Article

Educational inequalities in mortality are larger at low levels of income: A register-based study on premature mortality among 2.3 million Swedes, 2006–2009

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A B S T R A C T

Education develops skills that help individuals use available material resources more efficiently. When material resources are scarce, each decision becomes comparatively more important. Education may also protect from health-related income decline, since the highly educated tend to work in occupations with lower physical demands. Educational inequalities in health may, therefore, be more pronounced at lower levels of income. The aim of this study is to assess whether the shape of the income gradient in premature mortality depends on the level of education.

Total population data on education, income and mortality was obtained by linking several Swedish registers. Income was defined as five-year average disposable household income for ages 35–64 and mortality follow-up covered the period 2006–2009. The final population comprised 2.3 million individuals, 6.2 million person-years and 14,362 deaths. Income was modeled using splines in order to allow variation in the functional form of the association across educational categories. Poisson regression with robust standard errors was used.

The curvilinear shape of the association between income and mortality was more pronounced among those with a low education. Both absolute and relative educational inequalities in premature mortality tended to be larger at low levels of income. The greatest income differences in mortality were observed for those with a low education and the smallest for the highly educated.

Education and income interact as predictors of mortality. Education is a more important factor for health when access to material resources is limited.

1. Introduction

The association between socioeconomic position and health is well established. Both education (Sundquist & Johansson, 1997; Mackenbach et al., 2008; Shkolnikov et al., 2012; Mackenbach et al., 2016) and income (Backlund, Sorlie, & Johnson, 1996; Van Doorslaer et al., 1997; Gerdtham & Johannesson, 2004; Mortensen et al., 2016) have been consistently found to predict mortality risk in high-income populations. In social epidemiology, education, occupational class and income have been used interchangeably as an indicator of an underlying construct of socioeconomic position (Geyer, Hemström, Peter, & Vågerö, 2006; Bonaccio et al., 2016). However, empirical evidence suggests that although these dimensions of socioeconomic position are correlated, education, occupational class and income are independent predictors of mortality (Elo & Preston, 1996; Geyer et al., 2006; Torssander & Eriksson, 2010; Östergren, 2015). Geyer et al. (2006) interpret this finding as suggesting that different components of socioeconomic position, while correlated, indicate different underlying

phenomena and are related to health through different mechanisms (Geyer et al., 2006).

Although limited attention has been paid to the possibility that education and income may interact as predictors of mortality, some studies do suggest that the shape and size of the income gradient in self-rated health (Mirowsky & Ross, 2003; Schnittker, 2004), physical impairment (Mirowsky & Ross, 2003), and mortality (Bonaccio et al., 2016) are conditional on education. These studies indicate that health differences between educational groups seem to be larger at lower levels of income (and vice versa). Mirowsky and Ross (2003) conclude that"…at any given level of income, health tends to be better at higher levels of education, …within each level of education, health tends to be worst at the lowest levels of income, but … the differences in health across levels of income are smaller at higher levels of education." (Mirowsky & Ross, 2003, p. 78–79). Schnittker (2004) attributes a similar finding to differences in consumption patterns, resource allocation and the ability to navigate the medical system, all of which may favor the health of the well-educated within levels of income

(Schnittker, 2004). In contrast to these findings, a recent Italian study by Bonaccio et al. (2016) found larger differences in mortality by education at higher levels of income "…the inverse association between household income with all-cause death varied across educational level groups and was larger at higher levels of education" (Bonaccio et al., 2016, p. 771). This conclusion is based on an analysis in which a range of health and behavioural factors were adjusted for (Bonaccio et al., 2016). Both Mirowsky and Ross (2003) and Schnittker (2004) suggest that behavioural patterns are the main explanation for why income differences in health are larger among individuals with a low education, which could account for the reverse pattern found by Bonaccio et al. (2016).

The association between income and mortality is curvilinear (Preston, 1975; Gravelle, 1998; Mortensen et al., 2016; Rehnberg & Fritzell, 2016). This indicates that an increase in available material resources has greater benefits for health when resources are scarce than when they are plentiful. Additional resources at the lower end of the income spectrum may help individuals to avoid the most acute material risks, for example being without food and shelter. The health benefits of higher incomes, for example improving the quality of housing and nutrition or purchasing a more comprehensive insurance, are less dramatic. This is the basic outline of the *material explanation* of the curvilinear association between income and mortality (Miething, 2014). As Schnittker (2004) points out, uniformity of resource management is one of the assumptions of the material explanation for the income gradient in mortality (Schnittker, 2004). However, how individuals use their resources may differ systematically across educational groups. Mirowsky and Ross (2005) characterize education as *learned effectiveness*. Education develops cognitive skills such as information-gathering, valuing, synthesizing and decision-making. Developing these skills allows those with a high level of education to be more efficient as agents (Mirowsky & Ross, 2003, 2005). Education may, then, be interpreted as a proxy for decision-making skills, while income may be interpreted as a proxy for available material resources. If the highly educated are better at managing available resources, the amount of available resources should be comparatively less important for mortality in this group than among those with a low education. Having more material resources increases available options. Individuals with more resources have more chances to achieve a given goal, while for individuals with few resources, every decision is important (Molander, 2016). There is therefore an inverse association between the availability of material resources and the importance of decision-making skills. Both material resources and decision-making skills are probably more important for mortality at lower levels of income, which in turn indicates that education may be more important for mortality at lower levels of income.

Education and income may also interact as predictors of mortality if education protects from income decline caused by poor health. While studies have shown that childhood health can have an effect on educational attainment (Case, Fertig, & Paxson, 2005; Bambra, 2011), since education is generally stable across working ages, the impact of adult health on educational attainment is limited. Income, however, fluctuates across the working life. Empirical evidence suggests that the association between income and adult health is reciprocal (Stronks, van de Mheen, Van Den Bos, & Mackenbach, 1997; Benzeval & Judge, 2001; Halleröd & Gustafsson, 2011). This finding is intuitive. Health is needed to be able to work and income is needed to be able to obtain health-promoting resources. Education may protect from income decline resulting from poor health. Falk, Burström, and Nylén (2014) found that individuals with a low education were more likely to be unemployed as a consequence of musculoskeletal disorders, while Elstad and Dahl (2014) found that labor income preceding death started to decline earlier among individuals who had only completed compulsory education than among individuals with university degrees. The highly educated may be better at navigating the medical system (Mirowsky & Ross, 2003; Schnittker, 2004). By seeking medical attention earlier and being better at achieving and complying with treatment, those with a

high level of education may be better at avoiding the severe consequences of ill health for working capacity. Furthermore, individuals with low educational attainment may be more likely to have more mentally and physically strenuous working conditions, while well-educated individuals are likely to have jobs with less strain, greater autonomy and more flexible working conditions (Mirowsky & Ross, 2003). Poor health may therefore be more likely to prevent people with a low level of education from working.

Thus, the income gradient in mortality may be shaped differently across educational groups through several processes. 1) The highly educated may be more efficient at using available resources. Since every decision has a greater impact when resources are scarce, education is expected to have a greater importance for health at lower levels of income. 2) Education may protect from income decline resulting from ill health. The aim of this paper is, therefore, to examine whether the shape of the income gradient in mortality is different across different educational groups.

I hypothesize that educational inequalities in premature mortality are larger among individuals with low income and that the income gradient in mortality is steeper among those with a low educational level.

2. Materials and methods

2.1. Data material

The data were obtained from several linked Swedish national registers. Demographic characteristics were obtained from the total population register. Information about sex, births, and deaths were used to define the study population and to assess mortality. The aim of the paper, to examine whether the shape of the income gradient in mortality is different across different educational groups, requires accurate measurements of education and income. Therefore, the population was restricted to individuals for whom accurate information on these were available.

Education was obtained from the educational register and assessed according to the highest level of completed education in three levels: lower secondary or lower (ISCED 0–2, compulsory schooling in Sweden); upper secondary (ISCED 3–4); and tertiary (ISCED 5–6). Educational level will henceforth be referred to as low, intermediate and high. Information about the education of those born outside Sweden is often missing from the educational register (Statistics Sweden, 2006). Consequently, the population comprises only Swedish-born individuals.

The associations between education, income and mortality change over time (Shkolnikov et al., 2012; Mortensen et al., 2016). Using longitudinal data would introduce variation in the main effects that could obscure the interaction between education and income, if not adjusted for properly. Instead, the measurement period was restricted to a limited period in order to isolate the interaction between education and income as predictors of mortality. Income was collected from the tax register and defined as the average annual disposable household income (after taxes and transfers) over a five-year period. Income fluctuates over time and average income over a number of years provides a more stable estimate of available resources than if only one year is used. Household composition was adjusted for by weighting the income using the Oxford method in which each household member is assigned a weight, 1 for the first adult, 0.7 for the second adult and 0.5 for each child. The household income is then divided by the sum of the weights (OECD, 1982). Income was further adjusted for inflation using the consumer price index (KPI) provided by Statistics Sweden, with 2005 as the index year. Individuals for whom income was missing for at least one year during the period were excluded (1.5% of the population). Because income is collected from the tax register, the very low end of the income spectrum is a very heterogeneous group. It contains, among others, the very poor, tax evaders, entrepreneurs and individuals

Table 1
Description of the data.

	High			Int.			Low		
Income	Person years	Deaths		Person years		Deaths	Person years		Deaths
Q1	272,521	501		723,081		2524	255,551		1810
Q2	337,892	424		698,739		1509	208,093		775
Q3	383,625	559		646,002		1259	212,122		682
Q4	453,148	634		584,268		1106	194,378		501
Q5	659,678	958		436,148		810	112,928		310

living off capital. Disposable income, as collected from the tax register, is therefore likely to be a poor indicator of the available economic resources at the lower end of the income spectrum. Consequently, the bottom 5% of the income distribution was removed. Income was top coded at the 99th percentile.

In order to exclude those who were in education or transitioning from education to employment, individuals under the age of 35 were excluded. Income falls on retirement and other types of resources (savings, capital, family support) may become more important. In such cases, disposable income may not be properly captured by taxable income. In order to avoid misclassifying income due to retirement status, individuals over 64 years of age at the end of the income measurement was excluded. The mortality follow-up covered the period 01-01-2006 to 30-04-2009, which was the latest time period available for this analysis. The final population therefore covered the ages 35–64, with mortality measurement in ages 40–64, comprising 2.3 million individuals, 6.2 million person-years and 14,362 deaths (Table 1).

2.2. Methods

Age standardized mortality rates by 100,000 person years were calculated by income quintile and education. The age distribution in the total study population was used as the standard population. In order to assess whether relative educational inequalities in mortality varied across the income distribution, Incidence Rate Ratios (IRR) by education were calculated within each income quintile. The IRRs were estimated by fitting Poisson regression models using death as the dependent variable and person months at risk as the offset. In order to avoid overdispersion and autocorrelation the models were fitted with robust, clustered standard errors where each cluster was defined as an individual. The models further adjusted for sex and age, which was treated as a time-varying covariate.

I hypothesized that education and income interact as predictors of mortality, and that the interaction is more pronounced at low levels of income. One way of determining this is to examine whether the functional form of the income gradient in mortality is different across educational groups. Regression using splines is a suitable option when modeling continuous variables without restricting the functional form of the association, since this method allows the coefficient to change at defined knots. Using splines to model the income-mortality association allows the functional form to assume the familiar curvilinear form while at the same time allowing for different functional forms. A Poisson model was fitted using numbers of deaths as the dependent variable and the person months at risk as the offset controlling for sex and age. Five-year average income was treated as a time-varying covariate (for example, average income during the period 2001–2005 was used to model mortality in 2006, average income during 2002–2006 was used to model mortality in 2007, etc). Income was modeled using splines with four knots defined as the cut-off values between each quintile. Education was modeled using a set of dummy variables. By including interaction terms between each spline and educational level, both the functional form and the steepness of the income gradient in

mortality are allowed to vary across educational groups. The regression coefficients were used to predict absolute death risks by income and education in order to enable visual interpretation. Model fit statistics (AIC and BIC) were used to assess whether including interaction terms improved the overall fit of the model. All analyses were carried out in Stata while r was used to generate figures.

3. Results

Table 2 indicates that mortality varies by both education and income. Within each income quintile, mortality is highest among those with low education and lowest among those with high education. Within educational groups, mortality is lower at higher levels of income. With the exception of Q4 and Q5 (the two top quintiles) among those with low education, there is a gradient in mortality along the entire income distribution. The magnitude of the differences in mortality between educational groups tends to be larger at lower levels of income. The rate difference between high and low education was 443 in Q1 (the bottom quintile) and 114 in Q5 (the top quintile). The smallest rate difference by education was observed in Q4.

Table 3 shows that the educational gradient in mortality is steepest in the bottom income quintile, followed by Q2. Although the point estimates vary between Q3–Q5, the confidence intervals indicate that the educational gradient is of similar magnitude in these quintiles. Conversely, the income gradient in mortality is steepest among those with a low education (IRR = 3.52 (3.11–3.98)) and flattest among the highly educated (IRR = 2.22 (1.98–2.49)).

The estimates in both Tables 2 and 3 indicate that both absolute and relative educational inequalities in mortality tend to be larger at lower levels of income. However, while these estimates hint at the possibility of there being an interaction, neither approach directly addresses the issue. Further, assessing the IRR, as is done in Table 2, requires selecting a reference category (in this case the highly educated). This makes comparisons across income quintiles somewhat difficult because mortality differences by income within the highly educated group are ignored. In order to facilitate a more complete interpretation of the patterns, absolute death risks were predicted using Poisson regression, modelling income as splines. By including interaction terms between education and the splines, the functional shape of the income-mortality association was allowed to vary across educational groups. Plotting the

Table 2
Age standardized mortality rates per 100,000 person years by income and education.

		Education			Rate difference	
		High	Int.	Low	H-I	H-L
Income	Q1	279	483	722	204	443
	Q2	175	261	350	86	174
	Q3	165	196	276	31	111
	Q4	134	169	214	35	80
	Q5	124	155	238	31	114

Table 3
Incidence rate ratios (95% CI) by education at different income quintiles.

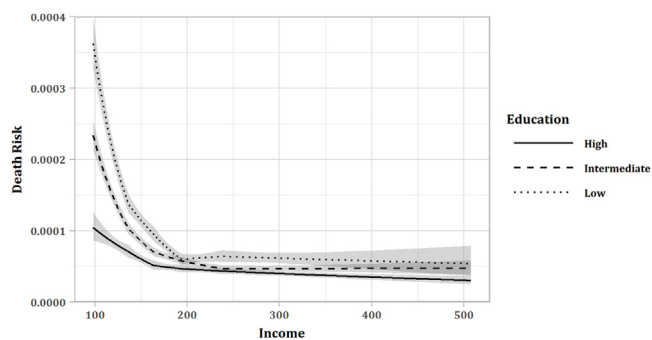|		Education				
		High (ref.)	Int.		Low	
Income	Q1	1	1.74	(1.58–1.91)	2.55	(2.31–2.82)
	Q2	1	1.54	(1.38–1.72)	1.98	(1.75–2.24)
	Q3	1	1.19	(1.07–1.31)	1.52	(1.36–1.71)
	Q4	1	1.24	(1.13–1.37)	1.42	(1.26–1.61)
	Q5	1	1.22	(1.11–1.34)	1.62	(1.43–1.85)

All models adjusted for sex and age.

Fig. 1. Predicted death risks and 95% confidence intervals by education and 1000s of SEK in annual disposable household income.

predicted death risks makes it possible to simultaneously interpret both the absolute and the relative scales. The regression coefficients used to calculate the predictions can be found in the supplementary material, Table A.1.

Fig. 1 displays predicted death risks by education and income based on the coefficients from the Poisson regression model. Death risks were predicted for the baseline values of sex (men) and age (40–45). The curvilinear relationship between income and mortality was present across at all levels of education, but was much more pronounced among those with a low education. The educational differences in mortality were larger at lower incomes and smaller at higher incomes. At below-median incomes (< 178 K/year) educational differences in mortality narrowed whereas at above-median incomes, educational differences in death risk were roughly stable. The estimated interaction terms between income and education were statistically significant mainly in the bottom income quintile (Table A1). The interaction between education and income appears to be present only among low-income earners.

Using splines to model income relaxes assumptions about the shape of the functional form of the association between income and mortality. However, attempting to determine statistically whether there is interaction may be difficult since the model includes several interaction terms. Comparing model fit statistics across models provides a single estimate which determines whether the interaction improved the fit between the predicted values and the observed data.

Table 4 displays model fit statistics for three alternative model

Table 4
Model fit statistics.

	AIC	ΔAIC	BIC	ΔBIC
Model 1[a]	220182.5	ref.	220489.5	ref.
Model 2[b]	220272.3	89.8	220439.7	-49.8
Model 3[c]	220199.8	17.3	220395.0	-94.5

Poisson models estimating mortality by education and income, using person-time at risk as the offset and adjusting for age and sex.
[a] Interaction between education and all income splines.
[b] No interaction.
[c] Interaction restricted to the lowest income spline.

specifications. Model 1 included interaction terms between education and income splines and was the basis for the predictions presented in Fig. 1. Model 2 included education as a set of dummy variables and splines to model income, but did not include interaction terms. While the AIC preferred Model 1, the BIC preferred Model 2. However, BIC is more sensitive than the AIC to adding additional parameters. Fig. 1 indicates that the interaction between education and income is primarily is located in the bottom income quintile. Consequently, a third model using splines but restricting the interaction to the bottom income quintile was fitted. Model 3 was preferred by the BIC over Model 1 and Model 2. Both the AIC and the BIC suggest that allowing for interaction improves model fit, but they prefer different specific models. The conclusions that can be drawn from Model 1 and 3 are similar, namely that there is an interaction between income and education, and that the interaction is primarily located in the bottom quintile. Model 1 was chosen as the main focus of the results since it places the fewest formal restrictions on the functional form of the income-mortality association across educational groups.

4. Discussion

4.1. Summary of findings

In this study, education and income interacted as predictors of premature mortality. Both absolute and relative educational inequalities in mortality tended to be larger at low levels of income. Income differences in mortality were observed to be the greatest among those with a low education and smallest among the highly educated. Educational inequalities in mortality were observed across all income levels.

4.2. Methodological considerations

Although the steepness of the income gradient varied across the educational groups, the income gradient in mortality assumed the typical curvilinear shape (Preston, 1975; Gravelle, 1998; Mortensen et al., 2016), implying that the data set and method used are suitable for modeling mortality as a function of income.

Fitting splines and interaction terms are computationally demanding techniques and require relatively large amounts of data. The data requirements are especially high for the research question under scrutiny here, because it requires a sufficient number of observations with unusual combinations of values (highly educated individuals with low incomes and vice versa). It is therefore potentially difficult to replicate the current analysis in smaller data sets or using survey data without continuous measures of income. An alternative approach for capturing the curvilinear association between income and education is to model mortality as a log-linear function of income. Using a log-linear function is computationally more efficient but restricts the shape of the functional form since the shape is assumed to be log-linear across the entire distribution. In order to compare the results of the two approaches, a Poisson model was fitted with mortality modeled as a log-linear function of income instead of using splines, including education and interaction terms. Although the log-linear model performed worse in terms of model fit, the model yielded overall patterns similar to the splines model. The regression coefficients and model fit statistics can be found in the supplementary material (Table A.2) along with predicted death risks by education and income (Fig. A.1). At higher incomes, mortality differences by education converged and even reversed, indicating that people with a low education and a high income may have had lower death risks than those with a high education and a high income. Because the log-linear use two terms (log income and an interaction term by education) to describe mortality across the whole income distribution, the shape of the gradient will be comparatively more dependent on the slope in the part of the income distribution where most observations are located. The log-linear model, therefore, gives

misleading estimates at higher incomes but is a viable option for detecting the general patterns in smaller data sets.

Income was defined as the average annual disposable income measured at the household level across five years. Income is understood as an indicator of available resources. For this reason, income was measured as disposable income at the household level. Even though there are empirical findings which indicate that the different measures of income which can be used provide similar estimates when measuring the association between income and health (McDonough, Duncan, Williams, & House, 1997; Geyer, 2010), it is possible that defining income differently would generate different patterns than the ones observed here.

Income fluctuates over time and an individual may experience a peak or a dip in income in the course of a single year. Five-year average income was used in order to avoid misleading classifications of available resources due to such peaks and dips. As a sensitivity analysis, the analyses were repeated using the level of income of the year before mortality follow up as well as using ten-year average income. The analysis were also repeated including the bottom 5% of the income distribution. Similar patterns were observed across all versions, although the point estimates varied, indicating that the measurement of income did not influence the main conclusions.

Mortality is lower among women, while socioeconomic inequalities in mortality tend to be more pronounced among men. This may indicate that the processes around social stratification and health, on a general level, are moderated by gender. However, there are few indications that the specific theoretical concepts and processes of interest in this study differ greatly by gender. Gender stratified analysis produced similar patterns for men and women (results not shown). There was a shift in the overall level of mortality and the slope of the income-mortality association (estimates of the educational gradient in mortality were similar among men and women in Sweden during this period, as reported elsewhere (Östergren, 2015; Mackenbach et al., 2016)). To improve statistical power, gender was treated as an independent covariate in the main analysis.

Mortality differences by income and education are salient features of high income populations. The specific size of these differences do, however, vary across national context but also change over time (Shkolnikov et al., 2012; Mortensen et al., 2016). It is possible that the interaction between income and education as predictors of mortality will differ not only across contexts but also across time. The current analysis was conducted on premature mortality among Swedish-born individuals observed during a short period in time and in a single national context. The advantage of observing a single population during a limited period is that it allows me to isolate the interaction between income and education as predictors of mortality. Although the processes described are not specific to the period and context analysed, the results should be interpreted with this in mind.

4.3. Interpretation of results

The results clearly indicated that educational inequalities in premature mortality were larger at the lower end of the income distribution and, conversely, that the income gradient in mortality was steeper among those with a low education. These results are consistent with those of previous studies of self-rated health, physical impairment, and multimorbidity (Mirowsky & Ross, 2003; Schnittker, 2004). However, the recent study of mortality by Bonaccio et al. (2016), found the opposite, namely that the inverse association between income and mortality is stronger among the highly educated (Bonaccio et al., 2016). One of the explanations suggested by both Schnittker (2004) and Mirowsky and Ross (2003) for the interaction between income and education is that there are systematic differences in behaviour across educational levels. The analysis in Bonaccio et al. (2016) adjusts for (among other things) dietary patterns, physical activity and smoking status (Bonaccio et al., 2016), which may also be proxies of behavioural

patterns beyond those specific behaviours. Potentially, adjusting for a key mechanism, as proposed by Schnittker (2004) and Mirowsky and Ross (2003), makes it difficult to compare the results from the different studies. Further, as Bonaccio et al. (2016) point out, there are large international variations in the socioeconomic gradient in mortality. Southern Europe and Italy typically show low mortality and small socioeconomic inequalities in mortality while socioeconomic inequalities in mortality in the Nordic countries and Sweden are of moderate magnitude (Mackenbach et al., 2008). The latter finding has received some attention because of the intuitive discrepancy between inequalities in health and comprehensive welfare programs (Bambra, 2011; Mackenbach, 2012).

From a theoretical perspective, the importance of decisions is inversely correlated with available resources. Each decision is crucial when resources are scarce, while a surplus of resources enables individuals to make mistakes and try again, with each decision mattering less. Educational attainment may be interpreted as a proxy for cognitive skills and the propensity to act – the efficiency of the individual in terms of agency (Mirowsky & Ross, 2005), while disposable income may be interpreted as a proxy for available material resources. The results are consistent with this interpretation. The educational gradient in mortality within levels of income may be interpreted as an indicator of how efficiently available resources are used to protect and promote health. The results showed that the educational gradient in mortality is steeper at lower levels of income, where each decision is more crucial. The highly educated may, furthermore, have access to a wider range of resources, for example through social networks. Using one type of resource to compensate for the lack of another type of resource is process referred to as *resource substitution* (Mirowsky & Ross, 2003, 2005). Resource substitution requires individuals to have other resources to use as substitutes to be efficient at resource management, both of which may be positively correlated with education (Mirowsky & Ross, 2003). Having a low income may, then, have fewer severe consequences for the highly educated, since they may use resource substitution to compensate, to some degree, for the lack of income.

For several reasons, the highly educated may experience less income decline as a result of health complications. They may have more influence over their working conditions and more flexible employers, thereby enabling them to adjust working conditions to accommodate impaired physical functioning. Education may also help individuals to navigate the medical system, leading them to receive more efficient treatment, which in turn limits the time they spend in poor health, and therefore its consequences. Those with low education and low income may, accordingly, be more likely than those with high education and low income to be low income earners because of poor health. Having a high income is, to some degree, an indication that severe income loss has not happened, which is consistent with the interaction between education and income only being observed at lower levels of income. Those with a low education may also be more likely to work in physically strenuous occupations which demand good physical functioning. These types of job may be clustered among low income earners in the low educated group, which implies that this process is consistent with the finding that the interaction between education and health is observable only at lower levels of income. However, it remains unclear whether income declines tend to steepen or flatten the income gradient in mortality. Studies of social mobility and health, tend to find that the health of socially mobile individuals is worse than those who are stable in higher strata but better than the health of those who are stable in lower strata (Blane, Harding, & Rosato, 1999; Elstad, 2001; Boyle, Norman, & Popham, 2009). Individuals with declining income may have worse health than the group they are leaving but better health than the group they are joining. Whether income decline contributes to steeper or flatter income gradients in an empirical issue that warrants specific attention.

At higher levels of income, the educational gradient in mortality seemed to remain stable. Even in the top income quintile, those with a

low education had a 51% (IRR = 1.51) higher risk of dying than those with a high education; the results are both statistically significant and substantial. This finding indicates that while each decision matter less when resources are abundant, it still matters to some degree how resources are spent. This corroborates the notion that education is an inherent good for health and improves health across all contexts. However, the high income earners, regardless of their educational attainment, represent a small part of the population and have low death risks. In policy terms, these results suggest efforts should be concentrated on groups that are exposed to multiple deprivation.

5. Conclusions

Educational inequalities in mortality are wider among low income earners. Conversely, the income gradient in mortality is wider among those with a low education. Education promotes decision-making skills. These are especially important at lower levels of income, where resources are scarce and each decision matters more. Education may also limit the income loss which can result from poor health.

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Conflicts of interest

None declared.

Ethical statement

The paper is based on the HSIA data base that is operated under a general ethics approval obtained by Prof. Denny Vågerö 2002-11-11, from the KI regional ethics committee (Karolinska Institutets Regionala Forskningsetikkommitté), Ref. 02–481.
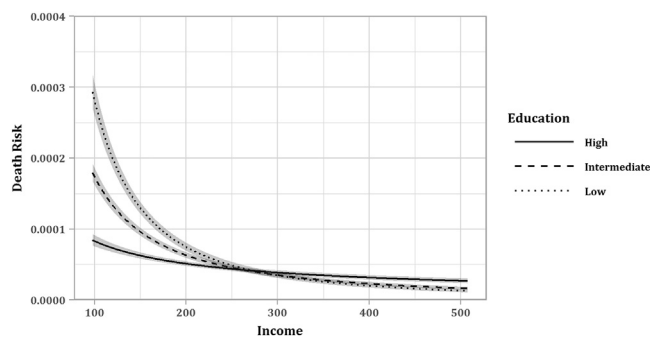
Appendix A

See Tables A1 and A2 and Fig. A.1.

Table A.1
Regression coefficients and standard errors, Poisson regression using splines.

		Coef	SE		Coef	SE		Coef	SE
Education	High	0							
	Int.	1.902***	0.452						
	Low	2.718***	0.463						
				Interaction terms					
		High		Int[1]			Low[1]		
Income	Q1	-0.010**	0.003		-0.011**	0.004		-0.015***	0.004
	Q2	-0.012**	0.003		-0.002	0.004		-0.002	0.004
	Q3	-0.002	0.003		-0.003	0.003		-0.012**	0.004
	Q4	-0.004	0.002		-0.003	0.002		0.003	0.003
	Q5	-0.001**	0.000		0.001	0.001		0.001	0.001

[1]Significance test for divergence from the slope of the high educated * = $p \leq 0.05$, ** = $p \leq 0.01$, *** = $p \leq 0.001$ Adjusted for sex and age.

Table A.2
Regression coefficients and standard errors, Poisson regression using log income.

		Coef	SE
Education	High	0	
	Intermediate	4.262***	0.380
	Low	6.823***	0.445
Log Income		-0.700***	0.056
Log income × Education	Intermediate	-0.765***	0.073
	Low	-1.215***	0.086
Model fit statistics	AIC	220569.9	
	BIC	220709.4	

* = $p \leq 0.05$, ** = $p \leq 0.01$, *** = $p \leq 0.001$
Adjusted for sex and age

Fig. A.1. Predicted death risks and 95% confidence intervals by education and income, log income.

References

Backlund, E., Sorlie, P. D., & Johnson, N. J. (1996). The shape of the relationship between income and mortality in the United States: Evidence from the National Longitudinal Mortality Study. *Annals of Epidemiology, 6*(1), 12–20.

Bambra, C. (2011). Health inequalities and welfare state regimes: Theoretical insights on a public health 'puzzle'. *Journal of Epidemiology and Community Health, 65*(9), 740–745.

Benzeval, M., & Judge, K. (2001). Income and health: The time dimension. *Social Science Medicine, 52*(9), 1371–1390.

Blane, D., Harding, S., & Rosato, M. (1999). Does social mobility affect the size of the socioeconomic mortality differential?: Evidence from the Office for National Statistics Longitudinal Study. *Journal of the Royal Statistical Society: Series A (Statistics in Society), 162*(1), 59–70.

Bonaccio, M., Di Castelnuovo, A., Costanzo, S., Persichillo, M., Donati, M. B., De Gaetano, G., & Iacoviello, L. (2016). Interaction between education and income on the risk of all-cause mortality: Prospective results from the MOLI-SANI study. *International Journal of Public Health, 61*(7), 765–776.

Boyle, P. J., Norman, P., & Popham, F. (2009). Social mobility: Evidence that it can widen health inequalities. *Social Science Medicine, 68*(10), 1835–1842.

Case, A., Fertig, A., & Paxson, C. (2005). The lasting impact of childhood health and circumstance. *Journal of Health Economics, 24*(2), 365–389.

Elo, I. T., & Preston, S. H. (1996). Educational differentials in mortality: United States, 1979–1985. *Social Science Medicine, 42*(1), 47–57.

Elstad, J. I. (2001). Health-related mobility, health inequalities and gradient constraint. Discussion and results from a Norwegian study. *The European Journal of Public Health, 11*(2), 135–140.

Elstad, J. I., & Dahl, E. (2014). Fordelingsvirkninger av overføringer og trygdekutt blant alvorlig syke menn. *Søkelys på arbeidslivet, 3*, 267–277.

Falk, J., Burström, B., & Nylén, L. (2014). Social differentials in non-employment following hospital admission for musculoskeletal disorders in Sweden, 2001–2006. *International Journal of Health Services, 44*(1), 155–168.

Gerdtham, U.-G., & Johannesson, M. (2004). Absolute income, relative income, income inequality, and mortality. *Journal of Human Resources, 39*(1), 228–247.

Geyer, S. (2010). Income, income, or income? The effects of different income measures on health in a national survey. *Journal of Epidemiology and Community Health, 65*, 491–496.

Geyer, S., Hemström, Ö., Peter, R., & Vågerö, D. (2006). Education, income, and occupational class cannot be used interchangeably in social epidemiology. Empirical evidence against a common practice. *Journal of Epidemiology and Community Health, 60*, 804–810.

Gravelle, H. (1998). How much of the relation between population mortality and unequal distribution of income is a statistical artefact? *BMJ, 316*(7128), 382.

Halleröd, B., & Gustafsson, J.-E. (2011). A longitudinal analysis of the relationship between changes in socio-economic status and changes in health. *Social Science Medicine, 72*(1), 116–123.

Mackenbach, J. P. (2012). The persistence of health inequalities in modern welfare states: The explanation of a paradox. *Social Science Medicine, 75*(4), 761–769.

Mackenbach, J. P., Kulhánová, I., Artnik, B., Bopp, M., Borrell, C., Clemens, T., Costa, G.,

Dibben, C., Kalediene, R., Lundberg, O., Martikainen, P., Menvielle, G., Östergren, O., Prochorskas, R., Rodriguez-Sanz, M., Heine Strand, B., Looman, C., & De Gelder, R. (2016). Changes in mortality inequalities over two decades: Register based study of European countries. *BMJ, 353*, 1–8.

Mackenbach, J. P., Stribu, I., Roskam, A.-J., Schaap, M. M., Menvielle, G., Leinsalu, M., & Kunst, A. E. (2008). Socioeconomic inequalities in health in 22 European countries. *The New England Journal of Medicine, 358*, 2468–2481.

McDonough, P., Duncan, G. J., Williams, D., & House, J. (1997). Income dynamics and adult mortality in the United States, 1972 through 1989. *American Journal of Public Health, 87*(9), 1476–1483.

Miething, A. (2014). *Others' income, one's own fate: How income inequality, relative docial position and social comparisons contribute to disparities in health.* Stockholm: Department of Sociology, Stockholm University.

Mirowsky, J., & Ross, C. E. (2003). *Education, social status, and health.* New Brunswick: Transaction Publishers.

Mirowsky, J., & Ross, C. E. (2005). Education, learned effectiveness and health. *London Review of Education, 3*(3), 205–220.

Molander, P. (2016). *The anatomy of inequality: Its social and economic origins-and solutions.* London: Melville House.

Mortensen, L. H., Rehnberg, J., Dahl, E., Diderichsen, F., Elstad, J. I., Martikainen, P., Rehkopf, D., Tarkiainen, L., & Fritzell, J. (2016). Shape of the association between income and mortality: A cohort study of Denmark, Finland, Norway and Sweden in 1995 and 2003. *BMJ Open, 6*(12), e010974.

OECD (1982). *The OECD list of social indicators.* Paris: OECD.

Preston, S. H. (1975). The changing relation between mortality and level of economic development. *Population Studies, 29*(2), 231–248.

Rehnberg, J., & Fritzell, J. (2016). The shape of the association between income and mortality in old age: A longitudinal Swedish national register study. *SSM-Population Health, 2*, 750–756.

Schnittker, J. (2004). Education and the changing shape of the income gradient in health. *Journal of Health and Social Behavior, 45*(3), 286–305.

Shkolnikov, V. M., Andreev, E. M., Jdanov, D. A., Domantas, J., Kravdal, Ø., Vågerö, D., & Valkonen, T. (2012). Increasing absolute mortality disparities by education in Finland, Norway and Sweden, 1971–2000. *Journal of Epidemiology and Community Health, 66*, 372–378.

Statistics Sweden (2006). *Evalvering av utbildningsregistret.* Stockholm: Statistics Sweden.

Stronks, K., van de Mheen, H., Van Den Bos, J., & Mackenbach, J. (1997). The interrelationship between income, health and employment status. *International Journal of Epidemiology, 26*(3), 592–600.

Sundquist, J., & Johansson, S.-E. (1997). Indicators of socio-economic position and their relation to mortality in Sweden. *Social Science Medicine, 45*, 1757–1766.

Torssander, J., & Erikson, R. (2010). Stratification and mortality – A comparison of education, class, status, and income. *European Sociological Review, 26*(4), 465–474.

Van Doorslaer, E., Wagstaff, A., Bleichrodt, H., Calonge, S., Gerdtham, U.-G., Gerfin, M., Geurts, J., Gross, L., Häkkinen, U., & Leu, R. E. (1997). Income-related inequalities in health: Some international comparisons. *Journal of Health Economics, 16*(1), 93–112.

Östergren, O. (2015). Growing gaps: The importance of income and family for educational inequalities in mortality among Swedish men and women 1990–2009. *Scandinavian Journal of Public Health* (1403494815585401).