ability and other personal characteristics (Mackenbach, 2010). Such radical changes in composition are likely to affect the comparability of educational inequalities in mortality between countries and over time. For example, some studies for the United States claim that most of the recently observed decline in life expectancy among the low educated is a delayed effect of a change in the forces of selection, i.e. an increased likelihood of less vulnerable people to obtain a higher level of education (Dowd and Hamoudi, 2014). Comparability problems related to changes in educational composition can partly be addressed by using inequality measures accounting for the relative sizes of educational groups (see Section 5.5 below), or by using some standard educational distributions (Meara, Richards and Cutler, 2008). None of these adjustments provide, however, a fully satisfactory solution. Therefore, when educational distributions are very different between countries or over time, the results of analyses should be interpreted with caution.

4.5. Cause of death

33. Four causes of death are generally mentioned on death certificates: (i) the immediate cause of death; (ii) the intermediate causes of death; (iii) the underlying cause of death; and (iv) any other diseases and disorders the person had at the time of death, even though they did not directly cause the death. Analyses of health inequalities usually focus on the underlying cause of death, and this is coded according to the International Classification of Diseases (ICD). This classification is regularly revised, and most countries now use the 10th revision. When a new version of the classification is released, discrepancies in coding practices may occur between the old and the new version, and the magnitude of these discrepancies may differ by country. When the study period covers several ICD classifications, the possible impact of the change in ICD version on the inequalities observed should be carefully assessed on a case-by-case basis. For some countries, empirical data are available on the impact of changes in some recent ICD revisions, e.g. obtained with dual coding (Rey et al., 2011) The results of these studies may, together with empirical information on trend breaks, be used to adjust mortality data and to obtain unbiased estimates of cause-specific mortality trends (Rey et al., 2011) .

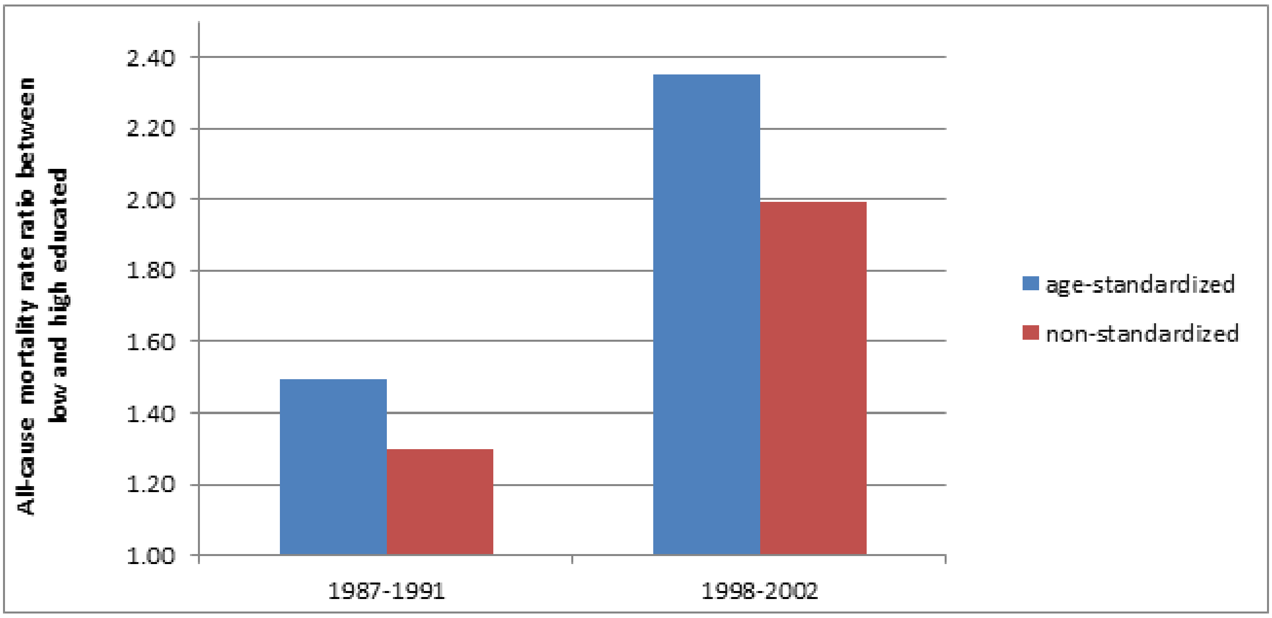
34. Despite the use of common coding procedures, classification of mortality by cause of death may still differ between countries due to differences in diagnostic and death certification practices. Some causes of death (e.g., Chronic Obstructive Pulmonary Disease (COPD) or ischemic heart disease) are more prone to misclassification than others (e.g. cancer) (Gittelsohn and Senning, 1979; Mackenbach, Van Duyne and Kelson, 1987). There is no clear evidence suggesting that certification practices differ by socio-economic group (Kulhanova et al., 2014). However, even without such differences estimates of absolute inequalities in mortality may still be affected by between-country differences in certification and coding of causes of death. Because misclassification is most likely to happen within, and not between, broad categories of causes of death, the scope for bias can be reduced by limiting the analysis to a few broad cause-of-death groups, such as cardiovascular disease, cancer, other diseases, and external causes (injuries). However, this comes at a price: broad groups are heterogeneous with regard to risk factors, and the interpretation of the results in terms of explanatory factors will be more complex.

5. Data analysis

5.1. Age-adjustment of mortality rates

35. Because mortality is strongly dependent on age, and because lower and higher educational groups usually have rather different age compositions, age is an important potential confounder of the relation between education and mortality. Age adjustment of mortality is therefore necessary. This can be accomplished either by regression analysis (e.g. by fitting a Poisson regression model with deaths as dependent variable, person-years at risk as offset variable, and age and education as independent variables) or by calculating age-standardized death rates. In the latter case, the choice is between indirect and direct standardization. Direct standardization is generally recommended, because this allows unbiased comparisons across educational groups, sexes, countries, etc. (Julious et al., 2001) Direct standardization involves the use of a common 'standard population' with a fixed composition by age, and application of the age-specific mortality rates of the populations to be compared to this standard population. For analyses of data from high income European countries, the European standard population can be used (Ahmad et al., 2001) (http://www.euphix.org/object_document/o5338n27620.html). Figure 5 shows the effect of age standardization on the magnitude of inequalities in mortality in the case of Estonia. Because the low educated group is relatively old, and the high educated group relatively young, the effect of age-standardization is to decrease the magnitude of inequalities in mortality between both groups.

Figure 3. Comparison of relative inequalities in mortality as estimated on the basis of crude (non-standardized) mortality rates and of age-standardized mortality rates, Estonia in 1987-1991 and 1998-2002, men



Note: Age-standardisation is performed by weighting age-specific mortality rates for each population with common weights derived from the European standard population.

Source: DEMETRIQ dataset (www.demetriq.eu).

36. In order to enable appropriate age-standardization, mortality data should ideally be provided in 5-year age-bands, e.g. 30-34, 35-39 etc. If the mortality data include the oldest age-group (e.g. 85+, 95+, …), this will usually be open-ended, but because remaining life expectancy differs between educational groups, countries etc., the age distribution of mortality within the oldest age group will also differ. As it is difficult to correct for this by age-standardization, it is recommended to exclude the last open-ended age category from the analyses.

5.2. Calculation of life expectancy by educational categories

37. In communications with a non-expert audience it is often preferable to present measures of both inequalities in mortality rates and inequalities in life expectancy. Life expectancy is the average number of remaining years lived after a particular age, which a group of people (usually a cohort of people with the same starting age, e.g. a birth cohort) can expect to live if currently observed age-specific mortality rates persist throughout their entire lives. This so-called 'period life expectancy' provides a cross-sectional measure of mortality and survival of a population at a particular point or period of time (Chiang, 1984). Life expectancy can be compared between different points in time or between different population groups, even if they differ in age composition. It should be noted that 'period life expectancy' may differ substantially from 'cohort life expectancy', i.e. the actual survival of a real cohort of people who were born at this point in time and are followed throughout their entire life (Vallin and Caselli, 2006). Educational inequalities in life expectancy at birth often amount to between 5 and 10 years (Bronnum-Hansen and Baadsgaard, 2012; Deboosere et al. 2009; Palosuo et al., 2012; Steingrimdottir et al., 2012)

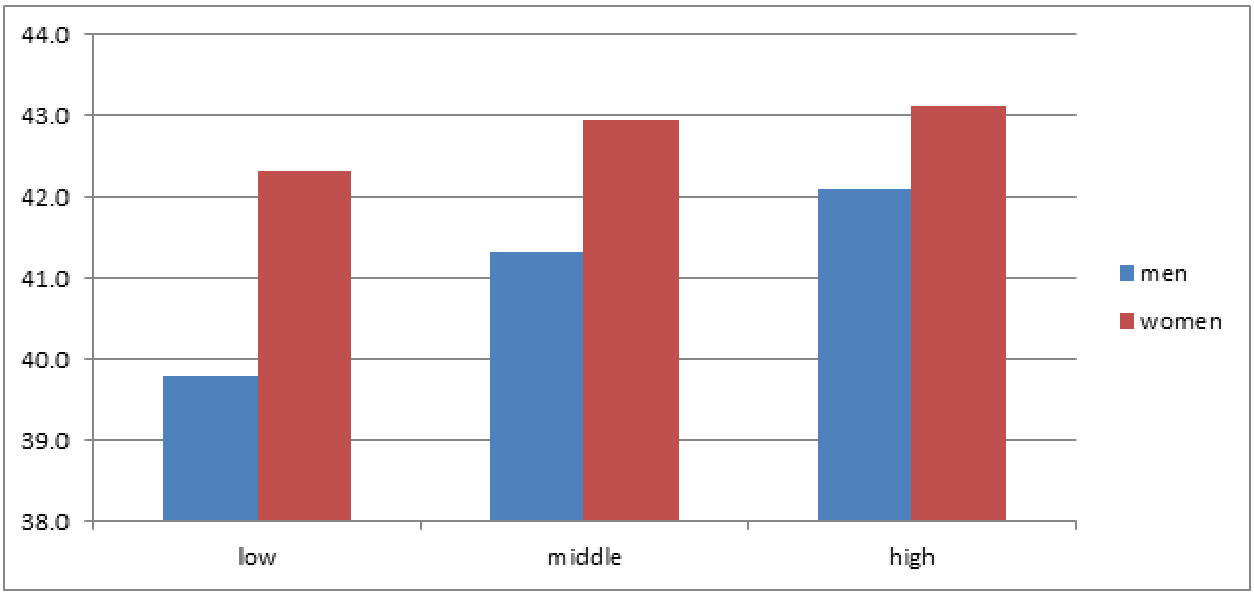
38. Life expectancy is calculated in a so-called life table. Life tables can be complete or abridged. In a complete life table, all measures are estimated for each single year of life, whereas in an abridged life table all measures are calculated for age intervals greater than one year (except the first year of life)

(Chiang, 1984). The most commonly used set of age intervals is 0, 1-4, 5-9, 10-14, …, 80-84, 85+. Note that the same age intervals must be used for the populations and/or time points being compared. Because of the small number of deaths in each age- and educational group, it will usually be better to use abridged life tables. The starting point in constructing a life table is to calculate age-specific death rates from age-specific numbers of deaths and person-years for the selected point or period of time (see above). In our case, we will need separate life tables for each educational group (and each sex). Guidelines for estimation of life tables can be found in the literature (Preston et al., 2000; Chiang, 1984; Wilmoth et al., 2007).

39. As noted above, analyses of mortality by education will often have to be limited to the age group 30-74 or 30-79 years. In this case, 'partial life expectancy' can be calculated, indicating the average number of years lived between two specific ages, e.g. between a person's 30^{th} and 75^{th} birthday, or between a person's 30^{th} and 80^{th} birthday. While the maximum number of years lived between these two ages is 45 and 50, respectively, the average number of years actually lived will be smaller due to mortality. This is shown in Figure 6 for 'low', 'middle' and 'high' educated people in Turin (Italy). As mentioned above, this is a population with rather small inequalities in mortality. High educated women can expect to live 43 years (out of the maximum of 45 years) between the ages of 35 and 79 years, whereas low educated women can expect to live 42 years – a difference of 1 year. Among men, the difference in partial life expectancy between low and high educated is a little more than 2 years. In other European countries, inequalities in partial life expectancy between education groups are often considerably larger (Martikainen et al., 2014; Tarkiainen et al., 2012). Life expectancy measures such as these often provide a more intuitive measure of inequalities in mortality than measures based on a comparison of mortality rates, like the Rate Ratio and Rate Difference.

Figure 4. Partial life expectancy between the ages of 35 and 79 years by sex and education, Turin, Italy in 2006-2010

Years



Source: DEMETRIQ dataset (www.demetriq.eu).

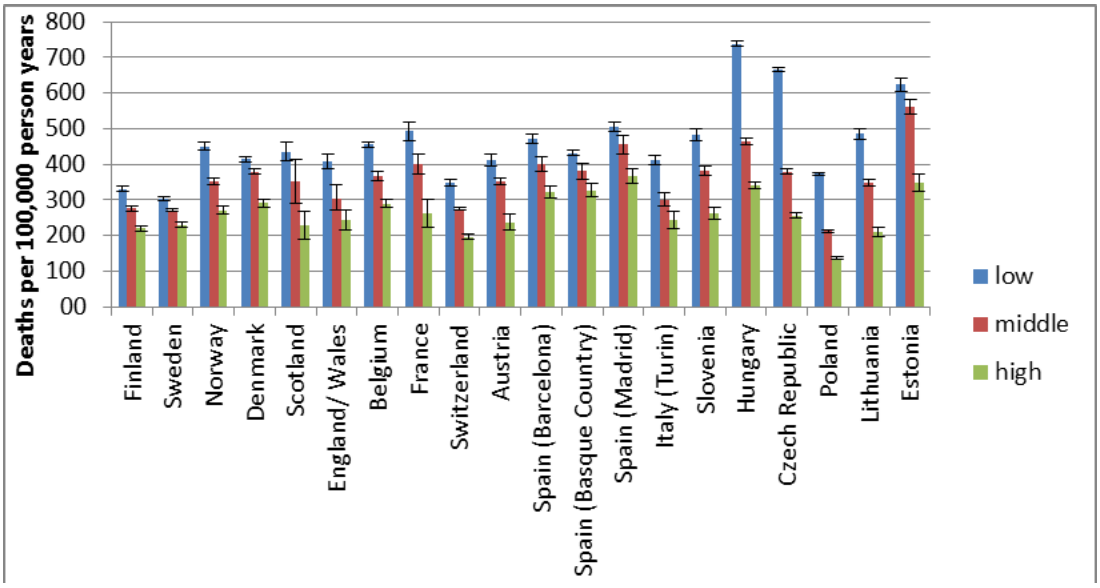
40. In addition to measures of (partial) life expectancy, life tables can provide several other useful measures of mortality and survival, such as measures of variation in age at death. Several measures of variation in age at death have been proposed, including the Gini and Theil coefficients and e-dagger (van Raalte and Caswell, 2013). If such measures are calculated within a life table, rather than on the basis of

the directly observed ages at death of individuals dying in a particular population in a particular year, they are independent of the age-distribution of the population and can validly be compared between populations, e.g. between educational groups. Variation in age at death is usually much larger for the low than for the high educated, because “premature” mortality (i.e. mortality at younger ages) has much more successfully been eliminated among the high than among the low educated (van Raalte et al., 2011). Life tables can also be used to decompose differences between two (partial) life expectancies into the contributions of specific age-groups or causes of death (Arriaga, 1984). This can be useful to identify the causes of death that make the largest contribution to inequalities in (partial) life expectancy between educational groups, and that therefore represent priorities for policies and interventions to reduce these inequalities (Kulhanova et al., 2014).

5.3. Confidence intervals

41. Observations on the number of deaths occurring in a population are always subject to random variations. This is not only the case when the observations are drawn from a sample of the population, but also when deaths occurring in a complete population have been counted. Some argue that there is no statistical uncertainty in estimates derived from ‘population’ statistics such as the mortality rate in a given national population. However, the occurrence of death is always determined by random processes. Even when all biological, environmental, genetic and other determinants of disease and mortality are the same, two comparable individuals may die at different time points because of this random variation. Similarly, mortality rates of whole populations will vary from year to year even if the underlying conditions remain the same (Brillinger, 1986; Harper, 2008). Confidence intervals can be used whenever there is a need to describe this uncertainty. Confidence intervals describe how much different the point estimate could have been if the underlying conditions stayed the same, but chance had led to a different set of data. Confidence intervals are calculated with a stated probability, often 95%, and in this case we say that there is a 95% chance that the confidence interval covers the true value (Health, 2012). Figure 5 shows the estimated uncertainty in cancer mortality by educational level in various European countries.

Figure 5. Age-adjusted cancer mortality rates and 95% confidence intervals among men in 20 European populations by educational level



Source: DEMETRIQ dataset (www.demetriq.eu).

42. Whether or not differences in mortality between education groups within a population may be due to random variation can be assessed by comparing the confidence intervals around the group estimates. When the 95% confidence intervals around the mortality rates of two education groups do not overlap, as in almost all cases in Figure 7, it is highly unlikely that the difference between the two groups is due to random variation. However, for determining the statistical significance of the difference a proper test should be conducted. Comparing confidence intervals is a conservative 'test', because in some cases a statistical test would indicate a statistically significant difference even though the confidence intervals do overlap, falsely implying no significant difference. This may be the case for the comparison of low and mid educated in Scotland in Figure 7. However, if two confidence intervals do not overlap, a comparable statistical test would always indicate a statistically significant difference (Health, 2012). Methods for calculating confidence intervals of age-standardized mortality rates (Morris and Gardner, 1988)and for calculating confidence intervals of life expectancies (Chiang, 1984)have been described in the literature.

5.4. Relative versus absolute inequalities

43. After rates of mortality by educational groups have been created and carefully inspected, one or more measures for the magnitude of inequalities in mortality rates be education can be calculated. A wide variety of summary measures for the magnitude of socio-economic inequalities in mortality has been proposed and applied in research (Mackenbach and Kunst, 1997), and it is beyond the scope of this paper to provide an overview of these measures and their pros and cons. This section will, however, briefly address two crucial issues: (i) the distinction between relative and absolute inequalities; and (ii) the distinction between measures that do and that do not take into account the size of the educational groups involved.

44. As mentioned in Section 2, inequalities in mortality between educational groups can be quantified on a relative scale (e.g. as a ratio of the mortality rates among the lower educated as compared to that among the higher educated) and on an absolute scale (e.g. as a difference of the mortality rates among the lower educated as compared to that among the higher educated). Analyses based on relative and absolute measures may lead to opposing conclusions, e.g. educational inequalities in mortality as measured on an absolute scale often tend to go down, whereas relative inequalities tend to go up. This is illustrated in Table 6, which shows that between 1990-95 and 2005-08 among Swiss men the Rate Ratio of mortality comparing the low and high educated increased from 1.90 to 2.07, whereas the Rate Difference declines from 676 to 580 deaths per 100,000 person-years. This is due to the fact that mortality declines expressed in relative (e.g. percentage) terms often are larger among the high educated, whereas mortality declines expressed in absolute terms (e.g., deaths per 100,000) are sometimes larger among the low educated (Mackenbach et al. 2015).

45. There is no agreement among researchers or policy-makers on which type of measure to prefer (Mackencbach, 2015). Some of the arguments against relative inequalities are mathematical. One problem with relative measures is that when ratios of mortality rates go up, ratios of the reverse outcome (survival) will go down, and vice versa, leading to diametrically opposed conclusions[6]. At the same time, there are also mathematical arguments against absolute measures of inequality. For example, when overall mortality levels fall, absolute inequalities in mortality will fall as well, without any changes in the socio-economic distribution of risk or protective factors for mortality among people with different characteristics (Mackencbach, 2015).

6 This can easily be seen in the following example. Suppose that in country X the mortality rate declines from 100 to 50 deaths per 100,000 among the rich, and from 200 to 120 deaths per 100,000 among the poor. In this case, the Rate Ratio of mortality will increase from 2.0 (200/100) to 2.4 (120/50), while the Rate Ratio of survival will decrease from 1.12 (900/800) to 1.08 (950/880).

46. Determining whether inequalities are increasing or decreasing is, however, a matter of ethics as well as mathematics. Using the ratios of mortality rates implies a strictly egalitarian position, in which what matters is equality in itself, independent of other considerations such as the absolute prevalence of disease for each group. Using the differences in mortality rates implies the more pragmatic view that absolute rates matter most for people in lower socio-economic groups, and that a smaller absolute mortality excess is to be preferred even if it goes together with a larger relative mortality excess (Harper, 2010). We therefore recommend using measures of both relative and absolute inequalities in mortality.

Table 6 All-cause mortality rates, absolute and relative inequalities: simple and complex measures of inequalities

Level of education		1990-2000				2000-2008		
			95% confidence interval				95% confidence interval	
low	*% of total population*	*21.80 %*				*16.5%*		
	Age-standardized mortality rate	**1424.4**	(1411.1 -	1440.9)		**1121.3**	(1105.0 -	1134.0)
middle	*% of total population*	*55.0%*				*52.6%*		
	Age-standardized mortality rate	**1014.7**	(1008.4 -	1021.0)		**766.8**	(759.9 -	772.5)
high	*% of total population*	*23.2%*				*30.9%*		
	Age-standardized mortality rate	**748.7**	(738.9 -	758.6)		**541.4**	(532.4 -	547.6)
Inequality measure	Rate Difference (RD)	**675.7**	(655.6 -	693.8)		**579.9**	(560.6 -	597.2)
	Slope Index of Inequality (SII)	**761.5**	(741.6 -	784.2)		**684.1**	(668.6 -	701.5)
	Rate Ratio (RR)	**1.90**	(1.86 -	1.94)		**2.07**	(2.03 -	2.12)
	Relative Index of Inequality (RII)	**2.14**	(2.10 -	2.18)		**2.49**	(2.42 -	2.55)

Source: DEMETRIQ dataset (www.demetriq.eu).

5.5. Accounting for differences in the size of educational groups

47. Ratios and differences of mortality rates by education are simple measures that are easy to understand, but they ignore important aspects of the data that one may also want to take into account, such as the levels of mortality of the intermediate educational group(s) and the size of the educational groups that are compared. Some analysts have argued that the same ratio or difference in mortality rates should be of much more concern to policy-makers if the groups with lower education make up a large fraction of the population, than if they are a tiny minority. This is not a trivial matter, because the educational composition of populations can vary substantially between populations and over time. For example, in Table 6 above, the size of the group of lower educated men in Switzerland decreased by 5 percentage points between the 1990s and the 2000s. This implies that in the more recent time-period the higher mortality rates among the lower educated affected a smaller proportion of the population, suggesting that the increase of the ratio of mortality rates is less serious than it would seem to be at first sight.

48. Various measures have been proposed to deal with this issue. Examples are the Concentration Index, the Average Inter-group Difference, and the Relative and Slope Indices of Inequality. As an example, we illustrate here the latter measures. The Relative Index of Inequality (RII) and Slope Index of Inequality (SII) take into account the size of educational groups by regressing the mortality rate of educational groups on the proportion of the population that has a higher position in the social hierarchy. This ensures that, when the lowest or highest educational groups are smaller, they are given a value closer to 1.0 or 0.0, respectively, corresponding to the more extreme position in the social hierarchy that their smaller numbers imply The resulting estimate can be interpreted as the (relative) ratio (in the case of the RII) or (absolute) difference (in the case of the SII) of the mortality rates of those with the very lowest education compared with those with the very highest education. In the example in Table 6, the RII is clearly larger than the RR (and the SII is larger than the RD), due to the fact that the RII and SII quantify the estimated differences in mortality between the individual with the very lowest and the individual with

the very highest educational position, whereas the RR and RD quantify the differences in mortality between whole groups which are somewhat heterogeneous in their mortality risks. Table 6 also shows that the RIIs increase over time like the RRs, but that the increase is somewhat stronger.[7] This is due to the fact that the RII makes an adjustment for the fact that the educational distribution of the population has become slightly more homogeneous over time.[8] Guidelines for the calculation and interpretation of the RII and SII can be found in the literature (Mackencbach, 1997; Moreno-Betancourt et al. 2015; Hayes, 2002).

6. Summary and conclusions

49. Comparative data on health inequalities based on people's socio-economic characteristics are rare and seldom compiled regularly, so as to allow monitoring trends over time. This unsatisfactory situation prevails despite the great attention paid to inequalities on income and wealth, the efforts in some countries to put this issue on the policy agenda, and the common perceptions that 'we are all equal in the face of death'. This paper has described the main methodological issues to be confronted when compiling, gathering and disseminating country-level estimates of educational inequalities in mortality. Based on this review, a number of recommendations can be provided to data-analysts who want to study and compare inequalities in mortality by education. Following on the structure of this paper, these recommendations can be grouped under the three headings on 'study design', 'data collection' and 'data analysis'.

6.1. Study designs: relating mortality to education

a) When relating mortality to education, preferably use a longitudinal census-linked design. When a longitudinal survey-linked design is used, users should clearly identify the population who participated to the survey, and assess (when feasible) the possible bias due to incomplete coverage of the target population.

b) When only a cross-sectional unlinked design is feasible, users should be aware of the risk of numerator-denominator bias, and assess (when feasible) the possible magnitude and direction of this bias. Simple plausibility checks such as visual inspection of age-specific patterns of education-specific mortality estimates can help to detect possible biases in the data; the bias can be reduced by excluding problematic parts of the data (e.g. excluding data for old ages) or by replacing problematic data by adjusted modelling-based data.

c) When linking death records to census or survey records, users should be aware of the possibility of failure in linkage and (when feasible) identify the failure rates (i.e. percentage of unlinked death records). If the share of unlinked of deaths is substantial, a correction factor should be used.

d) For calculating person-years at risk in longitudinal datasets, it is necessary to estimate the numbers of person-years lived during the follow-up by the group enumerated at the census. Person-years should be counted for each person at the census until the end of the follow-up, date of death or date of emigration (if information about emigration is available).

---

7 The increase in the relative excess mortality among the low educated is 100*(2.07-1.90)/(1.90-1.00)=19% for the RR, and 100*(2.49-2.14)/(2.14-1.00)=31% for the RII.

8 The share of low educated people declines by 5.3 percentage points, and the share of high educated people increases by 7.7 percentage points. This indicates that while the group of low educated becomes a bit more "extreme" in terms of its social position, the group of high educated becomes somewhat more less "extreme". The Rate Ratio does not adjust for this change in relative position (which, if nothing else changes, should in itself contribute to a slight narrowing of inequalities in mortality), and therefore underestimates the increase of inequalities in mortality.

e) In longitudinal datasets, allocation of deaths and person-years to an age-band should preferably be done using an ‘age-at-death’ format. If only an ‘age-at-baseline’ format is available, an appropriate adjustment procedure should be applied.

6.2. Data collection: harmonization issues

f) For cross-country comparisons, data for complete national populations (with no exclusions) should be used; when exclusions are inevitable, sensitivity analyses should be performed. Ideally, the same time-periods, length of follow-up, and age-limits (e.g. 30-74) should be used for all countries. Differences in study design and coverage applicable for certain countries should be clearly indicated.

g) The ISCED scheme should be used for classifying education. In case of comparability problems, analysis should be restricted to a few broad educational groups only. When comparing educational inequalities in mortality between countries and over time, the possible impact of changes in educational distribution and in underlying selection factors should be considered.

h) Broad and meaningful groups of causes of death should be used. Data should be checked for differences and/or changes in certification and coding of causes of death, with adjustments made when needed.

6.3. Data analysis: quantifying inequalities in mortality

i) In order to take into account differences in age composition of different education groups and ensure international comparability of the results, education-specific mortality rates should be calculated using the direct age-standardization method employing internationally recognized standards such as the WHO Standard European Population. When calculating regression-based mortality rate ratios, statistical models should always include age as a control variable.

j) Both relative (e.g. mortality rate ratios) and absolute (e.g. mortality rate differences) measures of inequality should be used. Absolute measures provide important information about the public health importance of the observed differentials.

k) In addition to simple range-type measures (e.g. mortality rate ratios and mortality rate differences), more complex measures that take into account the population size of each educational group should be used (e.g. Relative Index of Inequality (RII) or Slope Index of Inequality (SII)). These measures allow to partly overcome the comparability problems related to differences and changes in the educational composition of populations.

l) In addition to measures of mortality, education-specific life expectancies and partial life expectancies should be calculated. These provide important insights in the consequences of observed mortality differentials in terms of the differentials in survival and length of life.

m) Confidence intervals or similar measures of statistical uncertainty should be provided for all measures of mortality.

50. Consistent implementation of these recommendations would go a long way towards improving the comparative basis of available information on health inequalities. The goal pursued with this paper is to encourage more analysts and statistical offices to engage in this measurement field, and international organisations such as the OECD to more systematically collect and report on such data.

REFERENCES

Ahmad O., C. Boschi-Pinto, A. Lopez, C. Murray, R. Lozano et al. (2001), "Age Standardization of Rates: A New WHO Standard", *GPE Discussion Paper Series,* No. 31, World Health Organization.

Arriaga E.E. (1984), "Measuring and explaining the change in life expectancies", *Demography* No. 21, pp. 83-96.

Bartley M.and I. Plewis (1997), "Does health-selective mobility account for socioeconomic differences in health? Evidence from England and Wales, 1971 to 1991", *Journal Health Social Behaviour* No. 38 pp. 376-386.

Bauld L., P. Day and K. Judge (2008), "Off target: a critical review of setting goals for reducing health inequalities in the United Kingdom", *International Journal of Health Services: Planning, Administration, Evaluation,* 38(3), pp. 439-454. Epub 2008/08/30.

Bopp M., J. Braun and D. Faeh, “Swiss National Cohort Study G (2014), "Variation in mortality patterns among the general population, study participants, and different types of nonparticipants: evidence from 25 years of follow-up", *American Journal of Epidemiology* No 180, pp. 1028-1035.

Brillinger D.R. (1986), "The natural variability of vital rates and associated statistics", *Biometrics* No 42, pp. 693-734.

Bronnum-Hansen H. and M. Baadsgaard (2012), "Widening social inequality in life expectancy in Denmark. A register-based study on social composition and mortality trends for the Danish population", *BMC Public Health* No12, p. 994, Epub 2012/11/20.

Cavelaars A.E., A.E. Kunst, J.J. Geurts, R. Crialesi, L. Grotvedt, et al. (2000), "Educational differences in smoking: international comparison", *British Medical Journal* No 320, pp. 1102-1107.

Chiang C.L. (1984), *The life table and its applications*, Malabar (USA): Robert E. Krieger Publ. Co.

Commission on Social Determinants of Health (2008), *Closing the Gap in a Generation. Health Equity through the Social Determinants of Health,* World Health Organization, Geneva.

Deboosere P., S. Gadeyne. and H. Van Oyen (2009), "The 1991–2004 Evolution in Life Expectancy by Educational Level in Belgium Based on Linked Census and Population Register Data", *European Journal of Population* No 25, pp. 175-196.

Dowd J.B. and A. Hamoudi (2014), "Is life expectancy really falling for groups of low socio-economic status? Lagged selection bias and artefactual trends in mortality", *International Journal Epidemiology* No 43, pp. 983-988.

Federico B., J. P. Mackenbach., T.A. Eikemo, G. Sebastiani, C. Marinacci, et al. (2013), "Educational inequalities in mortality in northern, mid and southern Italy and the contribution of smoking", *Journal Epidemiology Community Health* No 67, pp.603-609.

Galobardes B.,J. Lynch and G.D. Smith (2007), "Measuring socioeconomic position in health research", *British Medical Bulletin* No 81-82, pp. 21-37.

Gittelsohn A. and J. Senning (1979), "Studies on the reliability of vital and health records: I. Comparison of cause of death and hospital record diagnoses", *American Journal Public Health* No 69, pp. 680-689.

Harper S., N.B. King, S.C. M.E. Meersman, Reichman, N. Breen, et al. (2010), "Implicit value judgments in the measurement of health inequalities", *Milbank Q* No 88, pp. 4-29.

Harper S., J. Lynch, S.C. Meersman, N. Breen, W.W. Davis, et al. (2008), "An overview of methods for monitoring social disparities in cancer with an example using trends in lung cancer incidence by area-socioeconomic position and race-ethnicity, 1992-2004", *American Journal Epidemiology* No 167, pp. 889-899.

Hayes L.J. and G. Berry (2002), "Sampling variability of the Kunst-Mackenbach relative index of inequality", *Journal Epidemiology Community Health,* No 56, pp. 762-765.

Health WSDo (2012), *Guidelines for Using Confidence Intervals for Public Health Assessment*, Washington State Department of Health, Seattle.

Huisman M., A.E. Kunst, M. Bopp, J.K. Borgan, C. Borrell, et al. (2005), "Educational inequalities in cause-specific mortality in middle-aged and older men and women in eight western European populations", *Lancet*, No 365, pp. 493-500.

Jasilionis D., V.M. Shkolnikov and E.M. Andreev (2009), "Commentary: The study by Leinsalu et al. on mortality differentials in Eastern Europe highlights the need for better data", *International .Journal Epidemiology* No 38, pp. 525-527.

Julious S.A., J. Nicholl and S. George (2001), "Why do we continue to use standardized mortality ratios for small area comparisons", *Journal Public Health Medicine,* No 23, pp. 40-46.

Krieger N., D.H. Rehkopf, J.T. Chen, P.D. Waterman, E. Marcelli, et al. (2008), "The fall and rise of US inequities in premature mortality: 1960-2002", *PLoS Medicine* No 5: e46.

Kulhanova I., R. Hoffmann, T.A. Eikemo, G. Menvielle. and J.P. Mackenbach (2014), "Educational inequalities in mortality by cause of death: first national data for the Netherlands", *International Journal Public Health* No 59, pp. 687-696.

Kulhanova I., G. Menvielle., M. Bopp, C. Borrell, P. Deboosere et al. (2014), "Socioeconomic differences in the use of ill-defined causes of death in 16 European countries", *BMC Public Health*, No 14, pp. 1295.

Kulik M.C., R. Hoffmann, K. Judge, C. Looman, G. Menvielle, et al. (2013), "Smoking and the potential for reduction of inequalities in mortality in Europe", *European Journal Epidemiology* No 28, pp. 959-971.

Lager A.C. and J. Torssander (2012), "Causal effect of education on mortality in a quasi-experiment on 1.2 million Swedes", *Proceedings of the National Academy of Science USA,* No 109, pp. 8461-8466.

Leinsalu M., I. Stirbu, D. Vagero, R. Kalediene, K. Kovacs, et al. (2009), "Educational inequalities in mortality in four Eastern European countries: divergence in trends during the post-communist transition from 1990 to 2000", *International Journal Epidemiology* No 38, pp.512-525.

Link B.G. and J. Phelan (1995), "Social conditions as fundamental causes of disease", *Journal Health Social Behaviour*, Spec No, pp. 80-94.

Lleras-Muney A. (2002), *The relationship between education and adult mortality in the United States*, National Bureau of Economic Research, Cambridge.

Macintyre S. (1997), "The Black Report and beyond: what are the issues?", *Social Science & Medicine*, No 44, pp. 723-745.

Mackenbach JP (2006), *Health inequalities. Europe in profile*, Department of Health, London.

Mackenbach J.P. (2010) "New trends in health inequalities research: now it's personal", *Lancet*, No 376, pp. 854-855.

Mackenbach J.P. (2012), "The persistence of health inequalities in modern welfare states: the explanation of a paradox", *Social Science & Medicine*, No 75, pp. 761-769.

Mackenbach J.P. (2015), "Should we aim to reduce relative or absolute inequalities in mortality?", *European Journal Public Health*, No 25, p. 185.

Mackenbach J.P., V. Bos, O. Andersen, M. Cardano, G. Costa, et al. (2003), "Widening socioeconomic inequalities in mortality in six Western European countries", *International Journal Epidemiology*, No 32, pp. 830-837.

Mackenbach J.P., M. Huisman, O. Andersen, M. Bopp, J.K. Borgan, et al. (2004), "Inequalities in lung cancer mortality by the educational level in 10 European populations", *European Journal Cancer*, No 40, pp. 126-135.

Mackenbach J.P., I. Kulhanova, M. Bopp, P. Deboosere, T.A. Eikemo, et al. (2015), "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*, No 127, pp. 51-62.

Mackenbach J.P., I. Kulhanova, G. Menvielle, M. Bopp, C. Borrell, et al. (2015), "Trends in inequalities in premature mortality: a study of 3.2 million deaths in 13 European countries", *Journal Epidemiology Community Health*, No 69, pp. 207-217; discussion 205-206.

Mackenbach J.P. and A.E., Kunst (1997), "Measuring the magnitude of socio-economic inequalities in health: an overview of available measures illustrated with two examples from Europe", *Social Science & Medicine*, No 44, pp. 757-771.

Mackenbach J.P., A.E. Kunst, A.E. Cavelaars, F. Groenhof and J.J. Geurts (1997), "Socioeconomic inequalities in morbidity and mortality in Western Europe. The EU Working Group on Socioeconomic Inequalities in Health", *Lancet*, No 349, pp. 1655-1659.

Mackenbach J.P., W.J. Meerding and A. E. Kunst (2011)," Economic costs of health inequalities in the European Union", *Journal Epidemiology Community Health*, No 65, pp. 412-419.

Mackenbach J.P., I. Stirbu., A. J. Roskam, M.M. Schaap, G. Menvielle, et al. (2008), "Socioeconomic inequalities in health in 22 European countries", *New England Journal of Medicine*, No358, pp. 2468-2481.

Mackenbach J.P., W.M. Van Duyne and M.C. Kelson (1987), "Certification and coding of two underlying causes of death in The Netherlands and other countries of the European Community", *Journal Epidemiology Community Health*, No 41, pp. 156-160.

Marinacci C., F. Grippo, M. Pappagallo, G. Sebastiani, M. Demaria, et al. (2013), "Social inequalities in total and cause-specific mortality of a sample of the Italian population, from 1999 to 2007", *European Journal Public Health*, No 23, pp. 582-587.

Marmot M.G. (2003), "Understanding social inequalities in health", *Perspectives in Biology and Medicine*, No 46, pp. S9-23.

Martikainen P., P. Makela., R. Peltonen. and M. Myrskyla (2014), "Income differences in life expectancy: the changing contribution of harmful consumption of alcohol and smoking", *Epidemiology*, No 25, pp. 182-190.

Meara E.R., S. Richards. and D.M. Cutler (2008), "The gap gets bigger: changes in mortality and life expectancy, by education, 1981-2000", *Health Affairs (Millwood)*, No 27, pp. 350-360.

Montez J.K. and A. Zajacova (2013), "Trends in mortality risk by education level and cause of death among US White women from 1986 to 2006" *American Journal Public Health*, No 103, pp. 473-479.

Moreno-Betancur M., A. Latouche, G. Menvielle, A.E. Kunst and G. Rey (2015), "Relative index of inequality and slope index of inequality: a structured regression framework for estimation", *Epidemiology*, No26, pp. 518-527.

Morris J.A. and M.J. Gardner (1988), "Calculating confidence intervals for relative risks (odds ratios) and standardised ratios and rates", *British Medical Journal*, No296 , pp. 1313-1316.

OECD (2012), *Divided we stand: Why inequality keeps rising*, OECD Publishing, Paris.

OECD (2014), *Health at a glance: Europe*, OECD Publishing, Paris

Organization WH (1999), *Health21: the health for all policy framework for the WHO European Region*, WHO Regional Office for Europe, Copenhagen.

Ostergren O., G. Menvielle and O. Lundberg (2012), "Adjustment method to ensure comparability between populations reporting mortality data in different formats in the EURO-GBD-SE project", *EURO-GBD-SE The potential of reduction of health inequalities in Europe Final report*, , Eikemo T, Mackenbach JP, editors, Department of Public Health, Erasmus MC., pp. 113-121, Rotterdam.

Palosuo H., S. Koskinen, E. Lahelma, E. Kostiainen, R. Prattala , et al., editors (2009), *Trends in socioeconomic health differences 1980-2005*, Ministry of Social Affairs and Health, Helsinki.

Preston S., P. Heuveline and M. Guillot (2000,*) Demography: measuring and modelling population processes*, Blackwell, Oxford

Regidor E., M.E. Calle, V. Dominguez and P. Navarro (2001), "Mortality by social and economic characteristics: The Mortality Study of the Autonomous Community of Madrid". *Medicina Clínica*, No 116, pp. 726-731.

Regidor E., A.E. Kunst, F. Rodriguez-Artalejo and J.P. Mackenbach (2012), "Small socio-economic differences in mortality in Spanish older people" *European Journal Public Health,* No 22, pp. 80-85.

Rey G., A. Aouba, G. Pavillon, R. Hoffmann, I. Plug, et al. (2011), "Cause-specific mortality time series analysis: a general method to detect and correct for abrupt data production changes", *Population Health Metrics,* No 9, p.52.

Rostron B.L., J.L. Boies and E. Arias (2010), "Education reporting and classification on death certificates in the United States", *Vital Health Stat,* No.2, pp.1-21.

Schneider S.L. and I., Kogan (2008)," The International Standard Classification of Education 1997: challenges in the application to national data and the implementation in cross-national surveys", in Schneider S.L. (editor), *The International Standard Classification of Education: An Evaluation of Content and Criterion Validity for 15 European Countries,* MZES, Mannheim.

Shkolnikov V.M., E.M.Andreev, D.A. Jdanov, D. Jasilionis, O. Kravdal, et al. (2012), "Increasing absolute mortality disparities by education in Finland, Norway and Sweden, 1971-2000", *Journal Epidemiology Community Health,* No 66, pp. 372-378.

Shkolnikov V.M., D. Jasilionis, E.M. Andreev, D.A. Jdanov, V. Stankuniene et al. (2007), "Linked versus unlinked estimates of mortality and length of life by education and marital status: evidence from the first record linkage study in Lithuania", *Social Science Medicine,* No.64, pp. 1392-1406.

Smith G.D., D. Blane and M. Bartley (1994), "Explanations for socio-economic differentials in mortality", *The European Journal of Public Health,* No.4, pp. 131-144.

Sorlie P.D. and N.J. Johnson (1996), "Validity of education information on the death certificate", *Epidemiology,* No.7, pp. 437-439.

Steingrimsdottir O.A., O. Naess., J.O. Moe, E.K Groholt., D.S Thelle. et al. (2012), "Trends in life expectancy by education in Norway 1961-2009" , *European Journal Epidemiology,* No.27 , pp. 163-171.

Tarkiainen L., P. Martikainen, M. Laaksonen and T. Valkonen (2012), "Trends in life expectancy by income from 1988 to 2007: decomposition by age and cause of death", *Journal Epidemiology Community Health* No. 66, pp. 573-578.

Toch-Marquardt M., G. Menvielle, T.A. Eikemo, I. Kulhanova, M.C. Kulik et al. (2014), *Occupational class inequalities in all-cause and cause-specific mortality among middle-aged men in 14 European populations during the early 2000s,* PLoS One 9, e108072.

UNESCO (1997), *International Standard Classification of Education-ISCED 1997.*

Vallin J. and G. Caselli (2006), "The hypothetical cohort as a tool for demographic analysis", in Caselli G., Vallin J., Wunsch G. (eds.), *Demography: analysis and synthesis*, pp. 163, Academic Press, Burlington.

van Oort F.V., F.J. van Lenthe and J.P. Mackenbach (2005), "Material, psychosocial, and behavioural factors in the explanation of educational inequalities in mortality in The Netherlands", *Journal Epidemiology Community Health*, No. 59, pp. 214-220.

van Raalte A.A. and H. Caswell (2013), "Perturbation analysis of indices of lifespan variability", *Demography,* No. 50, pp. 1615-1640.

van Raalte A.A., A.E. Kunst, P. Deboosere , M. Leinsalu , O. Lundberg et al. (2011), "More variation in lifespan in lower educated groups: evidence from 10 European countries", *International Journal Epidemiology*, No. 40, pp. 1703-1714.

Whitehead M. (1992), "The concepts and principles of equity and health", *International Journal Health Service,* No. 22, pp. 429-445.

Whitehead M. (2007), "A typology of actions to tackle social inequalities in health", *Journal Epidemiology Community Health,* No.61, pp. 473-478.

Wilmoth J.R., K. Andreev, D.A. Jdanov, D.A. Glei, C. Boe et al. (2007), *Methods protocol for the human mortality database,* University of California and Max Planck Institute for Demographic Research, Berkeley and Rostock.