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The shape of the association between income and mortality in old age: A longitudinal Swedish national register study

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ABSTRACT

This study used data on the total population to examine the longitudinal association between midlife income and mortality and late-life income and mortality in an aging Swedish cohort. We specifically examined the shape of the associations between income and mortality with focus on where in the income distribution that higher incomes began to provide diminishing returns. The study is based on a total Swedish population cohort between the ages of 50 and 60 years in 1990 (n=801,017) followed in registers for up to 19 years. We measured equivalent disposable household income in 1990 and 2005 and mortality between 2006 and 2009. Cox proportional hazard models with penalized splines (P-spline) enabled us to examine for non-linearity in the relationship between income and mortality. The results showed a clear non-linear association. The shape of the association between midlife (ages 50–60) income and mortality was curvilinear; returns diminished as income increased. The shape of the association between late-life (ages 65–75) income and mortality was also curvilinear; returns diminished as income increased. The association between late-life income and mortality remained after controlling for midlife income. In summary, the results indicated that a non-linear association between income and mortality is maintained into old age, in which higher incomes give diminishing returns.

1. Introduction

Income is one of the most stratifying dimensions of living conditions in Western societies. Despite welfare states' efforts to redistribute income and reduce inequality, relative differences in income and wealth persist and are even growing in most countries (Nolan et al., 2014; OECD, 2011). Both low income and income inequality are associated with a wide variety of negative outcomes for individuals and for society (Fritzell, Rehnberg, Hertzman, & Blomgren, 2014; Marmot, 2002; Pham-Kanter, 2009; Subramanian & Kawachi, 2004; Wilkinson & Pickett, 2011).

Some of the most detrimental consequences of low income are those linked to health. Income and wealth affect the health of individuals by enabling those who are well-off to lead healthy lifestyles and consume better and more health care, while at the other end of the spectrum, those at the bottom of the income distribution have fewer of these enabling resources (Marmot, 2002). Income inequality in itself has also been linked to people's health, often referred to as the relative deprivation hypotheses (Pham-Kanter, 2009; Pickett & Wilkinson, 2015). The mechanisms of this hypotheses is mainly the stress that people are exposed to from being in comparably lower social positions. More unequal societies should by this logic have higher inequality. Like

income inequality, the association between income and health persists even in countries with extensive welfare state programs designed to mitigate the influence of income on health (Åberg Yngwe, Fritzell, Burström, & Lundberg, 2005; Kondo, Rostila, & Yngwe, 2014; Lundberg, Åberg Yngwe, Kölegård Stjärne, Björk, & Fritzell, 2008).

There is ample evidence of a positive relationship between income and health in the working-age population (Deaton, 2002; Subramanian & Kawachi, 2004). Less is known about the relationship between income and health in those beyond normal working age, although some findings indicate that the pattern may be similar (Fors, Modin, Koupil, & Vågerö, 2011; Huisman, Kunst, & Mackenbach, 2003). In the working-age population, the association between income and health follows a curvilinear gradient; effects on health tend to decrease as income increases (Deaton, 2002; Dowd et al., 2011; Mackenbach et al., 2005; Rodgers, 1979). Sweden, with its high long history of universalistic, relatively generous policies, and its strong focus on egalitarianism, is not an exception: researchers have also found a curvilinear association between income and health there (Fritzell, Nermo, & Lundberg, 2004; Lundberg et al., 2008). Empirical findings on the shape of the association between income and health can provide insight into the efficiency of redistributive policies; in particular, the point in the income distribution at which

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increased income begins to have diminishing returns.

A better understanding of the income-mortality association in old age after retirement is needed. This area is of particular relevance given that a larger share of the population is surviving into old age. Most deaths today also occur in old age; 90 percent of all deaths during the mortality follow-up period in this study (2005 through 2009) occurred in people aged 65 or older (Human Mortality Database, 2015). Following an older cohort thus allowed us to capture a segment of the population in which a large share of deaths occur and one that is the focus of relatively few studies.

In studies of income in different age groups, it is important to take income variability and the source of income into account (Böhlmark & Lindquist 2006; Palme & Svensson, 1999). Palme and Svensson (1999) have shown that the share of income from work in Sweden drops steadily after age 58; simultaneously, income from pensions starts to increase rapidly, and the share of income from capital grow slightly. Income levels stabilize during the middle to late stages of working life and then fluctuate again at the very end of working life (Baker & Solon, 2003; Björklund, 1993; Böhlmark & Lindquist, 2006). After retirement, income variability tends to be smaller. This is especially true at the very bottom of the income scale because of minimum pension schemes (European Commision, 2015; Smeeding, 2001). In Sweden, the pension system was reformed during the 1990s and now includes both private and state-organized pension savings (Barr, 2013; Palmer, 2000). The level of income from pensions in old age is dependent on income during earlier working life, and there is a means-tested guaranteed pension for those with low or no previous income. The varying dynamics of the income distribution – both the source of incomes and income variability over the life course – can affect the form of the observed association between income and health at different ages. Late-life income may be a better measure of income and wealth accumulated during life than midlife income. We would then expect a stronger association between income in late-life and mortality. On the other hand, if income after retirement is heavily redistributed due to minimum pension schemes that leads to lower overall income inequality we would expect a weaker association between late-life incomes and mortality compared to midlife incomes.

To increase knowledge about the association between income and mortality in midlife and old age we followed an aging cohort in this study and look at the mortality in people age 65 and above. The aim of this study was to examine the longitudinal association between midlife income and late-life mortality and late-life income and late-life mortality in an aging cohort in Sweden. The shape of the association was examined for non-linearity, and differences in the shape of the association between midlife income and mortality and late-life income and mortality were explored. We seek to answer the following research questions:

1. Do we find an association between late-life income and late-life mortality?
2. Is the association between late-life income and late-life mortality curvilinear with diminishing returns of income and similar to that of midlife income?
3. Does the association between late-life income and late-life mortality remain when we control for midlife income?

This study built on previous findings of curvilinearity in the association between working-life income and mortality and focused on the shape of the association between income and health in older ages, the time when health starts to deteriorate more rapidly at a population level and the vast majority of all deaths occur.

2. Data and method

2.1. Design and population

The data used in the study came from The Swedish Work and Mortality Database (HSIA). HSIA consists of multiple national registers that are linkable at the individual level. The data in HSIA cover all individuals living in Sweden. Information is available for each year from 1990 to through 2009. The sample in this study consisted of a cohort of people who were between the ages of 50 and 60 years in 1990. Income was measured in 1990 and again in 2005 when most of the people in the cohort had retired, and mortality was followed up during the four-year period between 2006 and 2009. Only data from those who lived in Sweden at baseline in 1990 and at the start of mortality follow-up in 2006 were used in the analyses. Data on those who emigrated or died before 2006 or immigrated after 1990 were not included. Sample characteristics of the excluded people are shown in Supplementary Table 1. The study included 801,017 people.

2.2. Variables

2.2.1. Income

Yearly equivalent disposable income was measured as an aggregate variable that consisted of all after-tax income, including income from work, transfer payments, and capital. To compare the income of different types of households, the measure was equivalized by dividing disposable household income by the square root of number of household members. Income in 1990 was adjusted to 2005 price levels using the consumer price index. In the regression analyses, everyone with an income above the 99th percentile was given the 99th percentile income value (top coded).

2.2.2. Mortality

All-cause mortality was measured during the four-year period between 2006 and 2009. In our study population a total of 49,110 deaths occurred during this period.

2.2.3. Control variables

Age at baseline and sex were included as control variables.

2.3. Methods

Cox proportional hazard models with penalized splines (P-spline) were used to analyze the data (Eilers & Marx, 1996). The smoothHR package in R was used to fit the models (Cadarso-Suárez, Meira-Machado, Kneib, & Gude, 2010). P-spline is a smoothing function that can be used in regression models to better fit and describe non-linear data. Splines are fitted by polynomial sections joined together at knots that creates continuous and flexible estimation of the predicted variable. We choose P-splines over other smoothing methods because of its compatibility with many standard regression methods, because it is penalized as to not overfit the data and because it has limited boundary effects (Cadarso-Suárez et al., 2010; Eilers & Marx, 1996).

The first step in fitting the models was to establish whether the associations were non-linear. This was done by specifying income as linear or non-linear; non-linear terms were estimated by using a P-spline function. The Bayesian information criterion (BIC) was used to estimate the optimal amount of degrees of freedom (df) for the spline function. BIC was chosen over the Akaike information criterion (AIC) as the Bayesian criterion has less tendency to overfit the data when n is large (Dziak, Coffman, Lanza, & Li, 2012; Schwarz, 1978). Standard regression tables are presented. They show the results of regression analyses of income both as a linear and a non-linear variable. The tables are complemented by figures that show P-spline smoothed log hazard curves with 95 percent confidence intervals (CIs) to illustrate the shape of non-linear associations. All figures are presented with the

log hazard ratio on the y axis and yearly disposable household income on the x axis. The hazard ratios are presented on the logarithmic scale to make visual interpretations of the relative size between negative and positive effects of the hazard ratio more intuitive (Hosseinpoor & AbouZahr, 2010).

Cox proportional hazard regression estimates the hazard ratio for a specified model (Cox, 1972). The hazard ratio is the hazard that an event occurs in the exposed group divided by the hazard that the event occurs in the unexposed group. Thus, it is a relative measure that gives estimates on the multiplicative scale. The Cox model assumes proportional hazards during the time under exposure, we test for violation of proportional hazards in all models (Grambsch & Therneau, 1994).

2.3.1. Sensitivity analyses

We conducted four sensitivity tests aimed at testing the impact of basic design choices and the possible impact of reverse causality. First, we conducted stratified analyses of finer age categories (2 years) to see whether the results remained similar across all ages. Second, we conducted analyses stratified by sex. Third, we removed individuals identified as possible contributors to reversed causality. These included people who received any retirement income between the ages of 50 and 60. Such people were identified as more likely to have poorer health and lower incomes. Possible contributors to reversed causality also included those who did not receive any income from retirement after age 65; i.e., those who continued to work into late life. By removing these people, we controlled for healthy people whose extended working life gave them larger incomes, and in so doing, controlled for an effect similar to that of the healthy worker effect. Finally, we tested the impact of the one-year income measures by looking at the associations with the average disposable household income over three years. The sensitivity analyses are presented in Supplementary Fig. 1–20.

3. Results

Table 1 gives yearly equivalent disposable household income levels at different percentiles in our study population in 1990 and 2005. Median income in 1990, when the population was between 50 and 60 years old, was 185,899 Swedish crowns (SEK) at the 2005 price level. This corresponds to roughly 22,500 United States dollars (USD) at the current exchange rate. As expected, in 2005, when the study population was between 65 and 75 years old, the median income was lower (SEK 162,422), corresponding roughly to USD 19,700 at the current exchange rate. The shape of the income distribution was similar in 1990 and 2005 up to around the 90th percentile. Above the 90th percentile, incomes were much higher in 2005 than 1990; in the 99th percentile, income was twice as high in 2005 as 1990. The range of incomes within the top 1% was larger in 2005 than in 1990. In this study cohort, the Gini coefficient, a standard measure of income inequality, was 0.18 in 1990 and 0.25 in 2005, which also indicates that overall income inequality was higher in 2005 than 1990. While this increase in a population is large, one should bear in mind that the overall inequality in the Swedish income distribution increased with around 26 percent over the same period (Fritzell, Bäckman, & Ritakallio, 2012).

Table 1
Yearly disposable household income (SEK) by percentile in year 1990 (sample aged between 50 and 60) and year 2005 (sample aged between 65 and 75) at 2005 price levels.

Income percentile	Income 1990 (SEK)	Income 2005 (SEK)
10 %	115,019	107,800
30 %	156,413	134,209
50 %	185,615	162,300
70 %	216,109	201,525
90 %	268,080	291,469
99 %	387,100	777,988

Table 2
Cox proportional hazard regression showing the estimated effects of yearly disposable household income (SEK) on mortality between 2006 and 2009. Models 1 and 2 show the linear and non-linear (P-spline) effects of income on morality separately for midlife (in 1990) and late life (in 2005); model 3 shows the combined effects of midlife and late-life income on mortality. Incomes in 2005 price levels.

Model 1	Hazard ratio[a]
Age	1.107
Sex (Female=1)	0.580
1990 income (10,000 SEK)	0.961
P-spline(1990 income, df=7)	
Model 2	
Age	1.092
Sex (Female=1)	0.547
2005 income (10,000 SEK)	0.979
P-spline(2005 income, df=10)	
Model 3	
Age	1.094
Sex (Men=0)	0.549
1990 income (10,000 SEK)	0.982
P-spline(1990 income, df=7)	
2005 income (10,000 SEK)	0.988
P-spline(2005 income, df=10)	

[a] All estimates are significant at p < 0.001.

The correlation between the two income measures are 0.62 for Spearman's correlation and 0.48 for Pearson product-moment correlation. Spearman's correlation measures rank order correlation while the Pearson product-moment correlation measures the linear dependence between values. The difference in the correlation measures indicate that the rank order in the income distribution is maintained to a higher extent than the absolute values of income. This is mainly caused by the large increase in absolute values in the top 10 percent of the income distribution as they maintain their relative rank order.

Table 2 shows the results of the Cox regressions on mortality (models 1 to 3). Model 1 included income measured at midlife in 1990, model 2 included income measured in later life in 2005, and model 3 included both income measured at midlife and in later life. Older age was, of expected, associated with higher risk of dying, and women had a lower risk of dying than men in all three models. Income was included separately in each model as a linear and non-linear (P-spline) function. All non-linear effects of income were highly significant. Although the non-linear association was highly significant in all three models, the actual shape of the non-linearity cannot be seen in Table 2. The shape of the non-linear association is presented in Figs. 1–3.
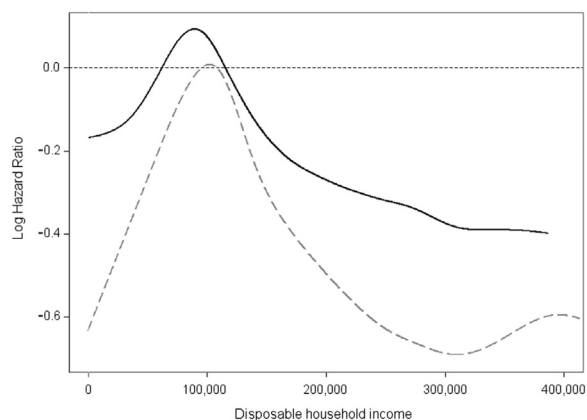
Figs. 1–3 show the smoothed log hazard curves (thick line) of
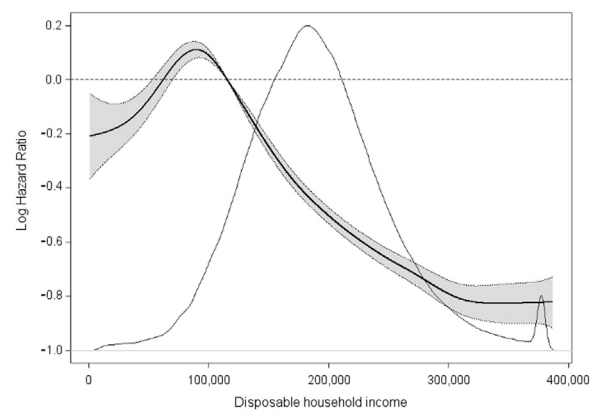
Fig. 1. Adjusted smooth log hazard ratio estimates of mortality by yearly disposable household income (SEK) measured in 1990 (thick line) with 95% confidence intervals (grey area) and density plot (thin line). The 10th percentile of income (SEK 115,019) was used as the reference.
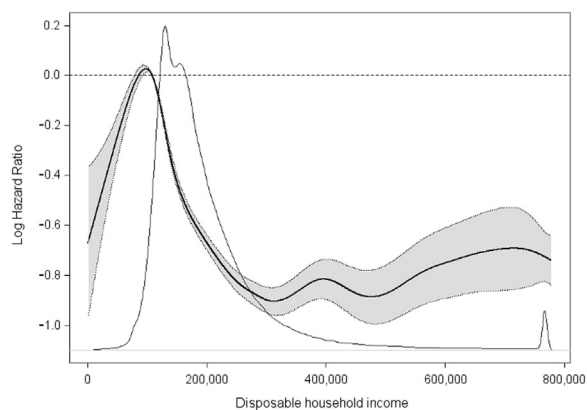
Fig. 2. Adjusted smooth log hazard ratio estimates of mortality by yearly disposable household income (SEK) measured in 2005 (thick line) with 95% confidence intervals (grey area) and density plot (thin line). The 10th percentile of income (SEK 107,800) was used as the reference.

Fig. 3. Adjusted smooth log hazard ratio estimates of mortality by yearly disposable household income (SEK) measured in 1990 (black line; the 10th percentile of income was used as the reference) and yearly household income (SEK) measured in 2005 (grey dashed line; the 10th percentile of income was used as the reference).

Table 3

Adjusted hazard ratios (HR) and logarithmic hazard ratios of mortality for different income percentiles with 95 percent confidence intervals. The 10th income percentile was used as the reference. Predicted from Table 2 model 3.

	Percentile	Swedish crowns	HR	Log HR	95% low	95% high
1990 (Midlife)	10	115,019	Ref.	Ref.		
	20	138,828	0.884	-0,123	-0.147	-0.099
	30	156,413	0.828	-0.189	-0.219	-0.158
	40	171,684	0.796	-0.228	-0.259	-0.197
	50	185,615	0.777	-0.252	-0.284	-0.221
	60	200,068	0.762	-0.272	-0.305	-0.240
	70	216,109	0.747	-0.292	-0.326	-0.257
	80	236,341	0.733	-0.311	-0.348	-0.274
	90	268,080	0.715	-0.335	-0.379	-0.291
2005 (Late life)	10	107,800	Ref.	Ref.		
	20	121,340	0.930	-0.073	-0.085	-0.061
	30	134,209	0.832	-0.183	-0.207	-0.160
	40	148,139	0.751	-0.287	-0.315	-0.259
	50	162,300	0.698	-0.359	-0.390	-0.329
	60	179,322	0.653	-0.426	-0.457	-0.395
	70	201,525	0.607	-0.500	-0.535	-0.465
	80	232,850	0.554	-0.591	-0.631	-0.551
	90	291,469	0.506	-0.681	-0.734	-0.627

income percentiles.

Fig. 2 (Model 2 in Table 2) shows income measured in late life (in 2005). The association between late-life income and mortality was similar to that for midlife income (Fig. 1) in that it followed a clear curvilinear pattern in which mortality decreased as income increased. The late-life gradient was slightly steeper partly because of the larger range in the top 1% of incomes and began to flatten at higher incomes (around SEK 280,000 to SEK 300,000) than in midlife (around SEK 170,000 to SEK 180,000). In the upper part of the income distribution, the mortality risk seems to increase slightly. As indicated earlier, the range of incomes was much wider in 2005 than 1990, skewing the distribution of income.

Fig. 3 (Model 3 in Table 2) shows the results of the analysis of mutually adjusted income measured in midlife (1990) and late life (year 2005). Although the shapes of the associations remained unchanged, as expected by including both measures in the model the associations between both midlife income and mortality (black line in Fig. 3) and late-life income and mortality (red line in Fig. 3) were weaker than in the models in Figs. 1 and 2. Late-life income was more strongly associated with mortality than was midlife income in the mutually adjusted model and the decrease in the gradient for midlife income was larger than the decrease in the gradient for late-life income.

In Figs. 1−3 there is a reversed association between income and mortality in the lowest part of the income distribution, were increased income is associated with higher mortality. There is relatively few people in this part of the income distribution but the observation seem robust also in most sensitivity analyses (see Supplementary Fig. 1−20).

Table 3 shows the predicted hazard ratio of mortality for every 10th percentile of midlife and late-life income. It was created on the basis of Model 3 in Table 2 and quantifies the shape shown in Fig. 3 for both standard coefficients and coefficients on the logarithmic scale at each 10th percentile value. Up to about the 50th income percentile, the decrease in the hazard ratio of mortality was similar in size for both years. Above the 50th income percentile, the effect of late-life (2005) income on mortality continued to decrease to a hazard ratio of 0.506 at the 90th income percentile but the effect of midlife (1990) income on mortality remained roughly stable (at a hazard ratio of approximately 0.7).

mortality with 95% confidence intervals (excluded in Fig. 3) for midlife and late-life income with the 10th percentile as the reference value in each figure. Figs. 1 and 2 also include a density plot of income (thin black line), which shows the distribution of individuals on the income scale.

Income in Fig. 1 (Model 1 in Table 2) was measured at midlife in 1990. The association between midlife income and late-life mortality shows a clear curvilinear shape over the whole income distribution; the marginal return on the hazard ratio of mortality decreased as income increased. The largest part of the decrease in the hazard ratio was observed for incomes of between approximately SEK 100,000 and SEK 300,000 kronor in equivalised disposable household income. This is also where the largest share of the population was situated. The density plot (thin line) shows an almost normal distribution of incomes up to the 99th percentile (above which incomes were top coded).

The interpretation of Figs. 1−3 should be done by looking at income on the x axis and log hazard ratio on the y axis. For every one unit increase in income the corresponding hazard ratio is found on the y axis, with the reference value for the hazard ratio set at the 10th income percentile. So for example in Fig. 1 at 200,000 SEK the log hazard ratio is -0.5 compared to the reference group at the 10th income percentile (115,019 SEK). Taking the exponent of -0.5 transforms the value from the logarithmic scale and gives a hazard ratio of 0.607, meaning that the hazard of mortality at 200,000 SEK is about 61 percent of the hazard in the reference group (10th percentile). See Table 3 for more exact point estimates for both log and non-log hazard ratios at specific

3.1. Sensitivity analysis: results

We conducted several tests to determine whether basic design choices (e.g., age categories, sex) impacted the results and whether there were crude indications of reverse causality (i.e., indications that health directly affected income) (See Section 2.3.1 Sensitivity analyses for detailed description). The results of the sensitivity analyses were similar in magnitude and shape to the presented results (see Supplementary Fig. 1–20). Thus, we concluded that the main findings were robust. The only notable deviation in the results was found in the analyses of reversed causality: removing the people identified as potential contributors to reversed causality attenuated the association between very low incomes and low mortality.

4. Discussion

Previous research has shown that the association between income and other indicators of socioeconomic position and health is maintained in old age (Fors et al., 2011; Huisman et al., 2003; Marmot & Shipley, 1996). The results of this study followed the same pattern and showed that the association between late-life income and mortality follows a curvilinear pattern with diminishing returns of income similar to that of working-life income and mortality (Dowd et al., 2011; Mackenbach et al., 2005; Rodgers, 1979). The main theories that explain the link between income and health are also compatible with these results. Looking at the materialistic approach (Marmot, 2002) one would expect a threshold effect or diminishing returns of increased income, as economic resources can only do so much when it comes to increasing health. The relative deprivation hypotheses (Wilkinson & Pickett, 2011) is less straight forward in regards to explaining a curvilinear association, but generally one would believe that health is always worse at the bottom of the income distribution compared to higher incomes. There is no easy way to disentangle these effects as they likely overlap and influence the income-health relationship differently at different parts of the income distribution.

We observed a larger and more pronounced gradient in the association between income and mortality in late-life than in midlife (see Fig. 3). Below we propose four possible explanations for this observation.

a) First, because late-life income reflects overall lifetime income as pensions are based on income from work, late-life income may be a better measure of income and wealth accumulated during life than midlife income. Thus, resulting in better predictions of mortality for late-life income. This interpretation is consistent with the cumulative advantage theory (CAD), which states that inequalities in health will increase with age as social processes that can affect health accumulate over the life course (Dannefer, 2003).

b) Second, vulnerability to social circumstances increases in old age (Hoffmann, 2011; House et al., 1994). A stronger link between income and mortality in old age may thus be the direct effect of greater vulnerability to negative social circumstances in old age than in earlier life.

c) Third, changes in the distribution of income, especially larger income disparities between people, could have an effect on the association income and mortality. We observed a substantial increase in the inequality measured by the Gini coefficient in the cohort from 1990 (Gini 0.18) to 2005 (Gini 0.25), a finding consistent with the increase in the income-mortality gradient in old age.

d) Fourth, the larger association in late life could simply be a result of the temporal relationship between exposure and outcome. That is, income measured closer to death could capture less random variation than income measured at midlife, thus resulting in a stronger association.

The large increase in the Gini coefficient (from 0.18 to 0.25) indicates that there were larger inequalities in the late-life income measure in our data than in the midlife income measure. We believe this is a result of both the age ranges in our cohort and of macro changes in Sweden during the same period. The Gini coefficient rose from 0.22 to 0.30 across all age groups in Sweden between 1990 and 2005, and the share of income accruing to the top 1 percent rose from 3.5 percent to 6.9 percent during the same period (SCB, 2016a). These changes combined with the substantial drop in income from work after age 65 (compensated by a larger share of income from pensions and capital) (Palme & Svensson, 1999; SCB, 2016b). Thus, the large increase in the share of top incomes and increase in the Gini coefficient in our data is not unexpected given developments in Sweden during this period and the increased share of income from capital in old age.

The reversed association at the lowest end of the income distribution is not an easy task to explain, it has been observed before in Swedish income register data (Fritzell et al., 2004). As can be seen in the Supplementary Fig. 1–20 the observation seem robust as it remains in most of the sensitivity analyses. The association at the bottom is mostly attenuated, but not entirely gone in Supplementary Fig. 17 where only individuals that retire close to the official retirement age is included, this is a very select population and we are cautious to draw any conclusions from this. We have previously conducted further tests in the Swedish registers without finding one conclusive answer to why these reversed patterns at low income exist. Therefore we can only speculate on the cause for this anomaly. We suggest that it is driven by a number of factors: migration, nontaxable incomes as well as tax evasion in combination with some degree of measurement error for both mortality and income. Although an interesting observation that invites speculation, we believe the main results and conclusions drawn in this study are not affected because of the relatively limited and select number of people at the very bottom of the income distribution (see the density plot in Fig. 1 and Fig. 2).

Regardless of the specific causes and mechanisms behind the results, the main findings reveal that the association between income and mortality in later life follows a curvilinear gradient with diminishing returns of income on mortality, similar in shape to that of the association between income and mortality in people of working age. Our study reveals not only the long arm of social stratification but also that present income among persons above retirement age matters for mortality risks. Although income from capital is a relatively large and growing proportion of the total income sum for older persons the major bulk of income originate from the pension system. In so far as some part of that association is seen as causally related it implies that the structure and generosity of pension play a role for old-age mortality. Such a finding is from an international policy perspective even more interesting given Sweden's record of having comparatively generous pension schemes. Evidence on income support policies from the US point towards similar results where expansions of income support for low income elderly show beneficial effects on health (Herd, House, & Schoeni, 2008).

4.1. Strengths and limitations

We do not believe that the findings in this study is limited to only this specific cohort, born from 1930 to 1940, considering the support of previous findings in widely varying working age populations. However, the gradient that we observe is likely to vary in strength and level between cohorts and populations. In future studies that focus on old age it would be useful to more closely examine the shape of the association between income and health in specific age groups, including the oldest old, rather than using an upper age limit as we have done in this study. Such studies could delve deeper into questions of the importance of income at more advanced ages and of the importance of selective mortality in the oldest old.

With this study we make no claims of trying to identify the causal

pathways from income to health resulting in limitations when it comes to interpreting the casual effect of income on mortality. Other studies have attempted this before but whether they are successful or not is dependent on what criteria for casual inference one follows (see Deaton (2003) for a discussion on the topic). For the purpose of casual inference other types of data and other methods are often better (for example see Glymour, Avendano, & Kawachi (2014). Because of this approach we did not include many covariates in the regression models that could potentially explain or change the association that we observe. We know that other measures of socioeconomic position such as education and occupation are also associated to mortality, these follow similar gradients to that of income with lower mortality among higher educated and higher status occupations than those in lower positions (Erikson & Torssander, 2008; Montez & Zajacova, 2013).

We handle income variability by measuring working life income between ages 50 and 60, a period where incomes are relatively stable and representative of work-life income. This design also reduces problems caused by direct health selection as midlife income is measured 16 years prior to mortality follow-up, but there is always possible that health problems even earlier in life could still cause selection (Deaton, 2003). We also condition on survival until the second income measure in late-life (age 65–75) and therefore cause some selection in our design due to mortality or migration. Additional analyses showed that income in 1990 do predict mortality for those that died between 1991 and 2005 (the people excluded due to conditioning on survival in 2005). This conditioning could cause an underestimation of the effect of midlife income. Sample characteristics of the excluded individuals can be seen in Supplementary Table 1.

5. Conclusion

This study used Swedish population register data on 801,017 people to examine the association between income and mortality. We selected one cohort, aged 50 to 60 in 1990, measured income during midlife (1990) and late life (2005), and measured mortality between 2006 and 2009. The strength and shape of the association between midlife income and mortality and late-life income and mortality was examined. Cox proportional hazard models with penalized splines enabled us to examine for non-linearity. Results showed a curvilinear association between income and later mortality. The shape of the association between midlife income (income between the ages of 50 and 60) and later mortality was curvilinear; incomes above the 50th to 60th percentile gave diminishing returns. The shape of the association between late-life income (income between the ages of 65 and 75) and later mortality was also curvilinear. Incomes above the 80th to 90th percentile gave diminishing returns. Late-life income was more strongly associated with mortality than midlife income when both variables were included in the same model; the gradient was steeper in late life than midlife. The results indicated that there was an association between late-life income and late-life mortality. This association was curvilinear with diminishing returns of income, like the previously known association between working age income and mortality. The analyses indicated that the association remained after controlling for midlife income.

Acknowledgements

Appendix A. Supplementary material

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.ssmph.2016.10.005.

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