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The association between educational level and adult mortality at individual level in Europe: a systematic review and meta-analysis

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Abstract

Introduction
Social inequalities contribute to premature mortality in Europe. Being associated with modifiable factors, these inequalities could be sensitive to intervention. Education is of special interest in the study of social inequalities: education is stable throughout adulthood, and more easily communicated to researchers than other components of social inequalities. Available literature confirms the existence of educational inequalities in mortality, and these inequalities vary depending on which educational levels are compared, gender, age, and across different regions. However, there is a lack of synthesized results on educational inequalities at the European level.

Aim
This thesis aims to conduct a systematic review and meta-analysis to explore the association between educational attainment and all-cause mortality in Europe. Increasing knowledge on this topic can provide knowledge for policy making and further research. Consideration will be given to how the educational inequalities in mortality vary when comparing different educational levels, regions, time periods, and social groups.

Methods
15017 articles were identified, following a search query in different databases. Abstract screening, full reading and extraction were conducted with the Centre for Global Health Inequalities Research (CHAIN), while data analysis was conducted individually. Hazard ratios of mortality were compared between different educational levels and upon stratification by region, time, age and gender.

Results
The association between educational level and mortality is the strongest when comparing low versus high education. However, an additional year of educational alone still has a statistically significant effect on mortality. Inequalities are larger in Eastern Europe, and smaller in the British Islands. They have increased over time, are stronger in males and younger cohorts.

Conclusion
Educational inequalities vary when comparing different educational levels, regions, time periods or groups. Additional research could help identifying the number of years of education most effectively reducing hazard of mortality, and further explain the causes behind regional disparities in educational inequalities and their increase over time. Joint implications of these findings include the need for a better understanding of the role of different mediators and confounders at play in the association between education and mortality. Potential for intervention remains: the fact that educational inequalities vary shows that they are modifiable. They could therefore be sensitive to interventions aiming to reduce inequalities in mortality.

Sammendrag

Introduksjon

Sosiale ulikheter bidrar til for tidlig dødelighet i Europa. Siden de er assosiert med modifiserbare faktorer, kan disse ulikhetene være følsomme for inngrep. Utdanning er av spesiell interesse for studiet av sosiale ulikheter. Utdanning er stabil gjennom voksen alder, og datainformasjon om utdanning er vanligvis lett å samle. Tilgjengelig litteratur bekrefter eksistensen av utdanningsulikheter i dødeligheten, og disse ulikhetene varierer avhengig av hvilke utdanningsnivåer som sammenlignes, kjønn, alder og på tvers av forskjellige regioner. Imidlertid mangler det oppsummerte resultater om utdanningsulikheter på europeisk nivå.

Mål

Denne oppgaven tar sikte på å gjennomføre en systematisk gjennomgang og metaanalyse for å utforske sammenhengen mellom utdannelsesnivå og alle forårsaker dødelighet i Europa. Kunnskap om dette temaet kan gi grunnlag for politikkutforming og videre forskning. Hensynet vil bli gitt til hvordan utdanningsulikhetene i dødelighet varierer når man sammenligner forskjellige utdanningsnivåer, regioner, tidsperioder og sosiale grupper.

Metoder

15017 artikler ble identifisert etter et søk i forskjellige databaser. Sammendrag screening, detaljert lesing og datautvinning ble gjennomført med Center for Global Health Inequalities Research (CHAIN), mens dataanalysen ble utført individuelt. Forekomst av dødelighet var sammenlignet mellom forskjellige utdanningsnivåer og ved stratifisering etter region, tid, alder og kjønn.

Resultater

Sammenhengen mellom utdanningsnivå og dødelighet er sterkest når man sammenligner høy utdannelse vs. lav utdannelse. Imidlertid har et ekstra utdanningsår alene fortsatt en statistisk signifikant effekt på dødeligheten. Ulikheter er større i Øst-Europa, og lavere i Britiske Øyene. De har økt over tid, er sterkere hos menn og yngre voksne.

Konklusjon

Ulikheter i utdanningen varierer når man sammenligner forskjellige utdanningsnivåer, regioner, tidsperioder eller grupper. Ytterligere forskning kan bidra til å identifisere antall utdanningsår som er mest effektivt for å redusere dødsfaren, og forklare årsakene bak regionale ulikheter i utdanningsulikheter og deres økning over tid. Felles implikasjoner av disse funnene inkluderer behovet for en bedre forståelse av hvilken rolle ulike mediatorer og konfunderer spiller i sammenheng mellom utdanning og dødelighet. Potensialet for tiltak gjenstår: det faktum at utdanningsulikhetene varierer, viser at de kan modifiseres.

Preface

This thesis explores the characteristics and the extent of the relationship between education and mortality in Europe by reviewing the available literature. It is part of a broader project I took part in as a research assistant: a systematic review and meta-analysis on the association between educational level and mortality, without any geographic restriction for inclusion. This initiative was led by CHAIN, a research center attached to the faculty of social sciences of the Norwegian University of Science and Technology (NTNU). It was motivated by the realization of a lack of systematic reviews and meta-analysis on the association between education and mortality. The objective was understanding whether education should be considered as an important predictor of mortality, beside traditionally accepted and documented predictors such as for example smoking, alcohol consumption or income. Doing so, CHAIN proceeded in two parts, first by conducting a review on parental education and child mortality, and then by conducting this second review I took part in, on adult mortality and education.

Using data collected collectively by CHAIN team members and myself, I decided to restrict my analysis to Europe. All steps following data extraction were conducted fully individually.

I would like to thank my supervisor, Terje Andreas Eikemo for his insights and guidance during the completion of this thesis, as well as all CHAIN team members for their collaboration and support.

Contents

Abbreviations

AF: Atrial Fibrillation

CHAIN: Centre for Global Health Inequalities Research

CI: Confidence Interval

EMBASE: Excerpta Medica dataBASE

EU: European Union

GBD: Global Burden of disease

HR: Hazard Ratio

ISCED: International Standard Classification of Education

MEDLINE: Medical Literature Analysis and Retrieval System Online

NTNU: Norwegian University of Science and Technology

OECD: Organisation for Economic Co-operation and Development

SES: Socioeconomic status

SSB: Statistisk sentralbyrå (Statistics Norway)

UNESCO: United Nations Educational, Scientific and Cultural Organization

UNITED KINGDOM: UK

WHO: World Health Organization

WOS: Web of Science

List of tables and figures

I-Introduction and background

1-Social inequalities in mortality

Social inequalities in mortality are an important public health issue, as they represent a significant amount of the burden of disease in Europe. Nearly 36 % of deaths occurring before age 75 were for example attributable to socioeconomic inequalities in the United Kingdom (UK), from 2003 to 2018 (Lewer et al., 2020). These inequalities represent opportunities for intervention in the lifetime of an individual, compared to non-modifiable factors such as genes (J. Mackenbach, Menvielle, Jasilionis, & Gelder, 2015). Social inequalities in mortality have been drawing increasing attention since 1980 and the publication of the Black Report by the Department of Health and Social Security (Department of Health and Social Security, 1980). Despite improvements in population health in the UK, the report highlighted persistent and increasing inequalities in health between lower and higher social classes. The Black Report drew a lot of attention on a national and an international level and inspired a second similar report: the Acheson Report in 1998 (Department of Health and Social Care, 1998). The conclusions of this second report were similar: since the 1970s, mortality decline had been faster and greater in the higher social classes than in the lower social classes.

Social and economic position is generally heard as socioeconomic status (SES) in the recent literature on social inequalities (Oxford University Press, 2021). SES encompasses different dimensions, such as income, education, subjective perception of social status (APA, 2017). The advantage of education over other components of SES is also that study participants are more likely to accurately self-declare their educational level than other components of the SES, such as income (Oakes, 2012). Additionally, educational attainment is generally stable after early adulthood. (Darin-Mattsson, Fors, & Kåreholt, 2017; Huisman et al., 2004; J. P. Mackenbach, Kunst, Cavelaars, Groenhof, & Geurts, 1997). That is why studies of SES inequalities in mortality often have education as a dependant variable of interest.

The available scientific literature from Europe and outside of Europe confirms the association between education and mortality. Individuals from lower educational categories have on average a higher mortality risk than individuals from higher educational categories (Byhoff, Hamati, Power, Burgard, & Chopra, 2017; Diderichsen et al., 2012). Developing an understanding of the educational inequalities in mortality therefore represents a potential for interventions aiming to decrease inequalities in life expectancy and reduce premature mortality.

This first introduction section will document how education and mortality can be measured, and further detail what is (un)known on the association between education and mortality in Europe.

2-Defining and measuring education and mortality

Mortality is understood in this thesis as all-cause mortality. The objective is to capture as accurately as possible the association between education and mortality in Europe. In the framework of longitudinal studies, mortality data are in most cases collected from administrative records or death certificates. In case of a prospective study, a cohort is generally followed, and mortality data collected continuously. In case of retrospective study, mortality data are generally collected from administrative registries and linked to a database containing information about individual education.

Education is understood as the highest educational attainment of an individual. It can be measured both by numbers of years of schooling and by educational level achieved. Measures of relative mortality risks or hazards are generally based on the mortality rates of different population groups, ranged by their education.

3-The magnitude of the educational inequalities in mortality upon comparison of different educational levels

Determining which educational levels to compare is an important element in the study of the educational inequalities in mortality. The educational inequalities can vary greatly, depending on what educational levels are compared. Danish data suggest that when the population is separated into quartiles depending on length of education, the educational inequalities in mortality are the largest when comparing the top and bottom educational category. Educational inequalities in mortality gradually decrease as the top educational categories are compared (Diderichsen et al., 2012). A Spanish prospective review came to the similar conclusion of larger educational inequalities when comparing the highest and lowest educational categories (Regidor et al., 2016).

It could be interesting to determine if educational inequalities in Europe are visible only when comparing the very higher and lower educational categories, or if there is conversely a statistically significant effect of one single year of educational alone. As of now, there is lack of synthetized evidence at European level.

4-Trends in education, mortality and in the educational inequalities in mortality

The average educational level has shifted towards the higher educational levels. Data from the World Bank reveal that in the European Union (EU), enrolment in secondary education has gone from about 73% in 1975 to 91% in 2018 (The World Bank, 2018b). Enrolment rates were calculated on the children of official age for secondary education. Enrolment in tertiary education followed the same trend: in the 5 years following high-school graduation, enrolment rates in tertiary education went from 17,35% in 1970 to nearly 68% in 2014 (Roser & Ortiz-Ospina, 2013). Efforts have also been made to increase quality in education, for example by reinforcing the pupils to teacher ratio. At primary school level in the EU, pupils to teachers ratio went from around 19,8 in 1970 to 13,3 in 2018 (The World Bank, 2018a).

Life expectancy has known a similar trend as education in the past years in Europe. Life expectancy has continuously increased over the 20th century in Europe, going from 62 old in 1950 to 77.6 in 2014 (Roser, Ortiz-Ospina, & Ritchie, 2019). This increase was partly due to a decline in premature mortality in the OECD countries, in other words to a decrease in "unfulfilled life expectancy" (Joel, 2017).The premature mortality halved between 1970 and 2009 (OECD, 2009). Unfulfilled life expectancy tends to be higher amongst males than females, and to be driven by external causes such accidents, suicide and violence, cancer, or circulatory diseases.

Europe has large data on the trends in mortality and in education. There is however a lack of synthetized data at European level on the trends in educational inequalities in mortality. Literature available from some countries like for example Norway or Denmark suggests an increase in the educational inequalities in mortality over the last decades (Diderichsen et al., 2012; Strand et al., 2010).

5-Geographic distribution of education, mortality and of the educational inequalities in mortality

The increase in life expectancy and decline in premature mortality still hides disparities between European countries. Enrolment rates in the educational system are typically higher in Northern and Western Europe, and lower in Eastern and Southern Europe. In 2017, while completion of upper secondary education in the population above 25 reaches 78.2% in Norway, the figure is of only 50.4% in Spain (The World Bank, 2020). Quality in the educational system also varies. At primary school level, pupils to teacher ratio is of 8,6 in Norway, but of 18,2 in France (The World Bank, 2018a).

Despite having among the lowest educational attainment, Southern Europe is the European region with the highest life expectancy. On the other hand, Eastern Europe cumulates both lower educational attainment than the rest of Europe and lower life expectancy (Eurostat, 2020). Additionally, a synthetic review from 2015 using data from the OECD statistics shows that countries in Eastern Europe face stronger educational inequalities in mortality than Nordic countries or Southern Europe (J. Mackenbach, Menvielle, Jasilionis, & Gelder, 2015).

Educational attainment and mortality rates differ between countries. However, there is a lack of synthetized evidence comparing the association between education and mortality in different European regions.

6-Distribution of education, mortality and of the educational inequalities between different social groups

This heterogeneous distribution of education and mortality is observed both across countries and across different groups. Age and gender are amongst the factors influencing education, mortality as well as the educational inequalities in mortality.

As a result of increasing educational attainment, younger adults have a higher educational level than older adults. In the European Union in 2019, 20.9% of adults in the age group 55-74 had higher education, against 34.6% in the age group 25-54 (Eurostat, 2019a). Age and education seem to interact when mortality is set as the outcome of interest. A synthetic review from 2017 reports that younger individuals are facing larger educational inequalities in mortality than older individuals (Byhoff et al., 2017).

Male gender is like older age associated with lower educational attainment (UNESCO, 2014). Polish females are for example 41% more likely than their male counterparts to have been enrolled in secondary education (UNESCO, 2014). Males also face a higher risk of premature mortality. For example, in Lithuania in 2016, premature standardized death rates of males were 658.3 against 224.8 for females, meaning a gender ratio of 2.9. Sweden had in 2016 one of the lowest premature standardized death rates of males in Europe, at 171.4 per 100 000 inhabitants, but still had a gender ratio in premature mortality of 1.73 (Megyesiova & Lieskovska, 2019). Males have lower educational attainment, higher premature mortality, and experience higher educational inequalities in mortality. A review on the relationship between socioeconomic status and mortality documents that males face higher educational inequalities in mortality than females (Taylor & Quine, 1992). However, using American data, a prospective cohort study found this interaction only amongst divorced men and women (Zajacova, 2006).

Results from studies at country level and synthetized reviews suggest that male gender and older age are associated with larger educational inequalities. It could be interesting to test these observations of varying educational inequalities between different groups, using data from European countries.

II-Aim, questions, and hypotheses

1-Rationale

Educational inequalities contribute to premature mortality in Europe. However, the association between education and mortality is not fully documented in Europe. No evidence using meta-analysis could be identified in the frame of this thesis, and there is a lack of synthetized data at European level, despite the availability of data on mortality and education at country level. The available evidence on educational inequalities in mortality mostly uses longitudinal studies at country level or synthetic reviews of publications in English.

Upon systematically reviewing the literature and running a meta-analysis, this thesis aims to explore what is the association between educational attainment and adult all-cause mortality in Europe. Increasing knowledge on the subject can provide guidance for intervention aiming to reduce premature mortality, while giving perspectives for further research.

This work can bring something new to the existing literature on the educational inequalities in mortality by being a meta-analysis on European data only, with no restriction based on language of publication.

2-Questions and hypothesis

Exploring the association between educational attainment and mortality implies analysing the strength of educational inequalities in mortality and how they vary:

- When comparing different educational levels: the objective is there to observe how the educational inequalities vary when comparing different educational levels, and if is there is any statistically significant effect of one additional year of education alone. Results at country level suggest that the magnitude of educational inequalities varies when comparing different educational levels, being the highest when comparing the lowest and highest levels. We can hypothesize that synthetized results for Europe also show larger educational inequalities when comparing top and bottom education.
- When comparing different time periods: in a context where educational attainment and life expectancy have increased, this thesis aims to explore trends in the educational inequalities in mortality. Educational inequalities in Europe could have increased over time, if synthetized data for Europe is similar to what is observed in single countries.
- When comparing different European subregions: the magnitude of educational inequalities seems to vary between different countries. This thesis aims to complete available evidence by exploring if such differences can be observed between European regions. Educational inequalities could be stronger in certain European regions, such as Eastern Europe.
- When comparing different social groups: the point is to observe how the educational inequalities vary when comparing female/male and young/older people. Results from the

literature suggest larger educational inequalities in younger adults and males. Europe could face the same situation.

III-Methods

1- Search query and exclusion criteria

1-1-Search query

Databases from Medline, Web of Science, Scopus, EMBASE, Global Health (CAB), EconLit and Sociology Source Ultimate database were screened using the search query in **appendix 1**. Search query was executed with the library for Humanities, Education and Social Sciences of the NTNU.

1-2-Exclusion criteria defined by CHAIN

The exclusion criteria for the screened abstracts were defined by CHAIN in 2019 and retained for this thesis. Studies were excluded if they had no data on all-cause mortality, no adults, no measures of relative inequalities between individuals of different educational levels, no data at individual level. Additionally, ecological studies, case-crossover studies, commentaries, editorials and letters were excluded. No further restriction was made on language used or confounders included. Most studies included confounders at least for age and/or gender. List of most included confounders is available in the appendix section (**appendix 2**).

1-3-Additional exclusion criteria retained in this thesis

To be included in this thesis, articles needed to fit additional criteria: use of hazard ratio (HR) with confidence interval (CI), report of results for Europe, use of educational categories convertible in the ISCED terminology (International Standard Classification of Education classification).

The effect size retained in this thesis was HR (with CI), because HR was the most used effect size measure amongst screened studies. It was not possible to convert all effect sizes into HRs, because of mortality rates not being provided for all studies. Studies not reporting CI were excluded, because their results could not have been computed in the meta-analysis.

Europe is understood as in the Global burden of diseases (GBD) regional classification from the World Health Organization (WHO), a system classifying member states into different regions

(WHO, 2020). Studies calculating a single effect size from both European and non-European data were excluded.

ISCED was used as reference tool, so that educational levels from different countries could be compared. ISCED recognizes 8 different educational levels (International Standard Classification of Education, 2020): pre-primary education (level 0), primary education (level 1), lower secondary education (level 2), upper secondary education (level 3), post-secondary non-tertiary education (level 4), short cycle tertiary education (level 5), bachelor (level 6), master's degree (level 7) and doctoral education (level 8). The use of ISCED classification enabled further coding of education into a categorical variable with three values: low education (ISCED levels 0-2), medium education (ISCED levels 3-4), high education (ISCED levels 5-8). That classification system is used by the European commission when measuring educational inequalities (Eurostat, 2016). In studies where it was difficult to determine the ISCED level, the participant was categorized in the lowest category he was guaranteed to have achieved, given that doing so had no impact on the low/medium/high educational classification from the European commission. For instance, if a study ranked participants as having "lower secondary education or less", classifying them in ISCED level 1 or 2 did not change their belonging to the "low education" category. However, if classifying participants in the lower guaranteed ISCED category impacted their low/medium/high education classification, the inconclusive rows or studies were excluded. For instance, rows or studies comparing higher education vs. no higher education were not included. A few studies reporting the effect of one additional year of education on mortality were still included (dose response).

2-Abstract screening and full reading

Abstracts were screened using results from the search query presented in subsection 1-1. CHAIN team members were paired together for abstract screening. Pairs needed to come to a common agreement for each of the abstract reviewed, using the exclusion criteria listed above. From the 15017 articles that went through this abstract screening phase, 1514 fitted the inclusion criteria and were retained for the next phase: full reading. Using a similar process as in the abstract screening phase, articles were fully read in pairs of research assistants, with discussion to come to a common agreement. Systematic reviews were not included for further extraction, but the relevant articles they mentioned were included for further abstract screening and potential full reading, in a "hand searching" process. Following abstract screening and full reading, 67 Articles fitted the criteria for extraction.

3-Extraction

Relevant information from the included articles was gathered in a dataset. Each extraction was checked by a coordinator in the team to assess its quality and fix mistakes, as well as to uniformize how team members had proceeded for the extraction. Further steps after this point fell strictly in the scope of this thesis and were therefore conducted fully individually. The flow chart below summarizes the process from search query to extraction.

Figure 1

Flow chart showing the process from search query to extraction

Rayyan
15017

Hand search
384

Abstract screening

13503 Excluded

- 1035 No human
- 8718 No mortality
- 1259 Cause-specific mortality
- 332 No individual level
- 1593 No social group analysis
- 301 No adults
- 71 Study design
- 138 Publication type
- 0 Abstract not avalaible
- 56 Duplicates

99 Excluded

- 0 No Human
- 35 No Mortality
- 17 Cause-specific mortality
- 16 No individual level
- 5 No social group analysis
- 2 No adults
- 5 Study design
- 6 Publication type
- 13 Abstract not avalaible

Full Reading

1732 excluded

- 92 No mortality
- 74 Cause-specific mortality
- 59 No individual level
- 682 No education
- 65 Wrong effect measure
- 47 No adults
- 58 Educational category unclear
- 8 Study design
- 22 Publication type
- 8 Definition of education
- 33 Full article not available
- 56 Only life expectancy measures
- 398 Outside of Europe GBD region
- 130 No HR and/or confidence

Note: Total number of studies extracted amounts 67

4-Data analysis

4-1-First steps

Participants were categorized in each study into exposed/non exposed, depending on their educational level. The outcome of interest is all-cause mortality during the timeframe where the study was conducted. Caution was given to which of the exposed or unexposed group had the highest educational level. For the studies where the unexposed group had the lowest educational level, inverse effect size was calculated, so that all studies had the group with the highest education level as the unexposed group.

4-2-Coding variables

Education was coded into a categorical variable with three categories, following the process described earlier (low, medium, high). Additional variables were coded for further stratification. Age, year at endpoint, and gender were coded into binary variables taking respectively the following values: aged 65 or older/younger than 65, study ending in 2000 or before/study starting from 2001, and male/female. A categorical variable was also created to cover different European regions: British Isles, Nordic countries, Western Europe, Eastern Europe, and Southern Europe.

4-3-Pooled effect size and stratification

STATA 16 random effect models for meta-analysis and command meta set were used to compute the effect size. Three subsets were created: low vs. high education, medium vs. high education, and low vs. medium education.

Analysis by subset

A pooled effect size was first calculated for each subset (Low vs. High education; medium vs. high education; low vs medium education). Studies often reported multiple subgroups, and/or analysed the changes in effect size upon inclusion of different confounders. Consequently, each study often reported multiple effect sizes. To address that problem, the effect sizes from different subgroups were combined into an average effect size. Additionally, when the study reported different effect sizes upon adjustment for different confounders for the same ISCED educational levels, only the rows including the most confounders were kept. In cases where the study reported different sub educational levels within the same low/mid exposed category (for example primary school and middle school), the average effect size was calculated.

Stratification

To analyse effect modification between education and other variables, studies were then stratified by year at endpoint/starting point, gender, age, and European subregion. Stratification was conducted from the subset “low vs. high education, because it was the one gathering the highest number of observations.

5-Quality assessment of included studies

The included studies went through a thorough selection process. Abstract screening and full reading were conducted in pairs of reviews, in addition the ROBIN-I assessment tool developed by Cochrane was used to evaluate risk of bias (Cochrane, 2016). The table displaying quality assessment of the studies is available in **appendix 3**. Three levels of risk of bias were retained for each of the different criteria: red (high), yellow (medium), green (low). ROBIN-I evaluates the risk of bias in non-randomized studies using the following criteria, that can be adapted to education:

-*Bias due to confounding*: assessment of the confounding risk in the study.

-*Bias in selection of participants into the study*: assessment of the quality in the selection process, considering acceptance rates, quality of registries used etc.

-*Bias in classification of interventions*: assessment of the quality of the classification in different educational levels. Attention was given to whether registries or self-declarations were used.

-*Bias due to deviations from intended interventions*: assessment of to what extent the educational level of a participant was truly corresponding to the quality standard of that educational level.

-*Bias due to missing data*: assessment of how many participants were lost to follow-up during the study, and of how did researchers handle these.

-*Bias in measurements of outcomes*: assessment of how reliable the measurement of mortality was.

-*Bias in selection of the reported result*: assessment of the likelihood of omissions in result report.

IV-Results

1-Descriptive statistics

This result section explores the educational inequalities in mortality, before and after stratifying the included studies into different regions, timeframes, genders, and age groups. Countries were gathered into 5 different sub-regional entities: Nordic countries, British Isles, Western Europe, Southern Europe and Eastern Europe. **Table 1** shows how many studies report results for the different European regions. **Appendix 4** is available for the full list of included countries. **Table 2** lists how many studies report results for the different age groups, year at endpoint and gender. **Table 3** lists how many studies report results for the different educational levels (low, medium, high). **Appendix 5** is available for more details on each included study (author, country, population selection criteria, study design sample size, timeline of the study).

Table 1

List of regions

Region (and countries covered)	*N. of studies (high vs. low education only)*	*N. of studies (from all included studies)*
Nordic countries: Denmark, Finland, Sweden, Norway, Iceland	27	34
British Isles: Republic of Ireland, United Kingdom	5	7
Western Europe: France, Belgium, Netherlands, Germany, Switzerland, Austria	15	17
Southern Europe: Italy, Greece	5	5
Eastern Europe: Estonia, Poland, Russia,	5	5

Note: Some of the studies included in this thesis were covering multiple European regions

Table 2

Year at end of study and age of participants

	N. of studies (high vs. low education only)	*N. of studies (from all included studies)*
Year at end		
Ends before 2001	*9*	*11*
Starts in 2001 or after	*15*	*16*
Age groups		
65 or older	10	10
Younger than 65	18	25
Gender		
Male	38	39
Females	31	32

Note: Some of the studies included in this thesis did not have subgroup results by age, gender, or did not fit the timeframe “ending before 2001”/“starting in 2001 or after”.

Table 3

Educational levels

	N. of studies
Low educational level	62
Medium educational level	35
High educational level	65

Note: Some of the studies included in this thesis were covering multiple educational levels at the same time.

2-The educational inequalities in mortality: differences by educational levels compared

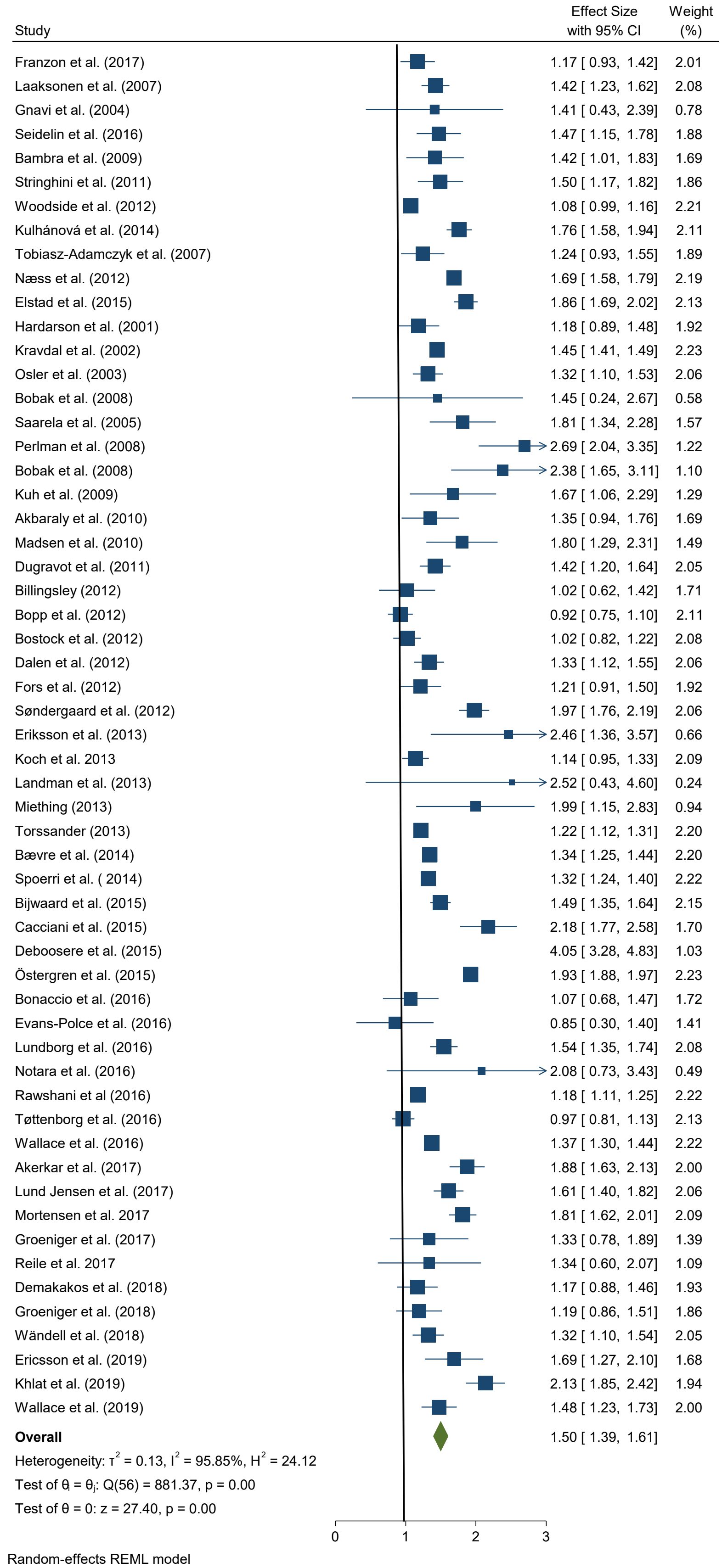
The educational inequalities in mortality are the highest when comparing low education to high education, and the lowest when comparing low to medium education. The results are statistically significant at the 0.05 significance level. There is however a high level of heterogeneity. All 4 subsets have a I^2 above 88% (high vs. low education, medium vs. low education, medium vs. high education, dose-response effect of education).

2-1-High (unexposed) vs. low educational level (exposed)

Having low education significantly increases hazard of mortality, compared to having high education. **Figure 2** highlight these educational inequalities in mortality by showing the forest plot of hazard ratios of mortality for low education vs. high education. Pooled hazard ratio of mortality is 1.5 when comparing low to high education (95% CI: 1.39-1.61, I^2= 95.85%).

Figure 2

Forest plot of hazard ratios of mortality, when the exposed group has low education and the unexposed high education



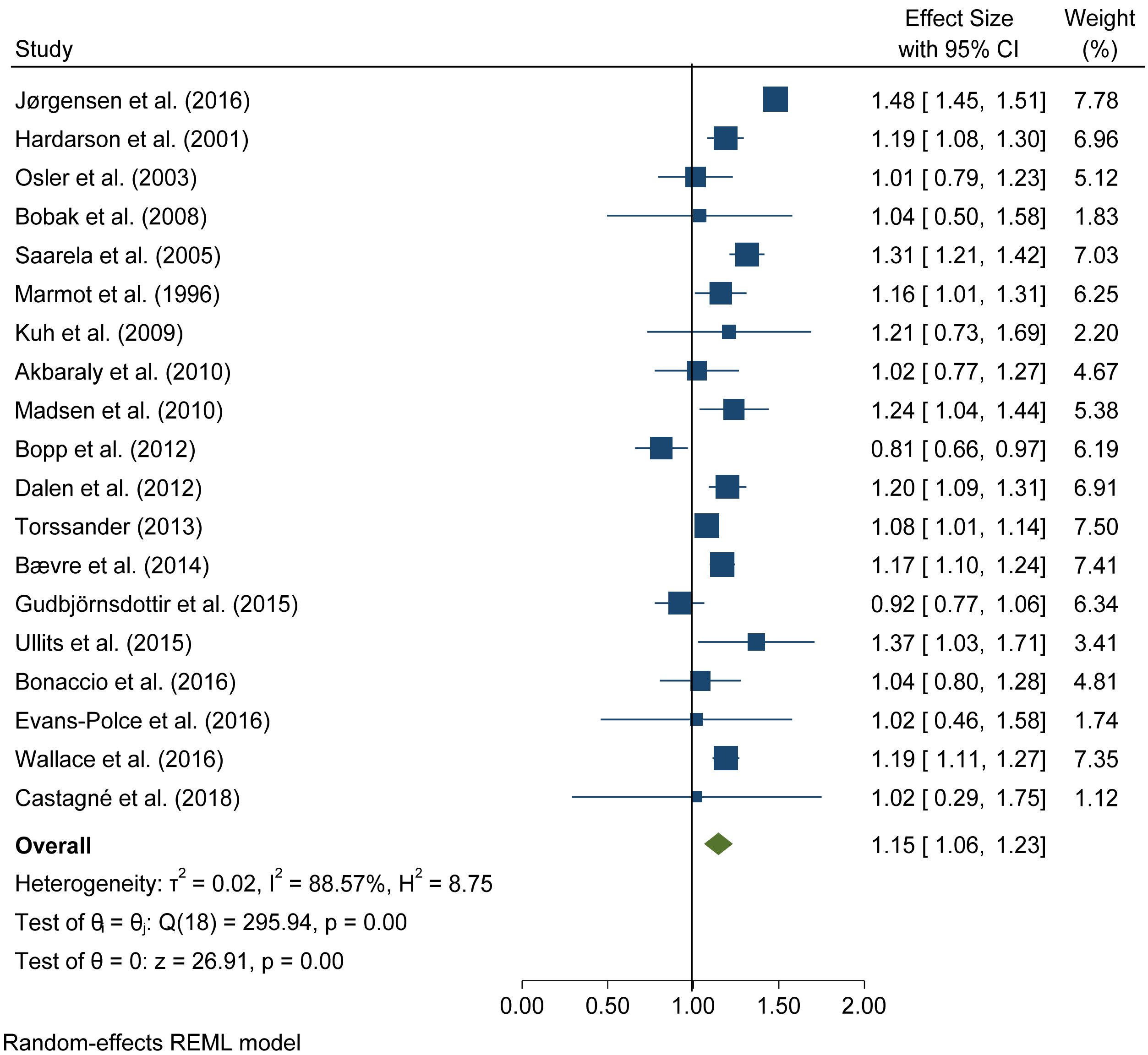
Study
Effect Size with 95% CI
Weight (%)
Franzon et al. (2017) 1.17 [0.93, 1.42] 2.01
Laaksonen et al. (2007) 1.42 [1.23, 1.62] 2.08
Gnavi et al. (2004) 1.41 [0.43, 2.39] 0.78
Seidelin et al. (2016) 1.47 [1.15, 1.78] 1.88
Bambra et al. (2009) 1.42 [1.01, 1.83] 1.69
Stringhini et al. (2011) 1.50 [1.17, 1.82] 1.86
Woodside et al. (2012) 1.08 [0.99, 1.16] 2.21
Kulhánová et al. (2014) 1.76 [1.58, 1.94] 2.11
Tobiasz-Adamczyk et al. (2007) 1.24 [0.93, 1.55] 1.89
Næss et al. (2012) 1.69 [1.58, 1.79] 2.19
Elstad et al. (2015) 1.86 [1.69, 2.02] 2.13
Hardarson et al. (2001) 1.18 [0.89, 1.48] 1.92
Kravdal et al. (2002) 1.45 [1.41, 1.49] 2.23
Osler et al. (2003) 1.32 [1.10, 1.53] 2.06
Bobak et al. (2008) 1.45 [0.24, 2.67] 0.58
Saarela et al. (2005) 1.81 [1.34, 2.28] 1.57
Perlman et al. (2008) 2.69 [2.04, 3.35] 1.22
Bobak et al. (2008) 2.38 [1.65, 3.11] 1.10
Kuh et al. (2009) 1.67 [1.06, 2.29] 1.29
Akbaraly et al. (2010) 1.35 [0.94, 1.76] 1.69
Madsen et al. (2010) 1.80 [1.29, 2.31] 1.49
Dugravot et al. (2011) 1.42 [1.20, 1.64] 2.05
Billingsley (2012) 1.02 [0.62, 1.42] 1.71
Bopp et al. (2012) 0.92 [0.75, 1.10] 2.11
Bostock et al. (2012) 1.02 [0.82, 1.22] 2.08
Dalen et al. (2012) 1.33 [1.12, 1.55] 2.06
Fors et al. (2012) 1.21 [0.91, 1.50] 1.92
Søndergaard et al. (2012) 1.97 [1.76, 2.19] 2.06
Eriksson et al. (2013) 2.46 [1.36, 3.57] 0.66
Koch et al. 2013 1.14 [0.95, 1.33] 2.09
Landman et al. (2013) 2.52 [0.43, 4.60] 0.24
Miething (2013) 1.99 [1.15, 2.83] 0.94
Torssander (2013) 1.22 [1.12, 1.31] 2.20
Bævre et al. (2014) 1.34 [1.25, 1.44] 2.20
Spoerri et al. (2014) 1.32 [1.24, 1.40] 2.22
Bijwaard et al. (2015) 1.49 [1.35, 1.64] 2.15
Cacciani et al. (2015) 2.18 [1.77, 2.58] 1.70
Deboosere et al. (2015) 4.05 [3.28, 4.83] 1.03
Östergren et al. (2015) 1.93 [1.88, 1.97] 2.23
Bonaccio et al. (2016) 1.07 [0.68, 1.47] 1.72
Evans-Polce et al. (2016) 0.85 [0.30, 1.40] 1.41
Lundborg et al. (2016) 1.54 [1.35, 1.74] 2.08
Notara et al. (2016) 2.08 [0.73, 3.43] 0.49
Rawshani et al (2016) 1.18 [1.11, 1.25] 2.22
Tøttenborg et al. (2016) 0.97 [0.81, 1.13] 2.13
Wallace et al. (2016) 1.37 [1.30, 1.44] 2.22
Akerkar et al. (2017) 1.88 [1.63, 2.13] 2.00
Lund Jensen et al. (2017) 1.61 [1.40, 1.82] 2.06
Mortensen et al. 2017 1.81 [1.62, 2.01] 2.09
Groeniger et al. (2017) 1.33 [0.78, 1.89] 1.39
Reile et al. 2017 1.34 [0.60, 2.07] 1.09
Demakakos et al. (2018) 1.17 [0.88, 1.46] 1.93
Groeniger et al. (2018) 1.19 [0.86, 1.51] 1.86
Wändell et al. (2018) 1.32 [1.10, 1.54] 2.05
Ericsson et al. (2019) 1.69 [1.27, 2.10] 1.68
Khlat et al. (2019) 2.13 [1.85, 2.42] 1.94
Wallace et al. (2019) 1.48 [1.23, 1.73] 2.00
Overall 1.50 [1.39, 1.61]
Heterogeneity: τ^2 = 0.13, I^2 = 95.85%, H^2 = 24.12
Test of $\theta_i = \theta_j$: Q(56) = 881.37, p = 0.00
Test of θ = 0: z = 27.40, p = 0.00
0
1
2
3
Random-effects REML model

2-2-Medium (unexposed) vs low educational level (exposed)

The pooled hazard ratio of mortality is lower when comparing low education to medium education than when comparing low to high education. The pooled hazard ratio of mortality is 1.15 when medium education is set as the unexposed group and low education as the exposed group (95% CI: 1.06-1.23, I^2= 88.57%) (**Figure 3**).

Figure 3

Forest plot of hazard ratios of mortality, when the exposed group has low education and the unexposed medium education

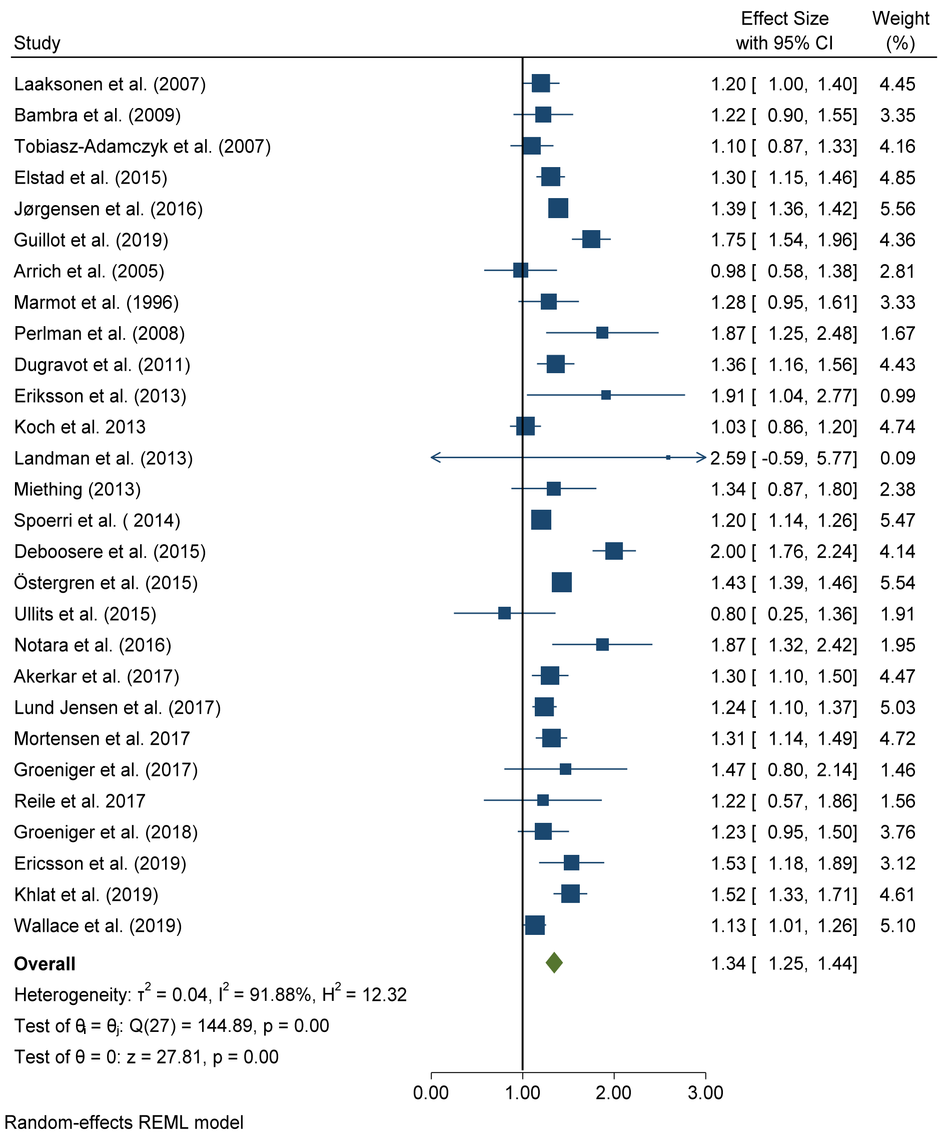


2-3-High (unexposed) vs. medium educational level (exposed)

The pooled hazard ratio of mortality for adults with medium education when compared to adults with high education is 1.34 (95% CI: 1.25-1.44, $I^2 = 91.88\%$). Pooled hazard ratio of mortality is higher in this subsection than when comparing low to medium education, but still lower than when comparing low to high education. **Figure 4** displays the forest plot of hazard ratios of mortality for people with high education vs. people with medium education.

Figure 4

Forest plot of hazard ratios of mortality, when the exposed group has medium education and the unexposed high education

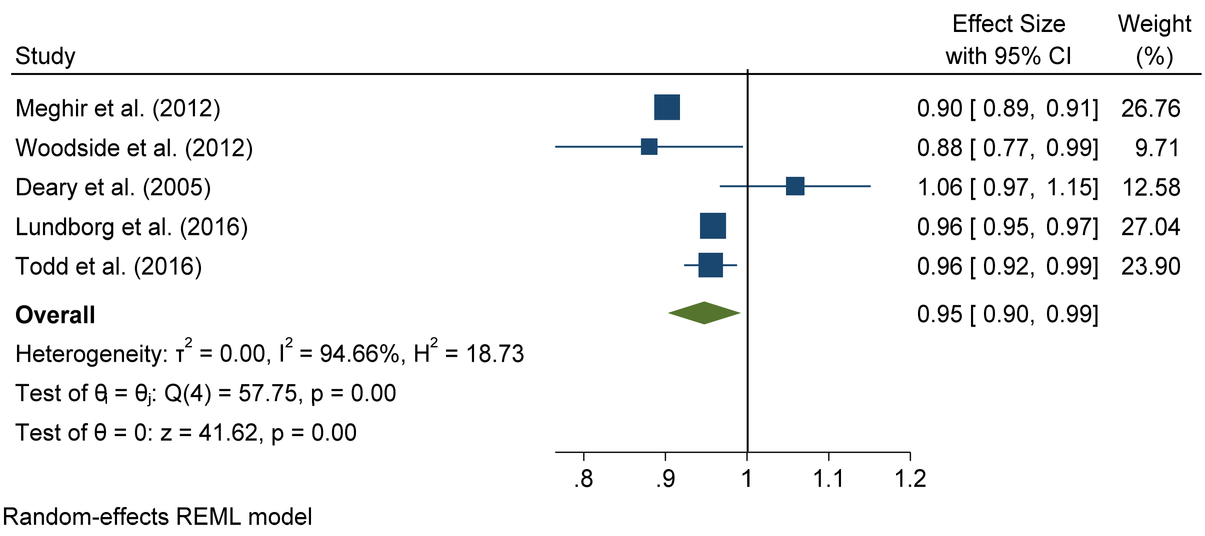


2-4-Effect of one additional year of education

One additional year of education statistically significantly reduces hazard of mortality, with a pooled hazard ratio of 0.95 (95% CI: 0.90-0.99, I^2 =94.66 %). **Figure 5** shows the forest plot of hazard ratios for the association between years of education and mortality.

Figure 5

Forest plot of hazard ratios of mortality of one additional educational year



The following subsections present results with stratification by year, region, gender, and age. Results are based on data from the low vs. high education subset, low education being the exposed group and high education unexposed.

3- An increase over time in the educational inequalities in mortality

The educational inequalities in mortality seem to have increased over the last decades. As presented in **figure 6**, the pooled hazard ratio of mortality for studies ending in 2000 (or before) is 1.48 (95% CI: 1.26-1.71, I^2 = 96.51%), against 1.62 for studies starting in 2001 or after (95% CI: 1.29-1.96, I^2 = 98.40 %) (**figure 7**).

Figure 6

Forest plot of hazard ratios of mortality for studies ending in 2000 or before, when the exposed group has low education and the unexposed high education

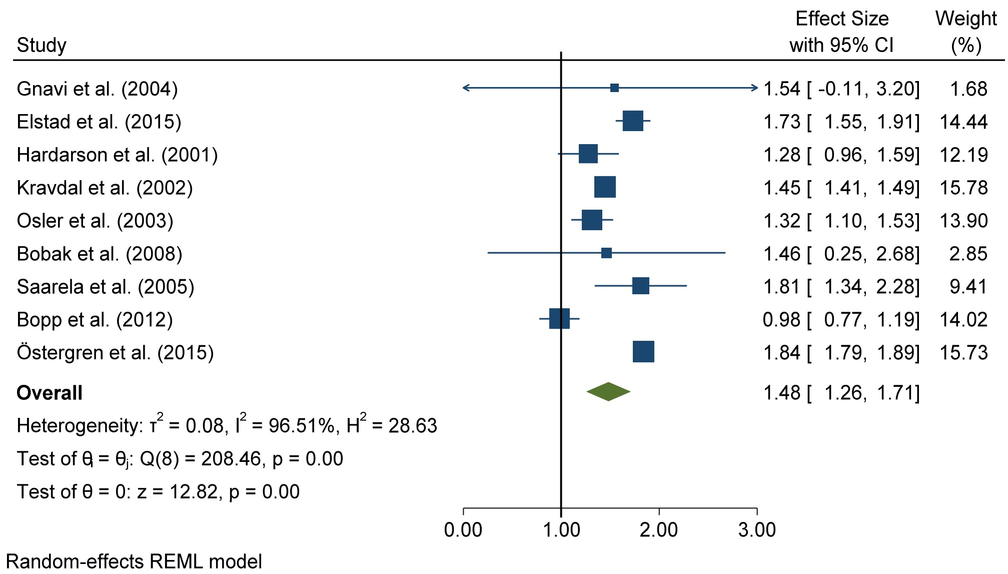
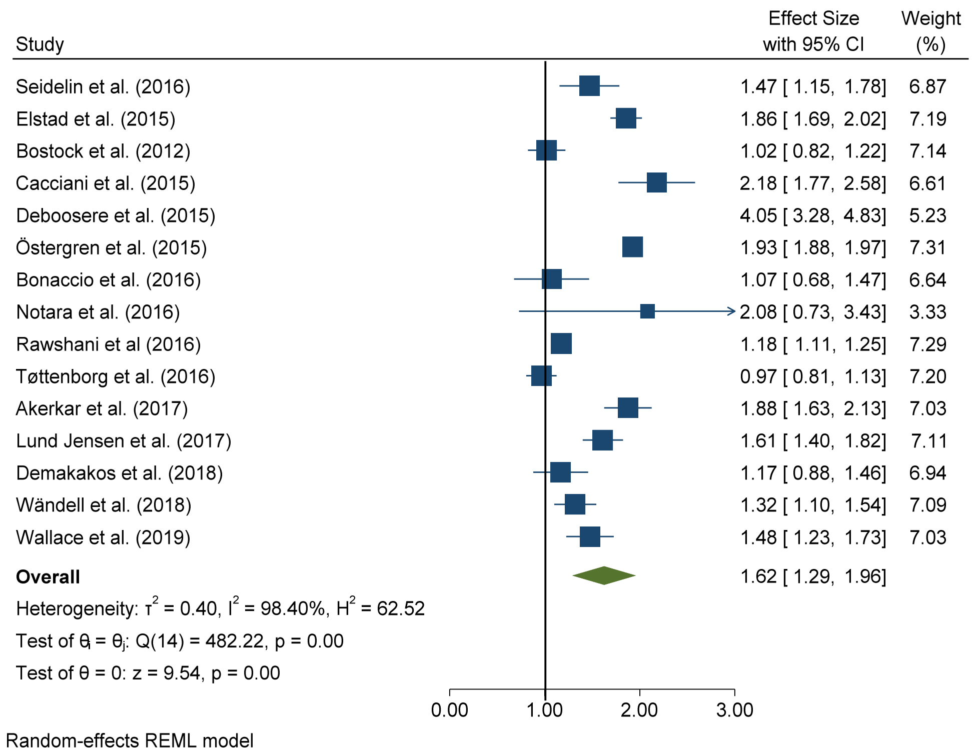


Figure 7

Forest plot of hazard ratios of mortality for studies starting in 2001 or after, when the exposed group has low education and the unexposed high education

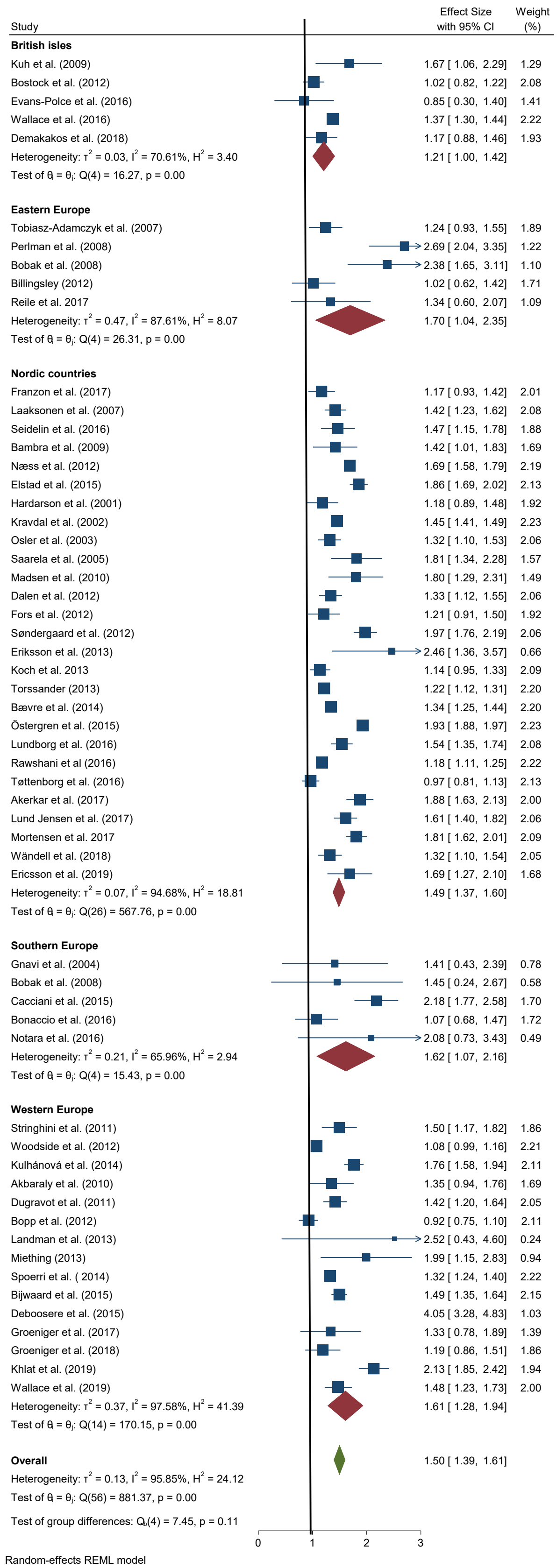


4-Regional differences in the educational inequalities in mortality

Eastern Europe has the largest educational inequalities in mortality in Europe (HR=1.70; 95% CI: 1.04-2.35 I^2=87.61%), while the British Isles have the lowest (HR=1.21; 95% CI: 1.00-1.42, I^2=70.61%). **Figure 8** shows the forest plot of hazard ratios for the different European regions.

Figure 8

Forest plot of hazard ratios of mortality, when the exposed group has low education and the unexposed high education, and upon stratification by European subregion


Study
Effect Size with 95% CI
Weight (%)
British isles
Kuh et al. (2009) 1.67 [1.06, 2.29] 1.29
Bostock et al. (2012) 1.02 [0.82, 1.22] 2.08
Evans-Polce et al. (2016) 0.85 [0.30, 1.40] 1.41
Wallace et al. (2016) 1.37 [1.30, 1.44] 2.22
Demakakos et al. (2018) 1.17 [0.88, 1.46] 1.93
Heterogeneity: τ^2 = 0.03, I^2 = 70.61%, H^2 = 3.40 1.21 [1.00, 1.42]
Test of $\theta_i = \theta_j$: Q(4) = 16.27, p = 0.00
Eastern Europe
Tobiasz-Adamczyk et al. (2007) 1.24 [0.93, 1.55] 1.89
Perlman et al. (2008) 2.69 [2.04, 3.35] 1.22
Bobak et al. (2008) 2.38 [1.65, 3.11] 1.10
Billingsley (2012) 1.02 [0.62, 1.42] 1.71
Reile et al. 2017 1.34 [0.60, 2.07] 1.09
Heterogeneity: τ^2 = 0.47, I^2 = 87.61%, H^2 = 8.07 1.70 [1.04, 2.35]
Test of $\theta_i = \theta_j$: Q(4) = 26.31, p = 0.00
Nordic countries
Franzon et al. (2017) 1.17 [0.93, 1.42] 2.01
Laaksonen et al. (2007) 1.42 [1.23, 1.62] 2.08
Seidelin et al. (2016) 1.47 [1.15, 1.78] 1.88
Bambra et al. (2009) 1.42 [1.01, 1.83] 1.69
Næss et al. (2012) 1.69 [1.58, 1.79] 2.19
Elstad et al. (2015) 1.86 [1.69, 2.02] 2.13
Hardarson et al. (2001) 1.18 [0.89, 1.48] 1.92
Kravdal et al. (2002) 1.45 [1.41, 1.49] 2.23
Osler et al. (2003) 1.32 [1.10, 1.53] 2.06
Saarela et al. (2005) 1.81 [1.34, 2.28] 1.57
Madsen et al. (2010) 1.80 [1.29, 2.31] 1.49
Dalen et al. (2012) 1.33 [1.12, 1.55] 2.06
Fors et al. (2012) 1.21 [0.91, 1.50] 1.92
Søndergaard et al. (2012) 1.97 [1.76, 2.19] 2.06
Eriksson et al. (2013) 2.46 [1.36, 3.57] 0.66
Koch et al. 2013 1.14 [0.95, 1.33] 2.09
Torssander (2013) 1.22 [1.12, 1.31] 2.20
Bævre et al. (2014) 1.34 [1.25, 1.44] 2.20
Östergren et al. (2015) 1.93 [1.88, 1.97] 2.23
Lundborg et al. (2016) 1.54 [1.35, 1.74] 2.08
Rawshani et al (2016) 1.18 [1.11, 1.25] 2.22
Tøttenborg et al. (2016) 0.97 [0.81, 1.13] 2.13
Akerkar et al. (2017) 1.88 [1.63, 2.13] 2.00
Lund Jensen et al. (2017) 1.61 [1.40, 1.82] 2.06
Mortensen et al. 2017 1.81 [1.62, 2.01] 2.09
Wändell et al. (2018) 1.32 [1.10, 1.54] 2.05
Ericsson et al. (2019) 1.69 [1.27, 2.10] 1.68
Heterogeneity: τ^2 = 0.07, I^2 = 94.68%, H^2 = 18.81 1.49 [1.37, 1.60]
Test of $\theta_i = \theta_j$: Q(26) = 567.76, p = 0.00
Southern Europe
Gnavi et al. (2004) 1.41 [0.43, 2.39] 0.78
Bobak et al. (2008) 1.45 [0.24, 2.67] 0.58
Cacciani et al. (2015) 2.18 [1.77, 2.58] 1.70
Bonaccio et al. (2016) 1.07 [0.68, 1.47] 1.72
Notara et al. (2016) 2.08 [0.73, 3.43] 0.49
Heterogeneity: τ^2 = 0.21, I^2 = 65.96%, H^2 = 2.94 1.62 [1.07, 2.16]
Test of $\theta_i = \theta_j$: Q(4) = 15.43, p = 0.00
Western Europe
Stringhini et al. (2011) 1.50 [1.17, 1.82] 1.86
Woodside et al. (2012) 1.08 [0.99, 1.16] 2.21
Kulhánová et al. (2014) 1.76 [1.58, 1.94] 2.11
Akbaraly et al. (2010) 1.35 [0.94, 1.76] 1.69
Dugravot et al. (2011) 1.42 [1.20, 1.64] 2.05
Bopp et al. (2012) 0.92 [0.75, 1.10] 2.11
Landman et al. (2013) 2.52 [0.43, 4.60] 0.24
Miething (2013) 1.99 [1.15, 2.83] 0.94
Spoerri et al. (2014) 1.32 [1.24, 1.40] 2.22
Bijwaard et al. (2015) 1.49 [1.35, 1.64] 2.15
Deboosere et al. (2015) 4.05 [3.28, 4.83] 1.03
Groeniger et al. (2017) 1.33 [0.78, 1.89] 1.39
Groeniger et al. (2018) 1.19 [0.86, 1.51] 1.86
Khlat et al. (2019) 2.13 [1.85, 2.42] 1.94
Wallace et al. (2019) 1.48 [1.23, 1.73] 2.00
Heterogeneity: τ^2 = 0.37, I^2 = 97.58%, H^2 = 41.39 1.61 [1.28, 1.94]
Test of $\theta_i = \theta_j$: Q(14) = 170.15, p = 0.00
Overall 1.50 [1.39, 1.61]
Heterogeneity: τ^2 = 0.13, I^2 = 95.85%, H^2 = 24.12
Test of $\theta_i = \theta_j$: Q(56) = 881.37, p = 0.00
Test of group differences: Q_b(4) = 7.45, p = 0.11
0
1
2
3
Random-effects REML model

5-The age and gender differences in the educational inequalities in mortality

5-1- Gender and educational inequalities in mortality

The educational inequalities in mortality observed in males (HR=1.63; 95% CI: 1.36-1.80, I^2= 98.52%) are similar for females (HR=1.61; 95% CI: 1.40-1.82, I^2=96.79%). **Figure 9** shows the forest plot of hazard ratios of mortality for females and **figure 10** the forest plot of hazard ratios of mortality for males. The educational inequalities in mortality become apparent if only studies controlling for marital status are included. Upon control for marital status, the pooled hazard ratio of mortality for males is 1.35 (95% CI: 1.24-1.46, I^2=76.46%) against 1.23 for females (95% CI: 1.09-1.36, I^2= 78.84%). **figure 11** shows the forest plot of hazard ratios of mortality when controlling for marital status for males and **figure 12** for females.

Figure 9

Forest plot of hazard ratios of mortality in females, when the exposed group has low education and the unexposed high education

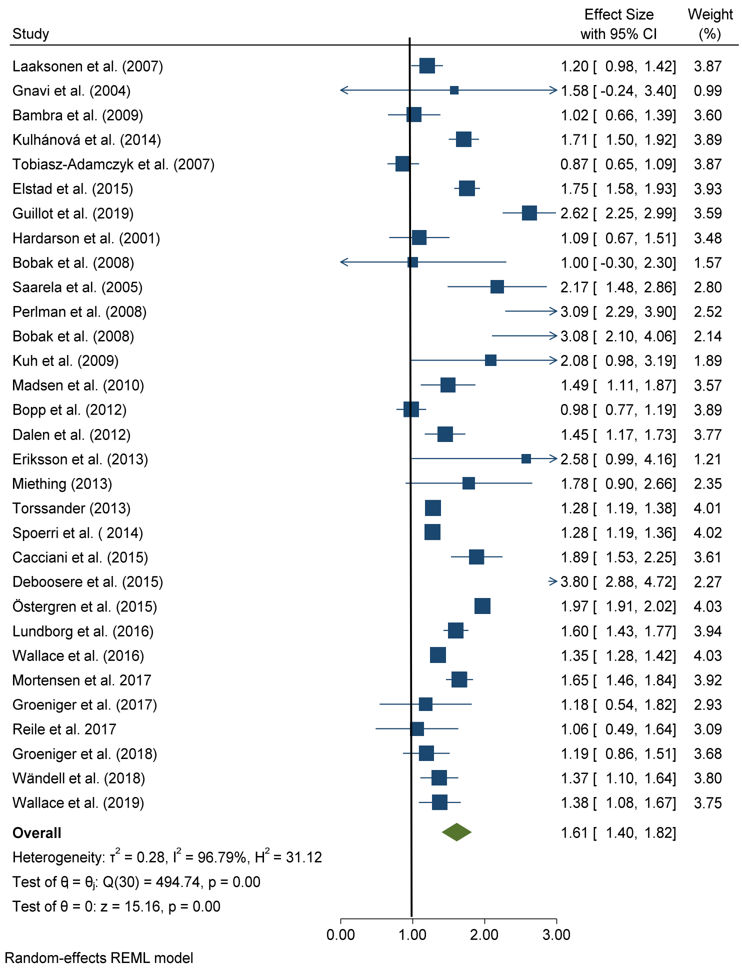


Figure 10

Forest plot of hazard ratios of mortality in males, when the exposed group has low education and the unexposed high education

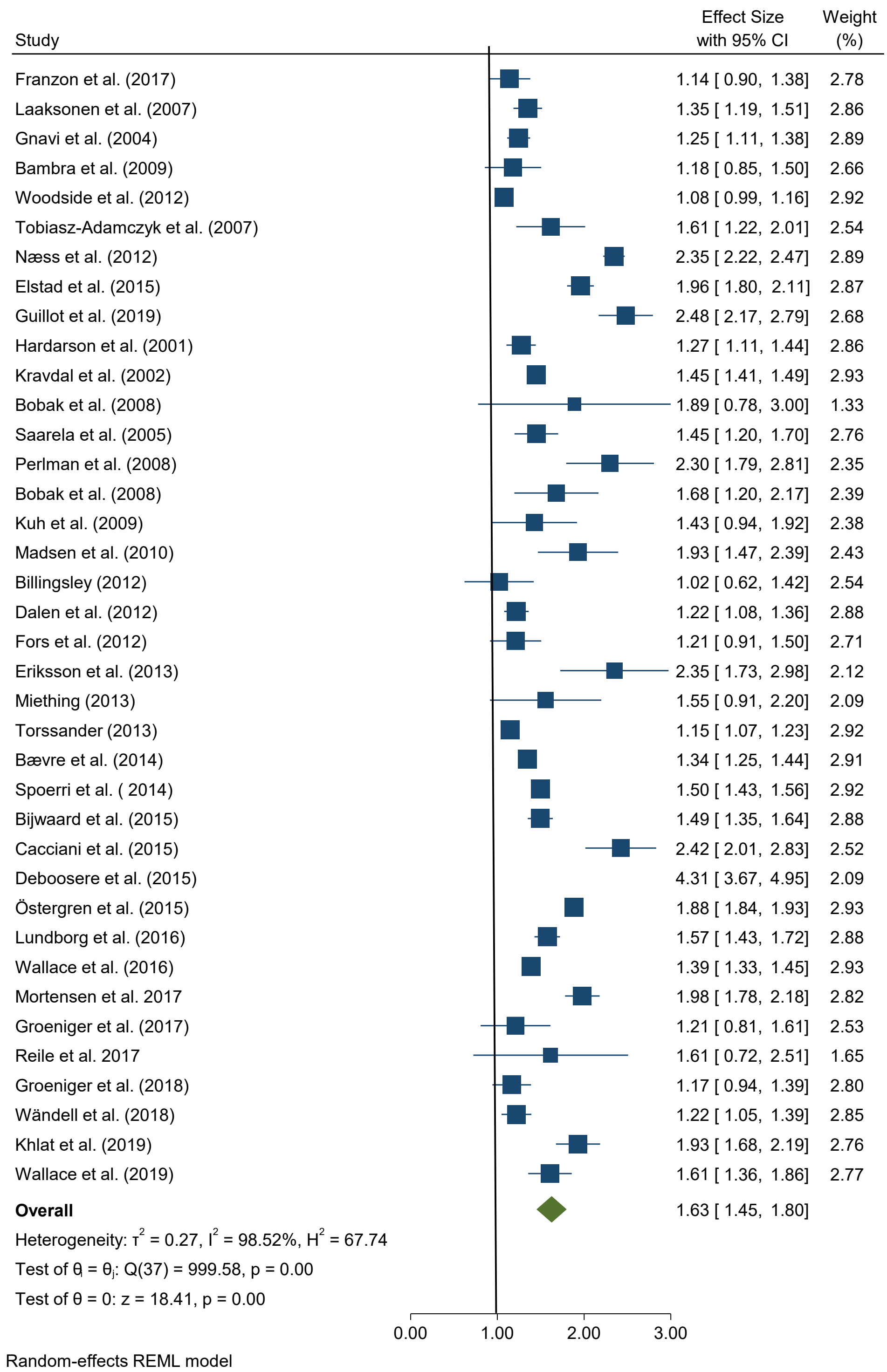


Figure 11

Forest plot of hazard ratios of mortality in males, when the exposed group has low education and the unexposed high education (controlling for marital status)

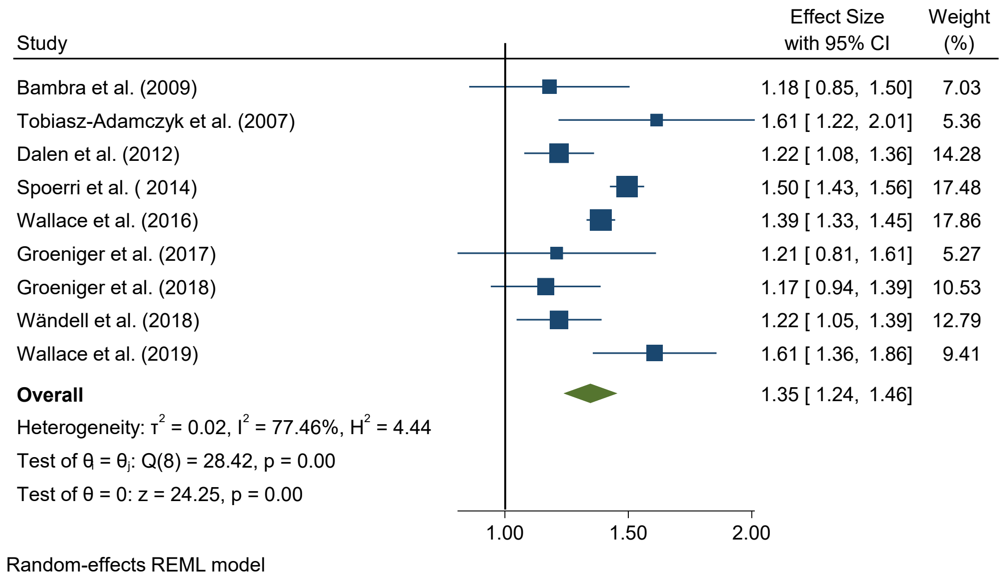
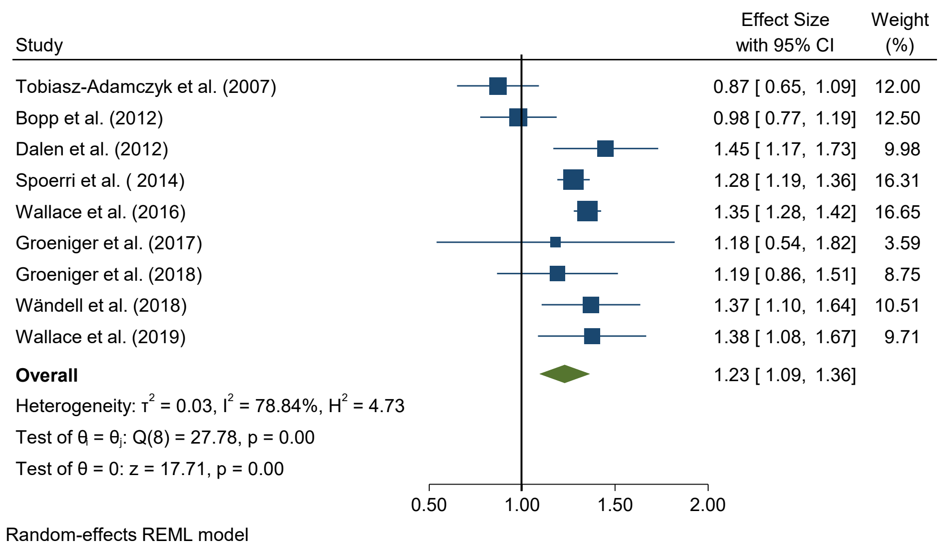


Figure 12

Forest plot of hazard ratios of mortality in females, when the exposed group has low education and the unexposed high education (controlling for marital status)



5-2-Age and educational inequalities in mortality

The educational inequalities in mortality are larger in younger (HR=1.79; 95% CI: 1.48-2.09, I^2= 96.81%) than in older adults (HR=1.31; 95% CI: 1.17-1.45, I^2=79.82%). **Figure 13** shows the forest plot of hazard ratios for adults 65 or older, while **figure 14** shows the forest plot of hazard ratios for adults younger than 65.

Figure 13

Forest plot of hazard ratios of mortality in participants aged 65 years or more, when the exposed group has low education and the unexposed high education

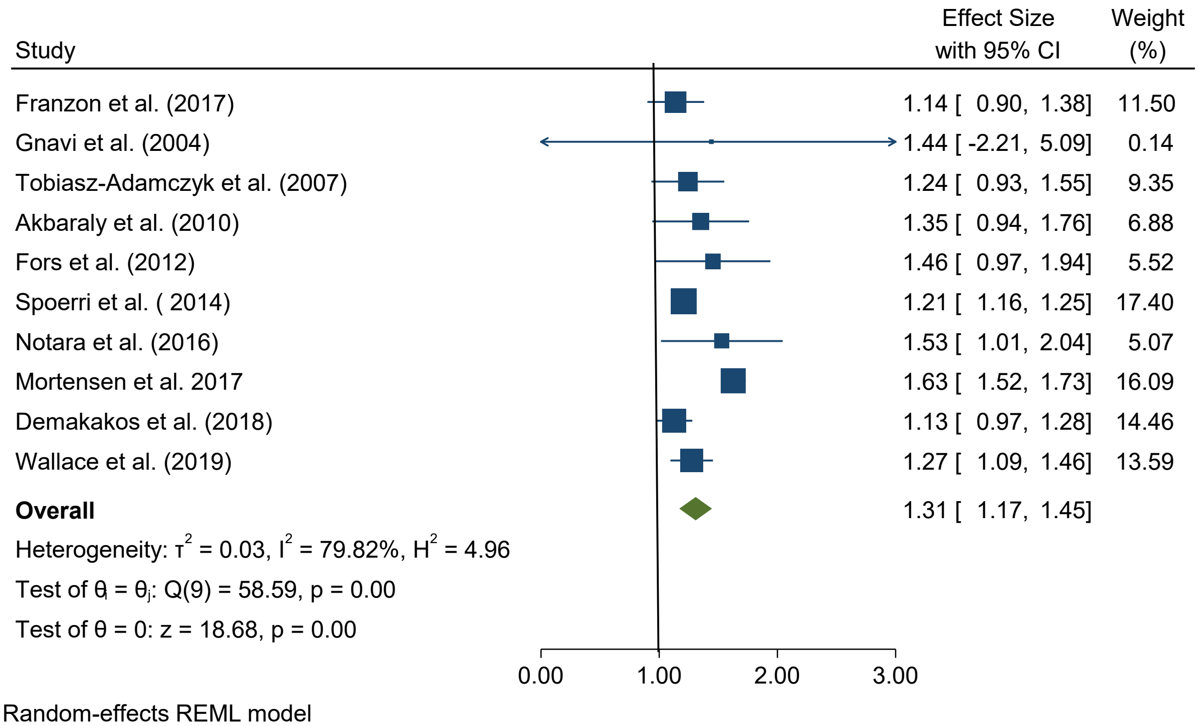
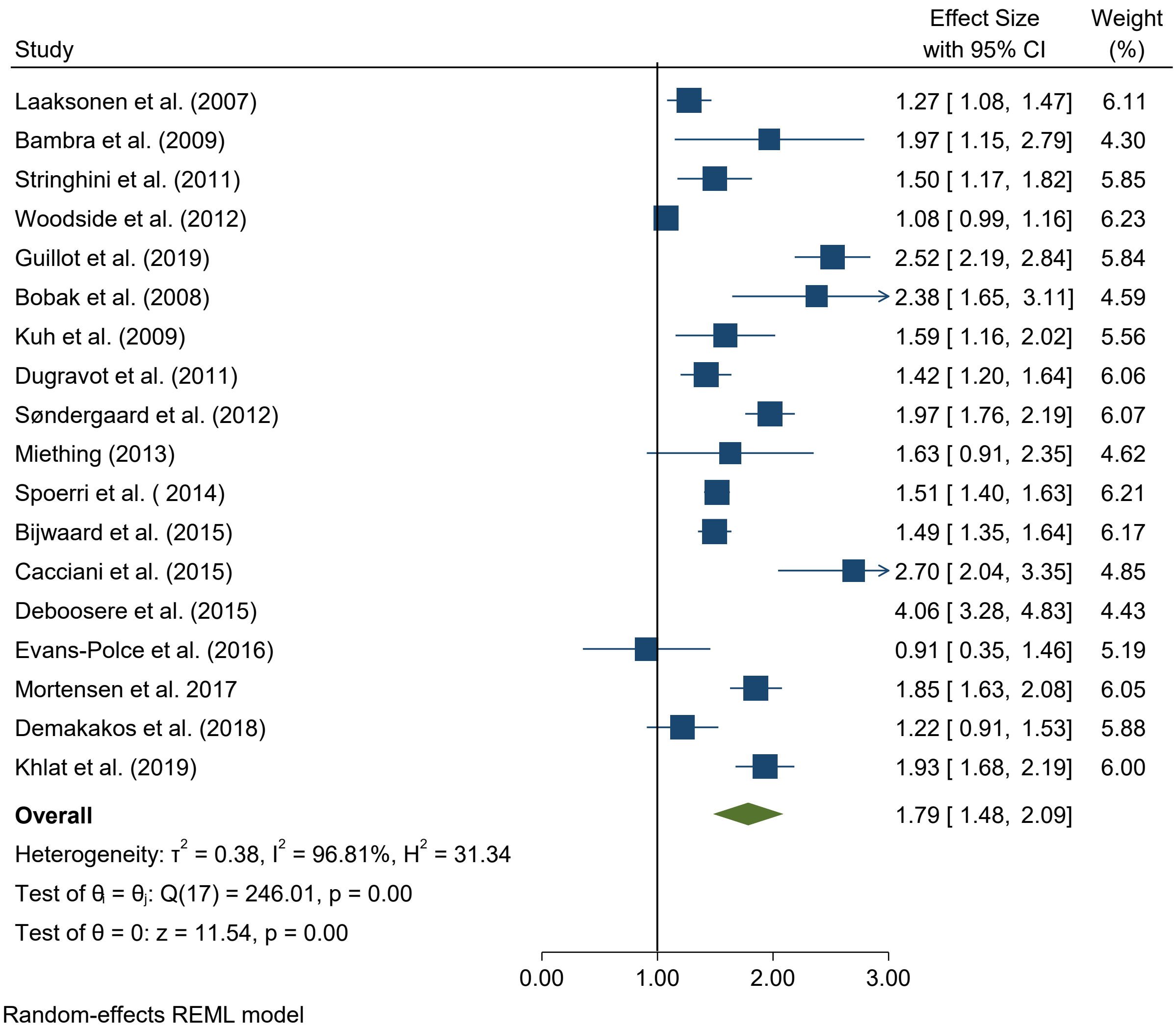


Figure 14

Forest plot of hazard ratios of mortality in participants younger than 65 years, when the exposed group has low education and the unexposed high education



V-Discussion

1- Educational inequalities translating into inequalities in front of death: summary of main findings

Educational attainment has increased in Europe over the past decades, while premature mortality has declined. This thesis aimed to conduct a review and meta-analysis using European data on the association between educational attainment and mortality. Results show that educational inequalities translate into inequalities in front of death, hence the notion of educational inequalities in mortality.

The first aim of this thesis was to explore the changes in the magnitude of educational inequalities when comparing different educational levels. Educational inequalities differ when comparing low to medium education, medium to high education and low to high education. They are the largest when comparing low to high education, and high to medium education, but one year of education alone is still statistically significant. These findings confirm the hypothesis of diverging inequalities depending on which educational levels are compared.

In a context where average educational level has increased over the last decades in Europe, and premature mortality decreased, the second aim was to analyze trends in the educational inequalities. Results from this thesis highlight that educational inequalities are larger in studies starting from 2001 than in studies ending before 2000. Such results confirm the hypothesis of increasing educational inequalities.

The third aim was to complete the trend analysis of educational inequalities by an analysis of the changes in educational inequalities over space. Educational inequalities vary over space, being the stronger in Eastern Europe. Such findings confirm the hypothesis of geographical disparities in the educational inequalities.

The fourth aim was to observe how educational inequalities vary in different social groups. Results highlight that the magnitude of educational inequalities differ between different social groups. They are larger in males (upon adjustment for marital status), and in people younger than 65. Such findings confirm the hypothesis of educational inequalities varying between different groups.

2-Previous empirical evidence and theories

The findings of this thesis are consistent with results from studies at country level and synthetized reviews highlighting educational inequalities in mortality (Byhoff et al., 2017; Hummer & Hernandez, 2013). Previous empirical evidence and theories further detail the association between education and mortality

2-1-Comparing different educational levels

Previous findings confirm that educational inequalities are larger upon comparison of top and bottom educational levels. (Diderichsen et al., 2012). Results from the United States and Japan also highlight that one year of education alone reduces hazard of mortality (Chiu, Hayward, & Saito, 2016).

A year of education alone significantly reduces hazard of mortality, which shows the strength of the relationship between education and mortality. Different theories bring light to the association between education and mortality. The relationship between low education and higher mortality has been explained by various perspectives, such as the social selection perspective, behavioural and material perspective. These perspectives came from the analysis of socioeconomic inequalities in mortality, following publication of the Black Report (Blane, 1985). Social selection analysis argues that individuals with better health are more likely to achieve higher education, and to die later than individual in poorer health. Lower educational level is there not seen as producing poor health, but as the product of poorer health. Childhood health has been documented as a component of the social selection perspective, influencing both educational attainment and adult health (Haas, 2006; Haas, Glymour, & Berkman, 2011). Poor childhood health slows cognitive development and educational attainment. It also changes time discounting preferences. Individuals having poor health as children are more likely to favour the short term over the long term when choosing their education. Longer education is therefore more discounted amongst individuals in poor health than amongst individuals in better health, despite its higher long-term prospects.

Behavioural and material approaches introduce factors that can act as mediators or confounders in the association between education and mortality. Low education can result in certain behavioural or material characteristics that in turn impact mortality. Low education is for example linked to determinants of mortality such as smoking (El Rhazi et al., 2008; McFadden, Luben, Wareham, Bingham, & Khaw, 2008; Mereu, Sardu, Minerba, & Contu, 2009), lower income, or lower self-perceived health (Eurostat, 2019b)·. Lower material conditions resulting from low education, both in the household and on the workplace, such as economic deprivation, income, manual work, unemployment, are also often presented as factors increasing hazard of mortality in the reviewed studies (Van Hedel, Van Lenthe, Oude Groeniger, & Mackenbach, 2018). Different behavioural and material variables can parallelly act as confounders influencing both education and mortality. For example, lower parental education and/or parental socio-economic status are linked with lower educational level achieved (OECD, 2007; Rodríguez-Hernández, Cascallar, & Kyndt, 2020), the same goes for health status, self-perceived health and drugs consumption (Haas & Fosse, 2008; Silins et al., 2015). These same factors, health status, self-perceived health, parental education, socio-economic status, parental and behavioural variables, are known determinants of all-cause mortality (Petrovic et al., 2018; Taylor & Quine, 1992).

2-2-An increase in the educational inequalities

The association between higher education and lower mortality is visible in Europe. This association has increased, educational inequalities in mortality being stronger from 2001 than before. Such results are concordant with previous findings from the literature (Diderichsen et al., 2012; Strand et al., 2010).

Some of the existing theories on increased social inequalities adopt an "artefact" perspective when explaining the increase. The artefact perspective suggests that increased social inequalities can be partly explained by how social categories have been constituted, and by an increase in the average social class (Blane, 1985). In a context where lower social classes shrink, the differences between individuals remaining in the lower social classes and individuals in the higher social classes become larger. Such a perspective can be applied to education. As the demand for occupations requiring higher education has increased, the demand for manual and routine occupations requiring little education has shrunk. Remaining in low education is therefore more than before linked to lower cognitive abilities and lower social classes, which in turns impacts mortality (J. P. Mackenbach, 2010).

2-3- Regional differences in the educational inequalities

Findings of geographic disparities in the educational inequalities are concordant with previous results from the literature. Eastern European countries have been reported as facing more inequalities than their neighbours in Southern, Western and Northern Europe (J. Mackenbach, Menvielle, Jasilionis, & Gelder, 2015).

Behavioural and material factors can be structural at country scale and contribute to explain the geographical distribution of the educational inequalities in mortality. Inequalities in the Nordic countries are for example not much smaller than average in Europe, and higher than in other European countries such as the British Islands, despite Nordic countries being often depicted as egalitarian countries. This trend has been described as “the Nordic paradox”. An explanation can be that the Nordic countries have implemented more health prevention and promotion programs than other countries. These prevention programs are both positively associated with educational attainment and mortality. Since people with higher education are more likely to adapt their behaviour to these recommendations, they see more benefits from such programs in terms of mortality reduction (J. P. Mackenbach, 2017). Mackenbach (2017) applies similar analysis to the large educational inequalities in mortality observed in Eastern Europe: the transition to capitalism in the 1990s resulted in a decreased quality of material conditions, affecting both educational attainment and hazard of mortality, with a stronger negative effect on people from lower social classes.

2-4- Larger educational inequalities in younger adults and in males

Educational inequalities vary over time and space, and when comparing different groups. They are larger in people younger than 65, a finding which is consistent with previous findings from the literature (Byhoff et al., 2017). However, larger educational inequalities in males are observed only upon adjustment for marital status. Diverging results on the effect of gender can also be found in the literature. While some authors highlight larger educational inequalities in males than in females (Taylor & Quine, 1992), other find that association only in married people (Zajacova, 2006).

Increased educational inequalities in males and females can be understood in light of the behavioral perspective. Educational inequalities in smoking are for example larger in younger than in older cohorts, and larger in males than in females (Maralani, 2013). Such educational inequalities in behavioural factors can explain educational inequalities in mortality.

3-Implication for policy making and further research

3-1-Implication of the variation in educational inequalities upon comparison of different educational level

An educational year alone reduces hazard of mortality. This shows how significant educational inequalities are. However, this thesis does not give detailed information on the curvature of the relationship between years of education and mortality. The preventive effect education has on mortality could decrease after a given threshold. From a public policies perspective, it is interesting to determine where the inflection point of the relation between education and mortality. Doing so could facilitate an effective allocation of resources.

3-2-Implications of the variation in educational inequalities over time

The association between education and mortality has been confirmed. This association is becoming stronger, as Europe is facing an increase in the educational inequalities. It can be questioned whether the common classification of education into low (less than high school), medium (high school) and high (higher education) is still adapted to the current situation, when rates of educational attainment and completion have known significant changes. In France for example, around 56% of the population 25 and above had completed upper secondary education in 2004, against 70% in 2017 (The World Bank, 2017b). On the other hand, completion of short-cycle tertiary education for those aged 25 and older went from 19% in 2004 to 30% in 2017 (The World Bank, 2017a). Using the same classification of education over time could lead to an overestimation of the increase in the educational inequalities in mortality. These findings of increased educational inequalities can therefore motivate adjustment for what is considered "low education" by the European Commission and other international institutions, and further monitoring of the impact of such adjustments.

3-3-Implication of the variation in educational inequalities over space

Educational inequalities vary over time and space. The findings of regional disparities in educational inequalities can motivate collaboration between European countries to explore to what extent policies in regions with low inequalities could be generalized to other regions.

3-4-Implication of the variation in educational inequalities between different groups

Inequalities also vary when comparing different groups. These findings can encourage policies aimed at reinforcing educational attainment in males and in younger adults. Additionally, interventions targeting males and younger adults with low education could mitigate the behavioural and material inequalities associated with low education.

3-5-Joint implications of findings

It could be interesting to further explore to what extend different behavioural and material factors act as mediators or confounders, in other words, how much the relationship between education and mortality in Europe can be explained by adjustment for confounders and identification of mediators.

Including the right behavioural and material factors as confounders reduces risk of an overestimation of the effect of education. Including more confounders often results in a decrease in the educational inequalities in mortality (Osler & Prescott, 2003). Even though included studies controlled for confounders, further research can improve understanding of the different confounders at play. Mediators could also be controlled for, to gain an insight in the direct effect of education, not mediated through other factors. Byhoff et al. (2017) suggests that if the effect of education remains strong after adjustment for mediators, emphasis should be put on increasing educational attainment. However, if the effect of education is low upon adjustment for mediators, groups with low education could receive targeted public health programs to mitigate the impact low education has on mediators.

Potential for intervention remains. The fact that educational inequalities vary (over time and space, when comparing different educational and groups) shows that they are modifiable, and that they could respond to policies aiming to reduce educational inequalities. It also suggests that increasing educational attainment of the general population could leave educational inequalities unchanged (or increased) if no policy is implemented to mitigate educational inequalities.

4-Limitations of the study

4-1-Quantity of education vs. quality of education and heterogeneity

One of the limitations of this study is that little differentiation could be made between different types of education. Consequently, quality of education can vary within the same level. This thesis compares hazard of mortality associated with different levels of education but not different types of graduate education, or specialization chosen for high school diploma. Available literature suggests that the association between education and mortality does not equate to the mere sum of years of education, but also to the nature of the education achieved (Montez, Hummer, & Hayward, 2012). Degrees from different universities, or different countries can be of a varying quality, even within the same specialization. The same level of education can also encompass different realities. For example, primary education lasts 4 years in Germany, but 5 years in France and 10 years in Norway. In a multi country meta-analysis setting, there is however a need for a systematic way to compare educational levels, hence the choice of the classification into low/medium/ high education. Because of few studies in the Europe GBD region reporting separately primary education and no education, individuals with primary education or lower were coded as "ISCED level 1 or lower", and no difference was made between primary education and less than primary education. For participants in tertiary education (ISCED level 5+), no difference was made in this review between short cycle tertiary education, bachelor, master, and PhD. This is because few included studies have separate entries for the different diplomas from post-secondary education. ISCED level 5 or higher was coded in a single "high education" category. The aim with that coding method was to reflect as thoroughly as possible the levels of education reported in the included studies, while having comparable levels of education.

Another element is that not all the included studies had reported education in the same way. To consider a participant as having attained an educational level, some studies required that this participant had passed a graduating exam, while others required a mere attainment until the end of the level. There was also no way to check for the accuracy of the declarations in cases where the educational level was self-declared.

All these differences in how education was measured and in the quality of education can be linked to the high degree of heterogeneity between all the studies included in this meta-analysis. In a multi country analysis, high degrees of heterogeneity is often explained by differences in administration of the study, differences in study environment (Imrey, 2020). Other explanations to the heterogeneity can be the population studied, and confounders included. Included studies have different selection criteria, some were for example using population registries, other targeting specific groups, or hospitalized patients.

4-2-Publication and selection biases

This thesis has shortcomings due to the geographic origin of the included studies. Some countries in the European GBD region were more documented than others, relatively to their population, notably the Nordic countries. In some countries, studies were conducted in specific urban areas and did not use national registries. French, Polish, Italian studies were often conducted in cities (Turin, Lyon, Krakow, Milano etc.). In these countries, the pooled effect sizes could therefore not be as representative for urban and rural populations. On the other hand, Nordic studies tended to use population registries at country level. Some social groups might be less represented than others, especially in studies that do not use population registries, since people with low education are less likely to take part in health studies (Jepsen et al., 2020; Pandya, 2014). Population registries can also fail to track certain groups such as unregistered migrants, and on the other hand report results for groups no longer living in the country, such as emigrants who have not reported their move abroad. This brings concerns related to external validity. The effect of education on mortality might therefore not be generalizable to groups that are less likely to take part in a study, or that are less likely to be included in population registries, despite living in the country.

Also, due to publication bias, studies finding no association between years of education and mortality are less likely to be published than studies finding an association. This meta-analysis might lack examples of contexts where no association was found, and therefore could overestimate the effect size of education.

4-3-Adjustment for confounders

Adjustment for confounders is an important limitation of this study. Most studies included various confounders. Age and gender were almost systematically included as confounders. Other common confounders included income, employment status, occupation, SES, marital status, chronic diseases. However, several studies still had moderate or high bias because of confounders included.

Not being able to include as many confounders as possible could lead to an overestimation of the effect size of education.

Different degrees of inclusion of confounders may explain why no larger educational inequalities in mortality are found in males before control for marital status. There is a higher number of confounders in the studies reporting results for males, than in the studies reporting results for females. Average number of confounders is 2.4 for the female subset, against 2.8 for the male subset. Additionally, more data is available specifically for males: aside the 31 studies reporting subgroup results for males and females, 7 studies reported results exclusively for males. These studies could have included more relevant confounders to the association between male gender and mortality. Results from the literature report for example that variation in family type (cohabitation, having children) account for a greater share of mortality inequalities for males than for females (Östergren, 2015). This could explain why the larger educational inequalities in mortality in males are found when adjusting for marital status.

VI-Conclusion

There is an association between educational level and mortality in Europe. Educational inequalities in mortality are the strongest when comparing low to high education, however one year of education alone still significantly decreases hazard of mortality. These inequalities further vary when comparing different regions or groups and have increased over time. Such findings are consistent with previous results from the literature outside of Europe or at country level. Further research could pinpoint what is the optimal level of individual education to reduce hazard of mortality, explore why educational inequalities have increased over time in Europe and investigate how regions with higher educational inequalities could benefit from regions with low educational inequalities.

Joint implications of these findings include the need for further research on the different mediators and confounders to the association between education and mortality. There is still a potential for successful intervention reducing educational inequalities. The fact that educational inequalities vary shows that they are modifiable and could be sensitive to interventions aiming to reduce inequalities in mortality. These interventions could first target groups with the largest educational inequalities such as younger adults or males.

VII-References

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VIII-Appendix

Appendix 1

Full search query used

Scopus

ALL (education OR educated OR "educational attainment" OR educational OR "educational attainment" OR "education level" OR "socio-economic status" OR socioeconomic OR "socioeconomic status" OR "social class" OR disparities OR differences OR income OR occupation OR "occupational position" OR "occupational inequalities" OR "social inequalities" OR "socioeconomic position" OR "health inequalities" OR "health equity" OR inequalities OR equity OR schooling OR literate OR literacy OR graduation OR "years of school" OR "school attendance" OR diploma OR "educational status" OR "social status" OR ethnicity OR employment OR gender OR emigrant* OR immigrant* OR poverty OR geography OR "marital status") W/10 adult* W/10 (mortality OR "mortality rate" OR "all-cause mortality" OR "all-cause mortality" OR "total mortality" OR death OR longevity OR survival OR "life expectancy") AND PUBYEAR > 1979

WOS

(education OR educated OR "educational attainment" OR educational OR "educational attainment" OR "education level" OR "socio-economic status" OR socioeconomic OR "socioeconomic status" OR "social class" OR disparities OR differences OR income OR occupation OR "occupational position" OR "occupational inequalities" OR "social inequalities" OR "socioeconomic position" OR "health inequalities" OR "health equity" OR inequalities OR equity OR schooling OR literate OR literacy OR graduation OR "years of school" OR "school attendance" OR diploma OR "educational status" OR "social status" OR ethnicity OR employment OR gender OR emigrant* OR immigrant* OR poverty OR geography OR "marital status") NEAR/10 adult* NEAR/10 (mortality OR "mortality rate" OR "all-cause mortality" OR "all-cause mortality" OR "total mortality" OR death OR longevity OR survival OR "life expectancy")

Ovid (Medline, EMbase, Global Health)

(education OR educated OR "educational attainment" OR educational OR "educational attainment" OR "education level" OR "socio-economic status" OR socioeconomic OR "socioeconomic status" OR "social class" OR disparities OR differences OR income OR occupation OR "occupational position" OR "occupational inequalities" OR "social inequalities" OR "socioeconomic position" OR "health inequalities" OR "health equity" OR inequalities OR equity OR schooling OR literate OR literacy OR graduation OR "years of school" OR "school attendance" OR diploma OR "educational status" OR "social status" OR ethnicity OR employment OR gender OR emigrant* OR immigrant* OR poverty OR geography OR "marital status") ADJ10 adult* ADJ10 (mortality OR "mortality rate" OR "all-cause mortality" OR "all-cause mortality" OR "total mortality" OR death OR longevity OR survival OR "life expectancy")

Econlit & sosciology source ultimate

(education OR educated OR "educational attainment" OR educational OR "educational attainment" OR "education level" OR "socio-economic status" OR socioeconomic OR "socioeconomic status" OR "social class" OR disparities OR differences OR income OR occupation OR "occupational position" OR "occupational inequalities" OR "social inequalities" OR "socioeconomic position" OR "health inequalities" OR "health equity" OR inequalities OR equity OR schooling OR literate OR literacy OR graduation OR "years of school" OR "school attendance" OR diploma OR "educational status" OR "social status" OR ethnicity OR employment OR gender OR emigrant* OR immigrant* OR poverty OR geography OR "marital status") N10 adult* N10 (mortality OR "mortality rate" OR "all-cause mortality" OR "all-cause mortality" OR "total mortality" OR death OR longevity OR survival OR "life expectancy").

Appendix 2

Table 4

List of commonly included confounders

Confounders	*N. of studies (high vs. low education only)*	*N. of studies ((from all included studies)*
Age	43	50
Sex	17	24
Marital status	14	15
Income	10	11
Occupation	7	7
Employment status	8	8
Ethnicity	3	3
Smoking	21	22
Alcohol	10	12
Physical activity	10	12
Dietary components	4	5
BMI	12	14
Hypertension	6	6
Diabetes	8	9
Self-reported health	3	3

Appendix 3

Table 5

Quality assessment of included studies

	Bias due to confounding	Bias in selection of participants into the study	Bias in classification of interventions	Bias due to deviations from intended interventions	Bias due to missing data	Bias in measurement of outcomes	Bias in selection of the reported result
Kravdal, 2002							
Miething, 2013							
Guillot, Khlat, & Wallace, 2019							
Wallace, 2016							
Evans-Polce, Staff, & Maggs, 2016							
Castagné et al., 2018							
Dalen, Huijts, Krokstad, & Eikemo, 2012							
Bostock & Steptoe, 2012							
Khlat, Wallace, & Guillot, 2019							
Kuh et al., 2009							
Stringhini, Dugravot, Kivimaki, et al., 2011							
Woodside et al., 2012							
Madsen, Andersen, Christensen, Andersen, & Osler, 2010							
Seidelin et al., 2016							

Næss, Hoff, Lawlor, & Mortensen, 2012						
Cacciani et al., 2015						
De Grande, Vandenheede, & Deboosere, 2015						
Landman et al., 2013						
Akerkar et al., 2017						
Kulhánová, Hoffmann, Eikemo, Menvielle, & Mackenbach, 2014						
Osler & Prescott, 2003						
Koch, Nørgaard, Schønheyder, Thomsen, & Søgaard, 2013						
Reile & Leinsalu, 2017						
Mortensen & Torssander, 2017						
Torssander, 2013						
Bijwaard, van Poppel, Ekamper, & Lumey, 2015						
Östergren, 2015						
Stringhini, Dugravot, Shipley, et al., 2011						
Bopp, Braun,						

Gutzwiller, & Faeh, 2012						
Laaksonen et al., 2007						
Rawshani, Svensson, Rosengren, Eliasson, & Gudbjörnsdottir, 2015						
Spoerri, Schmidlin, Richter, Egger, & Clough-Gorr, 2014						
Arrich, Lalouschek, & Müllner, 2005						
Bonaccio et al., 2016						
Billingsley, 2012						
Tobiasz-Adamczyk, Bartoszewska, Brzyski, & Kopacz, 2007						
Ericsson, Pedersen, Johansson, Fors, & Dahl Aslan, 2019						
Eriksson, Kajantie, Lampl, Osmond, & Barker, 2013						
Skalická, van Lenthe, Bambra, Krokstad, & Mackenbach, 2009						
Akbaraly et al., 2010						
Wallace, Khlat, & Guillot, 2019						

Saarela & Finnäs, 2005						
Franzon et al., 2017						
Elstad, Øverbye, & Dahl, 2015						
Oude Groeniger, Kamphuis, Mackenbach, & van Lenthe, 2017						
Vescio, Smith, & Giampaoli, 2003						
Perlman & Bobak, 2008b						
Marmot & Shipley, 1996						
Wändell et al., 2018						
Tøttenborg et al., 2016						
Ullits et al., 2015						
Demakakos, Biddulph, de Oliveira, Tsakos, & Marmot, 2018						
Lundborg, Lyttkens, & Nystedt, 2016						
Jørgensen et al., 2016						
Bævre & Kravdal, 2014						
Notara et al., 2016						
Lund Jensen et al., 2017						
Hardarson et al., 2001						
Van Hedel et al., 2018						

Rawshani et al., 2016							
Perlman & Bobak, 2008a							
Meghir, Palme, & Simeonova, 2012							
Deary & Der, 2005							
Todd, Shkolnikov, & Goldman, 2016							
Gnavi et al., 2004							
Fors, Modin, Koupil, & Vågerö, 2012							
Søndergaard et al., 2012							

Appendix 4

Table 6

List of countries represented

Country name	*N. of studies (high vs. low education only)*	*N. of studies ((from all included studies)*
Austria	1	1
Belgium	1	1
Denmark	10	8
Estonia	1	1
Finland	4	4
France	7	7
Germany	1	1
Greece	1	1
Iceland	1	1
Ireland	1	1
Italy	4	3
Netherlands	5	5
Norway	7	7
Poland	1	1
Russia	4	4
Sweden	12	10
Switzerland	2	2
United Kingdom	8	8

Note: Total exceeds number of studies included because several studies had pooled the results from several countries.

Appendix 5

Table 7

Summary information of included studies

Author	Country	Population selection criteria	Absolute sample size used	Study design	Timeline of data used
Kravdal, 2002	Norway	Resident in Norway aged 40-80 and with cancer diagnostic	386729	Retrospective cohort	1960-1991
Miething, 2013	Germany	Aged 25-64	22568	Prospective cohort	1995-2010
Guillot, Khlat, & Wallace, 2019	France	Aged at least 20	429207	Retrospective cohort	2004-2014
Wallace, 2016	United Kingdom	Living in England and Wales aged 20 or more	555111	Prospective cohort	1991-2012
Evans-Polce, Staff, & Maggs, 2016	United Kingdom	Adults born in 1958 and alcohol abstainers by age 33	11469	Prospective cohort	1991-2009
Castagné et al., 2018	United Kingdom	Aged 44	8113	Prospective cohort	2002-2013
Dalen, Huijts, Krokstad, & Eikemo, 2012	Norway	Aged 25 and older, residing in Nord-Trøndelag	56788	Retrospective cohort	1984-2204
Bostock & Steptoe, 2012	Norway	Living in Nord-Trøndelag	56788	Retrospective cohort	1984-2004
Khlat, Wallace, & Guillot, 2019	France	Aged 18-64	198409	Retrospective study	1999-2010
Kuh et al., 2009	United Kingdom	Living in England, Scotland or Wales	4461	Prospective cohort	1946-2006
Stringhini, Dugravot, Kivimaki, et al., 2011	United Kingdom, France	Londonian civil servants aged 35-55 + Workers from the French national gas and electricity	25453	Prospective cohort	1985-2005

		company in 1989			
Woodside et al., 2012	France, Ireland	Males 50-59	9709	Prospective cohort	1991-2001
Madsen, Andersen, Christensen, Andersen, & Osler, 2010	Denmark	Aged 30-87	112981	Prospective cohort	1921-2008
Seidelin et al., 2016	Denmark	Women diagnosed with endometrial cancer between 2005-2009	3868	Retrospective cohort	2005-2011
Næss, Hoff, Lawlor, & Mortensen, 2012	Norway	Individuals born 49-50, with siblings and alive in 1990	871367	Prospective cohort	1960-2008
Cacciani et al., 2015	Italy	Italian citizens from Rome	1283767	Prospective cohort	2001-2012
De Grande, Vandenheede, & Deboosere, 2015	Belgium	Living in Flanders or Brussel agglomeration	880117	Retrospective cohort	2001-2010
Landman et al., 2013	Netherlands	Adults with type 2 diabetes	656	Prospective study	1998-2009
Akerkar et al., 2017	Norway	Aged 30 or more with atrial fibrillation (AF)	42138	Retrospective cohort	2008-2012
Kulhánová, Hoffmann, Eikemo, Menvielle, & Mackenbach, 2014	Netherlands	Dutch people aged 30-79	332869	Retrospective cohort	1998-2007
Osler & Prescott, 2003	Denmark	Aged 30 and over living in Copenhagen	18344	Prospective cohort	1980-1999
Koch, Nørgaard, Schønheyder, Thomsen, & Søgaard, 2013	Denmark	Patients in Northern Denmark and Copenhagen suffering, from bacteraemia, aged 30-65	8382	Prospective cohort	2000-2008

Reile & Leinsalu, 2017	Estonia	Aged 25-79	3983	Retrospective cohort	1996-2013
Mortensen & Torssander, 2017	Sweden	Having full biological siblings	1732119	Retrospective cohort	1990-2012
Torssander, 2013	Sweden	Aged 29-79 with one child or more	624761	Retrospective cohort	1970-2007
Bijwaard, van Poppel, Ekamper, & Lumey, 2015	Netherlands	Non-institutionalized males examined for conscription	39789	Prospective cohort	1962-2011
Östergren, 2015	Sweden	Aged 30-79	729 million person-months	Prospective cohort	2005-2009
Stringhini, Dugravot, Shipley, et al., 2011	France	Workers from the French national gas and electricity company in 1989	17449	Retrospective cohort	1989-2009
Bopp, Braun, Gutzwiller, & Faeh, 2012	Switzerland	Adults residing in Switzerland	8251	Retrospective cohort	1977-2000
Laaksonen et al., 2007	Finland	Individuals aged 25-64	60608	Retrospective cohort	1979-2001
Rawshani, Svensson, Rosengren, Eliasson, & Gudbjörnsdottir, 2015	Sweden	Aged 18-70	217364	Retrospective cohort	2003-2012
Spoerri et al., 2014	Switzerland	Having been married	3648879	Retrospective cohort	2000-2008
Arrich, Lalouschek, & Müllner, 2005	Austria	Stroke patient hospitalized in neurology	2606	Prospective cohort	1998-2003
Bonaccio et al., 2016	Italy	35-99 living in Southern Italy	16247	Prospective cohort	2005-2015
Billingsley, 2012	Russia	Men aged 18-65	7518	Retrospective cohort	1994-2010
Tobiasz-Adamczyk, Bartoszewska, Brzyski, & Kopacz, 2007	Poland	Krakow old town residents	2580	Retrospective cohort	1986-2005

Ericsson, Pedersen, Johansson, Fors, & Dahl Aslan, 2019	Sweden	Born before 1935 with a twin	26364	Retrospective cohort	1960-2014
Eriksson, Kajantie, Lampl, Osmond, & Barker, 2013	Finland	Resident in Helsinki	13345	Retrospective cohort	1971-2007
Skalická, van Lenthe, Bambra, Krokstad, & Mackenbach, 2009	Norway	Resident in central Norway	36525	Retrospective cohort	1995-2003
Akbaraly et al., 2010	France	Living in Bordeaux, Dijon, Montpellier, 65 and older	7118	Prospective cohort	1999-2008
Wallace, Khlat, & Guillot, 2019	France	Aged 18-64	72847	Prospective study	1999-2010
Saarela & Finnäs, 2005	Finland	Aged 40-70, speaking finish and/or Swedish	57147	Retrospective cohort	1989-1999
Franzon et al., 2017	Sweden	Men living in Uppsala born from 1920 to 1924	1104	Prospective cohort	1993-2009
Elstad, Øverbye, & Dahl, 2015	Norway	Aged 20-69	2706633	Retrospective cohort	1993-2011
Oude Groeniger, Kamphuis, Mackenbach, & van Lenthe, 2017	Netherlands	Aged 25 and over living in Eindhoven urban area	4851	Prospective cohort	1991-2003
Vescio, Smith, & Giampaoli, 2003	Italy	Living in the province of Latina, Lazio, or central Italy	8414	Prospective cohort	1983-2000
F. Perlman & M. Bobak, 2008	Russia	Individuals not living alone	11482	Prospective cohort	1994-2002

Marmot & Shipley, 1996	Finland	Non institutionalized, aged 35-64	276592	Retrospective cohort	1989-1994
Wändell et al., 2018	Sweden	Aged 45 and over with AF, patients in a primary care centres	12283	Retrospective cohort	2001-2010
Tøttenborg et al., 2016	Denmark	COPD patients	217364	Retrospective cohort	2008-2012
Ullits et al., 2015	Denmark	Living in Northern Jutland, aged 30 or more	10105	Retrospective study	2007-2012
Demakakos, Biddulph, de Oliveira, Tsakos, & Marmot, 2018	United Kingdom	Aged 50 and over, living in England	9972	Prospective cohort	2002-2013
Lundborg, Lyttkens, & Nystedt, 2016	Sweden	Having a same-sex twin	49572	Retrospective cohort	1961-2009
Jørgensen et al., 2016	Denmark	Born 1939-1959	346500	Prospective cohort	1968-2013
Bævre & Kravdal, 2014	Norway	Aged 50-69	2125394	Retrospective cohort	1968-2002
Notara et al., 2016	Greece	Hospitalized with acute coronary syndrome in one of the 6 major Greek hospitals	1918	Prospective cohort	2003-2014
Lund Jensen et al., 2017	Denmark	Danish citizens	151546	Prospective cohort	2010-2014
Hardarson et al., 2001	Iceland	Residents in the agglomeration of Reykjavik	18912	Retrospective cohort	1968-1991
Van Hedel et al., 2018	Netherlands	Aged 25 and over living in Eindhoven urban area	13034	Retrospective cohort	1991-2013
Rawshani et al., 2016	Sweden	Younger than 70 with type 2 diabetes	217364	Retrospective cohort	2003-2012

Francesca Perlman & Martin Bobak, 2008	Russia	Adults from Moscow, St Petersburg and 38 additional population centers	11482	Prospective cohort	1994-2001
Meghir, Palme, & Simeonova, 2012	Sweden	Aged 28-60	1461785	Retrospective cohort	1970-2005
Deary & Der, 2005	United Kingdom	Aged 54-58, living in Scotland	898	Prospective cohort	1988-2002
Todd, Shkolnikov, & Goldman, 2016	Russia	Moscovians 55 and older	1604	Prospective cohort	2006-2014
Gnavi et al., 2004	Italy	Residents in Turin, older than 20	31264	Prospective cohort	1991-1999
Fors, Modin, Koupil, & Vågerö, 2012	Sweden	Retirees residing in Sweden, born 1915-1924 in the hospital of Uppsala	4156	Retrospective cohort	1991-2002
Søndergaard et al., 2012	Denmark	Born in Denmark between 1950-1979 and having at least 1 sibling	1381436	Prospective cohort	1978-2009