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Trends in the shape of the income–mortality association in Sweden between 1995 and 2017: a repeated cross-sectional population register study

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ABSTRACT

Objective We investigate recent trends in income inequalities in mortality and the shape of the association in Sweden. We consider all-cause, preventable and non-preventable mortality for three age groups (30–64, 65–79 and 80+ years).

Design and setting Repeated cross-sectional design using Swedish total population register data.

Participants All persons aged 30 years and older living in Sweden 1995–1996, 2005–2006 and 2016–2017 (n=8 084 620).

Methods Rate differences and rate ratios for all-cause, preventable and non-preventable mortality were calculated per income decile and age group.

Results From 1995 to 2017, relative inequalities in mortality by income increased in Sweden in the age groups 30–64 years and 65–79 years. Absolute inequalities increased in the age group 65–79 years. Among persons aged 80+ years, inequalities were small. The shape of the income–mortality association was curvilinear in the age group 30–64 years; the gradient was stronger below the fourth percentile. In the age group 65–79 years, the shape shifted from linear in 1995–1996 to a more curvilinear shape in 2016–2017. In the oldest age group (80+ years), varied shapes were observed. Inequalities were more pronounced in preventable mortality compared with non-preventable mortality. Income inequalities in preventable and non-preventable mortality increased at similar rates between 1995 and 2017.

Conclusions The continued increase of relative (ages 30–79 years) and absolute (ages 65–79 years) mortality inequalities in Sweden should be a primary concern for public health policy. The uniform increase of inequalities in preventable and non-preventable mortality suggests that a more complex explanatory model than only social causation is responsible for increased health inequalities.

Strengths and limitations of this study

- ► Total population register data allow for descriptions of trends that are representative of the population, including older persons.
- ► By analysing all-cause, preventable and non-preventable mortality, we can speculate about the causes behind increased health inequalities.
- ► No information in the population registers on personal characteristics and behaviours limits further investigation of individual-level mechanisms.

INTRODUCTION

Inequalities in mortality have been observed in Sweden for the last 50 years[1] and reducing them has been on the political agenda for more than 30 years.[2] Yet, income-based inequalities in mortality increased substantially in Sweden during the 1990s and the early 2000s.[3–6] Similar trends have been observed in other Nordic countries[5 7 8] and during the 2010s, social inequalities in life expectancy continued to increase in Sweden.[9 10] Less is known about recent trends in the shape of the income–mortality association, and whether mortality in any specific part of the income distribution contributes to widening social inequalities in mortality.

A multitude of inter-related and complex processes that occur as intertwined processes across the life course contribute to the association between income and health.[11 12] The most obvious processes are those related to social causation, such as poor material conditions,[13] reversed causation pathways where health impedes the ability to fully participate in the labour market, and thus negatively affects a person's income,[14] and various health behaviours, for example, smoking and alcohol consumption.[15] In addition, personal characteristics that are important to succeed on the labour market, both cognitive and non-cognitive, confound the association between income and health.[16 17] All these processes contribute to the often found non-linear association between income and health; the gradient tends to be stronger at lower incomes and weaker at higher incomes.[5 18–20]

Income and other socioeconomic assets have been suggested to be flexible resources that can be used to avoid health risks and to mitigate consequences that follow health

problems. This is at the core of the theory of fundamental causes that posits that resources are potentially beneficial for health no matter what specific health risks are prevalent in a given context at any given point in time.[21 22] However, health risks can only be actively avoided or mitigated when knowledge on how to do so is available; attempts to test the fundamental causes theory have been made by categorising causes of death according to how preventable they are. If socioeconomic position is in any way causally related to mortality, then deaths from causes that are less preventable should exhibit a smaller socioeconomic gradient and causes that are considered more preventable should exhibit a larger socioeconomic gradient. In support of the theory, studies often find stronger social gradients in preventable causes of death.[21 23–25]

The relationship between income and mortality changes across the life course,[26] and the importance of the contributing processes may change as the individual ages. For example, exposure to poor socioeconomic conditions during childhood and working life possibly has lasting effects on health throughout the life course.[27–29] Studies that have examined the association between income and mortality in different age groups have generally found smaller relative inequalities in old ages compared with young ages.[5 30] Fewer studies have examined absolute inequalities in different age groups, however, those that do generally find persistent or widening absolute inequalities in older age groups,[31 32] except among the oldest old (85 years and over) where income inequalities in mortality have been shown to converge.[26]

Diverging trends between absolute and relative measures of inequality are commonly observed.[33] Both absolute measures (eg, rate differences) and relative measures (eg, rate ratios) tend to be sensitive to the prevalence of the outcome. This makes it difficult to compare inequalities in mortality across groups with large differences in absolute level of mortality. For example, when overall mortality is reduced in a population, relative inequalities tend to be stable or increase, while absolute inequalities tend to decrease.[33] Due to these properties, it has been suggested that both relative and absolute measures of health inequalities should be reported.[34 35] Yet, King *et al*[36] showed that of studies on health inequalities published in public health journals in 2009, only 7% reported both absolute and relative measures while 88% only included a relative measure.

Based on previous evidence, we expect that the income–mortality gradient has continued to widen since the 1990s and 2000s.[4 5 7 9] Moreover, previous studies that examined trends in the income–mortality association primarily focused on working-age populations, therefore, we do not know whether the development has been similar among older persons. Finally, if income-based inequalities in mortality are widening due to increased social causation or social selection, we expect that this increase is mainly driven by mortality from causes that are considered preventable.

Aim

In this study, we investigate the development of the income–mortality gradient in 1995–1996, 2005–2006 and 2016–2017 in Sweden in three age groups (30–64, 65–79 and 80+ years). More specifically, we aim to investigate: (1) how the income–mortality gradient has changed between 1995 and 2017; (2) if this change has predominantly occurred in any specific part of the income distribution; (3) if changes have been similar in all age groups; and (4) whether the development has been similar for causes of deaths that are more preventable versus less preventable. We assess mortality inequalities between income groups using both absolute and relative measures.

METHODS

Data and participants

The data used in this study were compiled from various Swedish population registers and included the total population above age 30 years who were living in Sweden during the years 1995–1996, 2005–2006 and 2016–2017. In total, 8 084 620 persons were observed across these three time periods. Many individuals were observed at more than one time point and the total mid-year populations used for calculating death rates numbered 17 044 027 observations (see table 1).

Patient and public involvement

The population register data used in this study are collected for use in official statistics and figures and for administrative purposes. We did not involve patients or the public in the design, conduct, reporting or dissemination of our research.

Statistical analyses

All-cause mortality was measured by age-standardised mortality rates (ASMRs) per 100 000 person-years using the 2013 European Standard Population.[37] Age standardisation was performed to lessen the effect that changes in the age structure might have had on the income–mortality association between measurement points. ASMRs were calculated for three periods in 2-year intervals (1995–1996, 2005–2006 and 2016–2017), for three age groups (30–64, 65–79 and 80+ years) and by income deciles. We repeated the analysis using the same age categories but without applying age standardisation, observing similar patterns (results not shown).

We classified causes of death as either preventable or non-preventable. This classification was adopted from Mackenbach *et al*[24] and was similar to the classification that Phelan *et al*[23] used for testing the fundamental causes theory. The International Classification of Diseases (ICD) codes for this procedure are presented in online supplemental table 1.

Income was measured by the average equivalent disposable household income over 5 years and was divided into decile groups based on the income distribution within each age group (30–64, 65–79 and 80+ years). The

Table 1 Population and number of deaths 1995–1996, 2005–2006 and 2016–2017 by age group (n=8 084 620)

		1995–1996		2005–2006		2016–2017	
	Age	Mid-year population	Deaths	Mid-year population	Deaths	Mid-year population	Deaths
	30–64	3 702 509	23 795	4 016 345	23 283	3 976 011	16 537
	65–79	1 141 894	62 512	1 084 292	48 124	1 502 422	48 335
	80 and over	461 743	97 330	539 130	107 620	619 681	112 767
Income percentile	Age	Average yearly income 1990–1994*		Average yearly income 2000–2004*		Average yearly income 2011–2015*	
	30–64	143.8		156.0		194.1	
20%	65–79	115.5		131.6		166.3	
	80 and over	93.5		109.1		139.6	
	30–64	185.3		211.9		284.8	
50%	65–79	151.7		179.9		254.2	
	80 and over	109.6		131.7		172.2	
	30–64	241.8		285.8		397.1	
80%	65–79	206.5		256.6		391.6	
	80 and over	142.8		178.3		244.0	
	Age	Gini 1990–1994†		Gini 2000–2004†		Gini 2011–2015†	
	Total	0.213		0.247		0.297	
	30–64	0.196		0.235		0.277	
	65–79	0.212		0.249		0.324	
	80 and over	0.179		0.206		0.263	

*Swedish krona in thousands, adjusted for inflation with 2015 as index year.
†Gini coefficients were calculated for the 4-year average equivalised income with no top coding.

average was measured for the 5 years preceding mortality follow-up (eg, for mortality measured in 1995–1996, income groups were derived from the average equivalent disposable household income during the years 1990, 1991, 1992, 1993 and 1994). Measuring the average income over 5 years reduces the impact of short-term fluctuations in income that might occur during 1 year and lessens the impact that health complications can have on employment and income in the year preceding death.[38 39] To make income comparable across different household compositions, disposable household income was divided by the square root of number of household members.

Income inequalities in mortality were assessed on a relative and an absolute scale by comparing mortality in the top and bottom three income deciles to the total mortality within each age group. The relative difference was assessed by the ratio between the top or bottom three income deciles with the total mortality in the same group. Both the ratio and the natural logarithm of the ratio are presented to ease the interpretation of the non-symmetrical properties of the ratio scale above and below 1. The absolute difference was assessed by the difference in number of deaths per 100 000 person-years.

Locally estimated scatterplot smoothing (LOESS) was used to smooth the data in the visual presentations of mortality by income deciles.[40] The LOESS method is non-parametric and fits multiple regressions that are weighted toward the nearest neighbour observation. The underlying data and non-smoothed plots are presented in online supplemental table 2 and figure 1.

Sensitivity analyses showing the shape of the income–mortality association using finer age categories (5-year groups) (online supplemental figure 2) and stratified by sex were performed (online supplemental figures 3 and 4).

RESULTS

Table 1 presents descriptive statistics for the analytical sample in this study. In total, 8 084 620 individuals contributed with 17 044 027 observations and 540 303 deaths during the study period. Most observations in the data were in the age group 30–64 years and most observed deaths were in the age group 80+ years. Previous research and routine data collection of incomes in Sweden have shown increased income levels and inequality since the 1990s. These trends were observed in the analytical sample; the Gini coefficient of the averaged incomes between 1990 and 1994 was 0.213, and for incomes between 2011 and 2015, the Gini coefficient increased to 0.297. An increase in income inequality was observed in all age groups.

Figure 1A–C presents age-standardised death rates by income decile for the years 1995–1996, 2005–2006 and 2016–2017 in three age groups. To quantify the patterns seen in

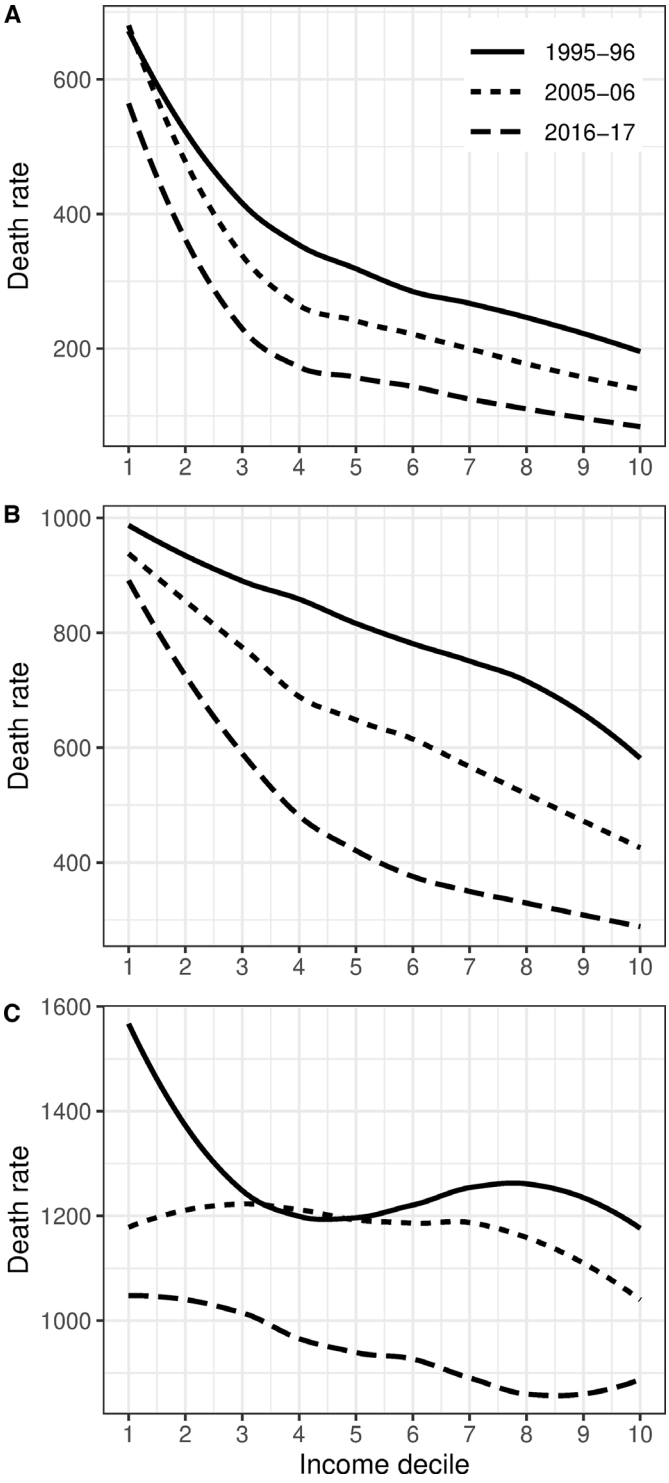

Figure 1 Age-standardised death rate by income decile in 1995–1996, 2005–2006 and 2016–2017 for persons aged (A) 30–64 years, (B) 65–79 years, and (C) 80+ years.

figure 1A–C, absolute and relative inequalities in death rates are presented in table 2. In this table, mortality in the top three and the bottom three income deciles are compared against the total mortality within each age group.

A curvilinear pattern was observed in the age group 30–64 years (figure 1A). The curve flattened between decile three and five, with an earlier and a more pronounced inflection of the curve in 2016–2017 compared with 1995–1996 and 2005–2006. Between 1995 and 2006, the largest mortality reduction was seen above decile four. In 2016–2017, mortality was reduced across the complete income distribution. Absolute inequalities in the age group 30–64 years were stable between 1995 and 2017, showing around 200 more deaths per 100 000 person-years in the bottom three income deciles compared with the average mortality rate in the sample (see table 2 age group 30–64 years). In the top three income deciles, there were around 100 fewer deaths per 100 000 person-years compared with the average mortality rate (see table 2 age group 30–64 years). The combination of an overall reduction of mortality and only a slight decline of absolute inequalities resulted in an increase of relative inequalities among those aged 30–64 years. Relative inequalities increased from 66% higher mortality in the bottom three income deciles compared with the average mortality in the sample in 1995–1996 to 104% in 2016–2017. Similarly, the top three income deciles showed 32% (1–0.68) lower mortality compared with the average mortality in the sample in 1995–1996; this difference increased to 49% (1–0.51) in 2016–2017. Increased relative inequalities were thus driven by changes in both the upper and lower part of the income distribution. Expressed on the logarithmic ratio scale, the estimates showed that this increase was slightly larger in the upper part of the income distribution.

A linear pattern in the income–mortality association was observed for those aged 65–79 years in 1995–1996 (figure 1B). During 2005–2006 and 2016–2017, tendencies towards non-linear patterns were observed: the income–mortality gradient was stronger below income decile four. Furthermore, in the age group 65–79 years, mortality was reduced in all income deciles. The decrease in the top three income deciles was 347 deaths per 100 000 person-years between 1995 and 2017 (658 -311), whereas the corresponding reduction in mortality in the lowest three income deciles was 197 (from 936 in 1995–1996 to 739 in 2016–2017). Consequently, both relative and absolute inequalities increased substantially in this age group. The bottom three income deciles showed an 18% higher mortality rate compared with the average mortality rate in the sample in 1995–1996; this difference increased to 55% in 2016–2017. Similarly, the top three income deciles had a 17% (1–0.83) lower mortality compared with the average mortality in 1995–1996; this difference increased to 35% (1–0.65) in 2016–2017. The logarithmic ratio scale confirmed that the relative increase of inequalities was constant across the income distribution. Increased inequalities in mortality among those aged 65–79 years were thus driven by reductions in mortality that were substantially larger in the upper part of the income distribution compared with mortality in the lower part of the income distribution.

In the oldest age group (aged 80+ years), the mortality pattern across income deciles shifted during the study period. In 1995–1996, a non-linear pattern was observed

Table 2 Relative and absolute differences in death rate between the overall age-standardised mortality rate in each age group and the age-standardised mortality rate in the top three and the bottom three income decile groups

	Year	Income group	Age-standardised death rate per 100 000	Ratio difference*	Log ratio difference	Rate difference†
Age 30–64						
	1995–1996	Bottom 30%	538	1.66	0.51	214
		Top 30%	222	0.68	−0.39	−103
		Total	325			
	2005–2006	Bottom 30%	496	1.89	0.64	234
		Top 30%	156	0.59	−0.53	−107
		Total	263			
	2016–2017	Bottom 30%	387	2.04	0.71	198
		Top 30%	97	0.51	−0.67	−93
		Total	189			
Age 65–79						
	1995–1996	Bottom 30%	936	1.18	0.17	142
		Top 30%	658	0.83	−0.19	−136
		Total	795			
	2005–2006	Bottom 30%	860	1.32	0.28	208
		Top 30%	472	0.73	−0.31	−179
		Total	652			
	2016–2017	Bottom 30%	739	1.55	0.44	261
		Top 30%	311	0.65	−0.43	−167
		Total	478			
Age 80+						
	1995–1996	Bottom 30%	1396	1.09	0.08	111
		Top 30%	1226	0.95	−0.05	−59
		Total	1285			
	2005–2006	Bottom 30%	1206	1.03	0.03	35
		Top 30%	1102	0.94	−0.06	−69
		Total	1171			
	2016–2017	Bottom 30%	1043	1.11	0.10	103
		Top 30%	866	0.92	−0.08	−74
		Total	940			

*Ratio difference between the total mortality and the three bottom/top income deciles.
†Rate difference between the total mortality and the three bottom/top income deciles.

with a stronger gradient at low incomes, while in 2005–2006, the income–mortality gradient was overall weaker and more linear. In 2016–2017, again a non-linear gradient was observed, which in figure 1C was somewhat obscured by the large overall reduction in mortality in this age group. A reduction in mortality occurred in the lowest and the highest income decile groups between 1995 and 2006. In 2016–2017, mortality had decreased substantially in all income decile groups. In the oldest age group, both relative and absolute inequalities thus remained stable at rather low levels during the entire observed period.

Table 3 presents differences in mortality rates between the top three income deciles and the bottom three income deciles compared with the average mortality in the sample for preventable and non-preventable causes of death. In the age group 30–64 years, relative inequalities were substantially larger in preventable mortality compared with relative inequalities in non-preventable mortality. An increase in relative inequalities occurred in both preventable and non-preventable mortality between 1995 and 2017, driven by changes across the whole income distribution. Similarly, in absolute terms, inequalities were larger in preventable mortality. Due to the large reduction of overall preventable mortality, however, absolute inequalities in preventable mortality decreased. In contrast, absolute inequalities in non-preventable mortality did not change.

Table 3 Relative and absolute differences in death rate between the overall age-standardised mortality rate and the age-standardised mortality rate in the top three and the bottom three income decile groups by causes of death

		Preventable mortality				Non-preventable mortality			
Year	Income group	Age-standardised death rate per 100 000	Ratio difference*	Log ratio difference	Rate difference†	Age-standardised death rate per 100 000	Ratio difference*	Log ratio difference	Rate difference†
Age 30–64									
1995–1996	Bottom 30%	302	1.73	0.55	127	237	1.58	0.46	86
	Top 30%	112	0.64	−0.45	−62	110	0.73	−0.31	−41
	Overall	175				150			
2005–2006	Bottom 30%	281	1.98	0.68	139	215	1.79	0.58	95
	Top 30%	79	0.56	−0.58	−63	77	0.64	−0.45	−43
	Overall	142				120			
2016–2017	Bottom 30%	192	2.14	0.76	102	195	1.96	0.67	95
	Top 30%	43	0.48	−0.73	−47	54	0.54	−0.62	−46
	Overall	90				100			
Age 65–79									
1995–1996	Bottom 30%	550	1.19	0.17	87	387	1.17	0.16	55
	Top 30%	375	0.81	−0.21	−88	283	0.85	−0.16	−49
	Overall	463				332			
2005–2006	Bottom 30%	489	1.38	0.32	134	370	1.25	0.22	74
	Top 30%	238	0.67	−0.40	−117	235	0.79	−0.24	−62
	Overall	355				297			
2016–2017	Bottom 30%	385	1.66	0.51	153	354	1.44	0.36	108
	Top 30%	132	0.57	−0.56	−99	179	0.73	−0.31	−67
	Overall	232				246			
Age 80+									
1995–1996	Bottom 30%	779	1.07	0.07	50	617	1.11	0.10	61
	Top 30%	703	0.96	−0.04	−26	523	0.94	−0.06	−33
	Overall	729				556			
2005–2006	Bottom 30%	597	1.02	0.02	12	609	1.04	0.04	23
	Top 30%	541	0.93	−0.08	−43	561	0.96	−0.04	−25
	Overall	584				587			
2016–2017	Bottom 30%	450	1.12	0.11	47	593	1.10	0.10	55
	Top 30%	352	0.87	−0.13	−51	514	0.96	−0.05	−24
	Overall	403				538			

*Ratio difference between the total mortality and the three bottom/top income deciles.
†Rate difference between the total mortality and the three bottom/top income deciles.

In the age group 65–79 years, relative inequalities were again larger in preventable mortality, however, the difference in inequality between non-preventable and preventable mortality was small in 1995–1996. This gap grew during the observed period, and relative inequalities in preventable mortality increased more than relative inequalities for non-preventable mortality. Absolute inequalities were larger in preventable mortality in 1995–1996, 2005–2006 and 2016–2017 compared with absolute inequalities in non-preventable mortality. Despite reductions in mortality in both preventable and non-preventable causes of death, absolute inequalities increased in both groups.

In the oldest age group (80+ years), relative inequalities were at similar levels for preventable and non-preventable mortality. In 2016–2017, relative inequalities in preventable mortality widened somewhat compared with previous periods, this change was mainly driven by lower absolute mortality in the upper part of the income distribution.

To test whether there were variations within the age groups that we choose, we present crude death rates in 5-year age groups in online supplemental figure 2. In the first seven 5-year age groups (30–64 years), the shape of the association was similar to the extent that it showed curvilinear associations at the three time periods across similar income deciles. In the youngest age group (30–34 years), the association deviated somewhat compared with the other age categories, with much stronger associations in the lowest two income deciles and no association at higher income deciles. In the age group that included the

younger old (65–79 years), all 5-year age groups showed more linear trends in 1995–1996 and 2005–2006, and more curvilinear patterns in 2016–2017. Among those aged 80 years and over, there were somewhat more varied patterns, but with similar tendencies in all included 5-year intervals.

Analyses stratified by sex are presented in online supplemental figures 3 and 4. As expected, mortality was lower for women at all observed periods and income levels. In the age groups 30–64 years and 65–79 years, the overall shape of the associations was similar. In the oldest age group (80+ years), the shapes between men and women were similar in 2005–2006 and 2016–2017. In 1995–1996, the shape was somewhat more curvilinear for women than for men.

DISCUSSION

The results of this study showed that relative inequalities in mortality by income increased in Sweden in the age groups 30–64 years and 65–79 years, and that absolute inequalities increased in the age group 65–79 years during the period from 1995 to 2017. Relative and absolute inequalities in the oldest age group (80+ years) were low but showed increasing trends that were driven by increasing absolute inequality in the upper part of the income distribution. The commonly observed curvilinear shape of the income–mortality association[5 18–20 41] was most pronounced in the age group 30–64 years. In the age group 65–79 years, the shape of the associations shifted from linear in 1995–1996 to a more curvilinear shape in 2016–2017. In the oldest age group (80+ years), varied shapes were observed and in 1995–1996, the shape was more curvilinear for women than for men.

Several studies have previously observed growing income-based health inequalities since the early 1990s in Sweden.[3–6] Hederos *et al*[3] examined how specific causes of death contributed to life expectancy changes and Mortensen *et al*[5] studied the shape of the association in four Nordic countries in 1995 and 2003. Fors *et al*[6] showed that income differences in life expectancy increased also among older persons up to 2015. The current study contributes to a more comprehensive understanding of time trends in income inequalities in mortality. Using more recent data than has been previously available, we examine both absolute and relative inequalities in mortality and present time trends in the shape of the income gradient in different age groups, including older persons.

Our results are consistent with previous research that has found smaller relative health inequalities among older persons compared with younger age groups.[5 30] During the study period, however, relative income inequalities in mortality in the age group 65–79 years increased substantially and were in 2016–2017 more similar to the levels in the age group 30–64 years than they were in 1995. Fewer studies have examined trends in absolute inequalities in mortality. Our results showed that in 1995–1996, absolute income inequalities in mortality were largest among persons aged 30–64 years. This changed in 2016–2017, absolute inequalities were at this time by far largest in the age group 65–79 years. These results show that health inequalities in Sweden persist in older ages, and, if these trends continue, future cohorts of older persons will experience similar or even higher levels of health inequalities compared with working-age persons.

Age variations in the shape of the income–mortality gradient highlight the importance of considering age-specific processes. These are shaped by age-stratified institutions that individuals age in and out of, such as the educational system, the labour market, and the tax and pension systems. The organisation of these institutions may have consequences for the functional form of the income–mortality association, in part since it affects income inequality. The distribution of income is an important component in the income–mortality association. We observed substantial increases in income inequality measured by the Gini coefficient in all age groups. Increased income inequalities in Sweden have been driven by higher top incomes[42] and in the 2000s by stagnation of benefits and reduced taxes on earnings that led to a growing gap between insiders and outsiders on the labour market.[43] The latter changes are intentional consequences of political decisions. Several earned income tax credits were introduced between 2007 and 2019 (jobbskatteavdrag) as activation measures, which meant that income from work was taxed significantly lower than other types of incomes, including pensions. Moreover, the universal guaranteed pension, distributed to persons with no or low earnings during their working life, is indexed to prices, unlike the major earnings-related pensions which are indexed to the 'real growth'.

Among older persons who aged into retirement during the late 1990s and 2000s, this was reflected by increased income inequalities and growing relative poverty rates, which may have contributed to the growing income–mortality gradient that we observed in the age group 65–79 years in two different ways. First, the growing income differences between insiders and outsiders on the labour market are likely to have disproportionally affected the finances of people with poor health and traits associated with poor health, resulting in a larger clustering of people with poor health at the bottom of the income distribution. Second, to the extent relative poverty has a negative causal effect on health, the increased rates of relatively poor retirees may have aggravated these health inequalities further. Along these lines, the increasing income inequalities among working-age adults and older persons suggest that the distribution of pension incomes may be increasingly important for health inequalities as current and future cohorts enter retirement.

We observed the income–mortality gradient in both preventable and non-preventable mortality; however, consistent with previous research, the gradient was more pronounced in preventable mortality.[21 23 24] Between 1995 and 2017, income inequalities in mortality increased for

both preventable and non-preventable causes of deaths in the age groups 30–64 years and 65–79 years. If social causation or social selection was the main driver for the increased inequalities in mortality that were observed, we would expect a larger increase in inequality in preventable mortality, based on the hypothesis that socioeconomic resources can be more effectively used to protect individuals against causes of death that can be prevented. The results on the income gradient in preventable and non-preventable mortality, therefore, suggest a more complex explanatory model where social causation, social selection and health selection may all contribute to increased health inequalities.[11]

Population register data do not offer direct measurements of respondents' behaviours and subjective assessment of their situation. This limits further investigations on how specific mechanisms influence the income–mortality association, such as health behaviours or cognitive abilities. We tried to overcome this by dividing mortality into preventable and non-preventable causes of death, however, the conclusions that we can draw from these results are limited to only speculating what the underlying mechanisms might be.

CONCLUSIONS

The reduction of health inequalities has been on the Swedish political agenda for more than 30 years.[2] Contrary to this goal, the results from this study showed that in all age groups except among those aged 80+ years, relative inequalities increased over the last 30 years with no indication of slowing down. One argument against a sole focus on relative inequalities is that they tend to be stable or increase when overall rates of morbidity and mortality are reduced in a population.[33] It has therefore been suggested that absolute measures of inequality are better metrics to focus on in contexts of declining mortality rates.[44 45] We showed that absolute inequalities declined only slightly in the age groups 30–64 years, were stable among persons aged 80+ years and increased in the age group 65–79 years. In terms of health inequalities, this development can hardly be considered a success.

Contributors JR, OÖ, SF and JF contributed to the study conception and design. Data collection was done by OÖ. Data analysis was performed by JR. The first draft of the manuscript was written by JR. All authors commented and contributed to all iterations of the manuscript. All authors read and approved the final manuscript. JR is responsible for the overall content as guarantor.

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Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not required.

Ethics approval The use of data for the purposes of this study was granted by the Swedish Central Ethical Review Board (Dnr Ö 25-2017).

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data may be obtained from a third party and are not publicly available. The data used in this study were collected from Swedish administrative registers. These data can be requested for research use from Statistics Sweden and the National Board of Health and Welfare. To apply for the data, an ethical permit is needed which can be obtained from the Swedish Ethical Review Authority.

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REFERENCES

1 Debiasi E, Dribe M. Ses inequalities in cause-specific adult mortality: a study of the long-term trends using longitudinal individual data for Sweden (1813-2014). *Eur J Epidemiol* 2020;35:1043–56.
2 Lundberg O. The next step towards more equity in health in Sweden: how can we close the gap in a generation? *Scand J Public Health* 2018;46:19–27.
3 Hederos K, Jäntti M, Lindahl L, *et al*. Trends in life expectancy by income and the role of specific causes of death. *Economica* 2018;85:606–25.
4 Kondo N, Rostila M, Yngwe Monica Åberg. Rising inequality in mortality among working-age men and women in Sweden: a national registry-based repeated cohort study, 1990-2007. *J Epidemiol Community Health* 2014;68:1145–50.
5 Mortensen LH, Rehnberg J, Dahl E, *et al*. Shape of the association between income and mortality: a cohort study of Denmark, Finland, Norway and Sweden in 1995 and 2003. *BMJ Open* 2016;6:e010974.
6 Fors S, Wastesson JW, Morin L. Growing Income-Based inequalities in old-age life expectancy in Sweden, 2006-2015. *Demography* 2021;58:2117–38.
7 Kinge JM, Modalsli JH, Øverland S, *et al*. Association of household income with life expectancy and cause-specific mortality in Norway, 2005-2015. *JAMA* 2019;321:1916.
8 Tarkiainen L, Martikainen P, Laaksonen M. The changing relationship between income and mortality in Finland, 1988-2007. *J Epidemiol Community Health* 2013;67:21–7.
9 Statistics Sweden. *Life expectancy and mortality in different social groups*. Statistics Sweden, Forecast Institute, 2016.
10 SOU. *Det handlar Om jämlik hälsa: utgångspunkter för Kommissionens vidare arbete: delbetänkande*. Stockholm, Sweden, 2016.
11 Kröger H, Pakpahan E, Hoffmann R. What causes health inequality? A systematic review on the relative importance of social causation and health selection. *Eur J Public Health* 2015;25:951–60.
12 Lundberg O. Next steps in the development of the social determinants of health approach: the need for a new narrative. *Scand J Public Health* 2020;48:473–9.
13 Kawachi I, Adler NE, Dow WH. Money, schooling, and health: mechanisms and causal evidence. *Ann N Y Acad Sci* 2010;1186:56–68.
14 O'Donnell O, Van Doorslaer E, Van Ourti T. Health and Inequality. In: *Handbook of income distribution*. Elsevier, 2015: 1419–533.
15 Östergren O, Martikainen P, Tarkiainen L, *et al*. Contribution of smoking and alcohol consumption to income differences in life expectancy: evidence using Danish, Finnish, Norwegian and Swedish register data. *J Epidemiol Community Health* 2019;73:334–9.
16 Gottfredson LS. Intelligence: is it the epidemiologists' elusive "fundamental cause" of social class inequalities in health? *J Pers Soc Psychol* 2004;86:174–99.

17 Smithers LG, Sawyer ACP, Chittleborough CR, *et al*. A systematic review and meta-analysis of effects of early life non-cognitive skills on academic, psychosocial, cognitive and health outcomes. *Nat Hum Behav* 2018;2:867–80.
18 Dowd JB, Albright J, Raghunathan TE, *et al*. Deeper and wider: income and mortality in the USA over three decades. *Int J Epidemiol* 2011;40:183–8.
19 Fritzell J, Nermo M, Lundberg O. The impact of income: assessing the relationship between income and health in Sweden. *Scand J Public Health* 2004;32:6–16.
20 Mackenbach JP, Martikainen P, Looman CWN, *et al*. The shape of the relationship between income and self-assessed health: an international study. *Int J Epidemiol* 2005;34:286–93.
21 Phelan JC, Link BG, Tehranifar P. Social conditions as fundamental causes of health inequalities: theory, evidence, and policy implications. *J Health Soc Behav* 2010;51 Suppl:S28–40.
22 Link BG, Phelan J. Social conditions as fundamental causes of disease. *J Health Soc Behav* 1995;Spec No:80–94.
23 Phelan JC, Link BG, Diez-Roux A, *et al*. "Fundamental causes" of social inequalities in mortality: a test of the theory. *J Health Soc Behav* 2004;45:265–85.
24 Mackenbach JP, Kulhánová I, Bopp M, *et al*. Variations in the relation between education and cause-specific mortality in 19 European populations: a test of the "fundamental causes" theory of social inequalities in health. *Soc Sci Med* 2015;127:51–62.
25 Ericsson M, Pedersen NL, Johansson ALV, *et al*. Life-Course socioeconomic differences and social mobility in preventable and non-preventable mortality: a study of Swedish twins. *Int J Epidemiol* 2019;48:1701–9.
26 Rehnberg J, Fors S, Fritzell J. Divergence and convergence: how do income inequalities in mortality change over the life course? *Gerontology* 2019:313–22.
27 Martikainen P, Elo I, Tarkiainen L, *et al*. The changing contribution of childhood social characteristics to mortality: a comparison of Finnish cohorts born in 1936-50 and 1961-75. *Int J Epidemiol* 2020;49:896–907.
28 Fors S, Lennartsson C, Lundberg O. Childhood living conditions, socioeconomic position in adulthood, and cognition in later life: exploring the associations. *J Gerontol B Psychol Sci Soc Sci* 2009;64:750–7.
29 Darin-Mattsson A, Andel R, Celeste RK, *et al*. Linking financial hardship throughout the life-course with psychological distress in old age: sensitive period, accumulation of risks, and chain of risks hypotheses. *Soc Sci Med* 2018;201:111–9.
30 Elo IT, Preston SH. Educational differentials in mortality: United States, 1979-85. *Soc Sci Med* 1996;42:47–57.
31 Huisman M, Kunst AE, Andersen O, *et al*. Socioeconomic inequalities in mortality among elderly people in 11 European populations. *J Epidemiol Community Health* 2004;58:468–75.
32 Kibele EUB, Jasilionis D, Shkolnikov VM. Widening socioeconomic differences in mortality among men aged 65 years and older in Germany. *J Epidemiol Community Health* 2013;67:453–7.
33 Mackenbach JP, Martikainen P, Menvielle G, *et al*. The arithmetic of reducing relative and absolute inequalities in health: a theoretical analysis illustrated with European mortality data. *J Epidemiol Community Health* 2016;70:730–6.
34 Harper S, King NB, Meersman SC, *et al*. Implicit value judgments in the measurement of health inequalities. *Milbank Q* 2010;88:4–29.
35 Eikemo TA, Skalická V, Avendano M. Variations in relative health inequalities: are they a mathematical artefact? *Int J Equity Health* 2009;8:32.
36 King NB, Harper S, Young ME. Use of relative and absolute effect measures in reporting health inequalities: structured review. *BMJ* 2012;345:e5774.
37 Pace M, Lanzieri G, Glickman M. *Revision of the European Standard Population: report of Eurostat's task force*. Luxembourg: Publications Office of the European Union, 2013.
38 Tarkiainen L, Rehnberg J, Martikainen P, *et al*. Income trajectories prior to alcohol-attributable death in Finland and Sweden. *Addiction* 2019;114:807–14.
39 Elstad JI, Hermansen Åsmund, Brønnum-Hansen H, *et al*. Income security in Nordic welfare states for men and women who died when aged 55–69 years old. *Journal of International and Comparative Social Policy* 2019;35:157–76.
40 Cleveland WS. Robust locally weighted regression and smoothing scatterplots. *J Am Stat Assoc* 1979;74:829–36.10.1080/01621459.1979.10481038
41 Rehnberg J, Fritzell J. The shape of the association between income and mortality in old age: a longitudinal Swedish national register study. *SSM Popul Health* 2016;2:750–6.
42 Roine J, Waldenström D. The evolution of top incomes in an egalitarian Society: Sweden, 1903–2004. *J Public Econ* 2008;92:366–87.10.1016/j.jpubeco.2007.06.012
43 Fritzell J, Hertzman JB, Bäckman O. Sweden : Increasing income inequalities and changing social relations. In: Nolan B, Salverda W, Checchi D, eds. *Changing inequalities and societal impacts in rich countries*. Oxford University Press, 2014: 641–65.
44 Mackenbach JP. Should we aim to reduce relative or absolute inequalities in mortality? *Eur J Public Health* 2015;25:185.
45 Mackenbach JP. Re-thinking health inequalities. *Eur J Public Health* 2020;30:615.