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To what extent do rising mortality inequalities by education and marital status attenuate the general mortality decline? The case of Finland in 1971-2030

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Abstract

This study examines the relationship between growing inequality within the population, and the general mortality decline in Finland after 1971. The general mortality trend is considered as a simultaneous shift of population groups toward lower mortality over time, with the group-specific mortality rates linked to the mortality trend in the best practice (vanguard) group. The inequality measure accounting for all groups and their population weights reveals increases in both relative and absolute mortality inequalities. Changes in population composition by education and by marital status tend to compensate each other and the combined change does not produce significant effect on the total mortality. The widening of mortality inequalities produces important impact on the total mortality trend. The modeling allows to quantify this impact. If mortality inequalities remained frozen after 2000, the total mortality in 2026-30 would be by about one quarter lower compared to trend-based expectations.

Keywords

differential mortality, Finland, education, marital status

Introduction

The last decades of the twentieth century were marked by growing divergence in mortality trends between countries (Caselli et al., 2002; McMichael et al., 2004; Moser et al., 2005). During the 1980s-1990s, it could be often observed that countries with greater initial mortality levels have gained substantially less in terms of survival and longevity of their populations than countries with initially lower mortality levels. The latter unexpectedly significant progress has been achieved due to the success in combating degenerative diseases, which, until the late 1970s, were considered hardly preventable or treatable.

Similar trends have been observed in sub-national populations (Valkonen 2001; Mackenbach et al., 2003; Kunst et al., 2004). In Finland, mortality decreased continuously over the 1970s-1990s, but this decrease was uneven across different social and marital status groups. The progress tended to be slower in groups with higher starting levels of mortality, and steeper in the groups with the lowest starting levels of mortality. These trends have led to a widening of relative differences in mortality by social status (Martelin, 1996, Valkonen, 1997), and to further concentrations of deaths in worse-off groups. The latter is a matter of serious ethical concern (Peter & Evans, 2001). Mortality differences by marital status also increased continuously (Martikainen et al., 2005; Murphy et al., 2007), so that deaths became further concentrated in unmarried groups.

The best practice (or vanguard) groups within national populations are the first groups showing the new frontiers of survival and longevity that will eventually be reached by others (Desplanques, 1973, cited in Vallin, 1979; Martelin, 1996; Valkonen, 1997). Several studies on Finland have suggested that, in terms of time lag, the lowest mortality groups are 30 years ahead of the population groups with the highest mortality. Valkonen (1997) showed that manual workers did not reach the life expectancy of non-manual workers of the 1960s until the 1990s (Valkonen, 1997). Martelin (1996) found that male life expectancy at age 60 of the vanguard group of married white-collar employees with higher or secondary education living in western Finland observed in 1971-75 had been not achieved by the total male population by the mid-1990s.

To what extent do the growing inter-group mortality differences matter for overall mortality, given the fact that mortality eventually goes down in all groups, and that the absolute mortality reductions tend to be greater in higher mortality groups? This study examines the relationship between growing relative inequality within the population, and the general mortality decline in the case of Finland.

We simultaneously analyse two principal dimensions of inequality: education and marital status. Our main motivation for choosing these two dimensions for study is the fact that in terms of their impact on overall mortality, the educational population composition improves, whereas the marital status composition deteriorates. Therefore, this approach allows us to quantify the impact of compositional changes more precisely. Education and marital status are the two principal health dimensions characterising availability of human and social capital (Anson, 1989; Smith & Zick, 1994; Ross & Mirowsky, 1999; Goldman, 2001), and we are not the first to examine mortality by education and marital status in Finland. Four earlier works studied differences in strength of socioeconomic mortality gradients among adult women , depending on their marital status (Koskinen & Martelin, 1994; Martikainen, 1995; Martikainen, et al. 2005; Kohler et al., 2008).

This study analyses the education-marital status-time mortality surface in Finland over six post-census periods from 1971-76 to 1996-2000. This evolution is considered as a simultaneous shift of all population groups toward lower mortality over time. We assume that group-specific mortality rates in all non-vanguard groups are linked to the mortality trend in the vanguard group. Therefore, we fit a simple proportional mortality model to the observed surface of the group-specific mortality from 1971 to 2000. The modeling approach allows to obtain mortality rates in all non-vanguard groups by means of group-specific mortality rate ratios relative to mortality rates in the vanguard group. The model-based group-specific mortality rates are used for assessment of amounts of absolute and relative mortality inequalities and public health losses by means of average inter-group differences (AID), Gini coefficients, and population-attributable risks. Finally, the same model is also applied to project the mortality surface into the future, and to see to what extent future mortality of the total population and population-attributable risk depend on trends in inter-group mortality differences.

Data and methods

Census-linked mortality data of Finland

The census-linked mortality data were provided by Statistics Finland. The data were given to us in the format of frequency tables containing death counts and population exposures classified by sex, age, calendar year, educational, and marital status categories. The data cover 1.35 million deaths and 82.1 million person-years for people aged 31 and older. Six subsequent post-census periods are presented: 1971-75, 1976-80, 1981-85, 1986-90, 1991-95, and 1996-2000. Age is split by five-year groups: 30-34, 34-39, ..., 85-89, 90+ [1].

Based on prior studies of mortality differentials in Finland, three broad educational categories are distinguished: high (tertiary) education lasting at least 13 years, secondary education lasting 10-12 years, and low education lasting nine years or less (Valkonen et al., 1993). Marital status is split into four categories: (officially) married, never married (including cohabitating), divorced and separated, and widowed. Specifics of Finnish classifications and related problems and solutions have been discussed elsewhere (Valkonen et al., 1993; Valkonen, 1993).

Combinations of the marital status and educational categories generate 12 two-dimensional groups: high education-married (HM), high-never married (HN), high-divorced (HD), high-widowed (HW), secondary-married (SM), secondary-never married (SN), secondary-divorced (SD), secondary-widowed (SW), low-married (LM), low-never married (LN), low-divorced (LD), and low-widowed (LW). Death counts and population exposures across the 12 groups are given in Annex 1.

Measures of mortality and mortality inequality

Mortality in the 12 groups and in the total population is measured by the age-standardised death rates

$$SDR(t,i) = \sum_x ps(x)M(t,x,i)\,, \tag{1}$$

where $M(t,x,i)$ is death rate for period t, age x, and group i and $ps(x)$ is standard population weight of age x. [2] The groups are numbered i= 0, 1, 2, … , 11 with i=0 corresponding to the vanguard (best practice) group HM.

In most studies, magnitude of inter-group mortality differences is measured by the absolute and relative ranges of variation. To be comparable with other studies, we also use those measures that are equal to the absolute and the relative differences between the highest and the lowest group-specific SDRs. As a measure of inequality, the range of variation has a major disadvantage. It is insensitive to mortality redistributions among the groups other than the two extreme groups. In addition, it does not take into account population weights of the

[1] All further calculations of aggregate mortality indicators are for the range of ages over 30. It is always assumed that mortality rate at age 30 is the same as the one at age 31.
[2] The European standard population is used (Health for All Database, 2008).

groups, and can be affected by statistical fluctuations in the two extreme groups, which can be small.

The average inter-group difference (AID) is an absolute inequality measure that is equal to the population-weighted average of mortality differences within all pairs of group-specific SDRs

$$AID(t) = \frac{1}{2[P(t)]^2} \sum_{i=0}^{11} \sum_{j=0}^{11} \left| SDR(t,i) - SDR(t,j) \right| P(t,i) P(t,j) \,,$$

where *P(t,i)* and *P(t)* are the population exposures for group *i* and the total population in period *t*. By definition, *AID* is based on the idea of individual-level equity, since it expresses the average difference between *any* two individuals regardless of the groups to which they belong. Gini coefficient is a relative measure that is equal to *AID* divided by the average mortality rate in the total population (Kendall & Stuart, 1966; Anand et al., 2001; Moser et al., 2005). The Gini coefficient is

$$G(t) = \frac{AID(t)}{SDR(t)} \,,$$

where

$$SDR(t) = \sum_x ps(x) [\frac{1}{P(t,x)} \sum_i M(t,x,i) P(t,x,i)] \,. \quad (2)$$

The principal property of both *AID* and *G* is that their values decrease in case of any mortality transfer between a higher mortality group and a lower-mortality group that do not reverse their relative ranks (Anand, 1983).

The population-attributable risk is a public health measure of losses. It is defined as the share of deaths that can be avoided if the mortality differences between the vanguard and other population groups were instantly eliminated:

$$PAR(t) = 1 - \frac{\sum_i P(t,i)(SMR(t,i) - 1)}{\sum_i P(t,i) SMR(t,i)} \,, \quad (3)$$

where the standardized mortality ratio for group *i* expresses mortality excess relative to the vanguard group $SMR(t,i) = \frac{D(t,i)}{\sum_x P(t,x,i) M(t,x,0)}$.

Modeling mortality distribution across population and its change

Next, we define the model to fit the surface of the differential mortality over time. The mortality hazard is expressed as a function of age, time period, education, and marital status, assuming that the two explanatory variables act simultaneously and independently of each other.

$$D(t,x,ed,ms) = P(t,x,ed,ms) \cdot e^{\beta_0 + \beta_x(t) + \beta_{ed}(t) + \beta_{ms}(t)}, \qquad (4)$$

where $D(t,x,ed,ms)$ and $P(t,x,ed,ms)$ denote deaths and population exposures across four-dimensional cells, and the β_0, $\beta_{ed}(t)$, $\beta_{ms}(t)$, $\beta_x(t)$ are the intercept and the regression coefficients related to age, education, marital status in period t estimated by the maximum likelihood method.

For the vanguard group, the age-specific death rate $\widehat{M}(t,x,0)$ is

$$\widehat{M}(t,x,0) = e^{\beta_0 + \beta_x(t)}. \qquad (5)$$

Coefficients $\beta_x(t)$ tend to increase with age and decrease with time. Corresponding age-standardised death rate can be computed from formula (1) after substituting the observed age-specific death rates by the model age-specific death rates (5). For a non-vanguard education-marital status group i the equivalent formula is

$$\widehat{M}(t,x,i) = e^{\beta_0 + \beta_x(t) + \beta_{ed}(t) + \beta_{ms}(t)} = M(t,x,0) \cdot RR(t,i), \qquad (6)$$

where $RR(t,i)$ is the mortality rate ratio for group i in period t.

The age-standardised death rate for the total population is computed from formula (2) with the observed age-specific death rates substituted by the population-weighted averages over the group-specific model death rates (6).

The model population attributable risk is computed from formula (3) with the observed group- and period-specific *SMR*s substituted by the model *RR*s.

Model (4) is the simplest model that can provide quantitative assessments that address the question of interest to us. The model captures principal regularities in the data, and smoothes out random fluctuations of mortality in small groups. It does not account for any interactions between variables, including possible interactions between education or marital status with age and time (Wilmoth & Valkonen, 2002; Li & Lee, 2005), and/or interactions between education and marital status (Koskinen & Martelin, 1994; Martikainen et al., 2005). These specific features are important for understanding the mechanisms underlying socio-demographic differences in mortality. However, such interactions do not have a significant impact on patterns of mortality distributions across population groups and time. At the same time, model (4) captures well such these distributions. The model provides good approximations of the observed group-specific death numbers and SDRs, and also of the total and the age-specific death numbers and death rates in the total population. The model fits the observed age curves of group-specific mortality less precisely.

One of the main advantages of our approach is that we define the changes in group-specific mortality as a joint process with all population groups linked to the vanguard group by means of mortality rate ratios. Another important feature of the model is that at any time point, mortality of the total population can be obtained from a weighted sum of the group-specific death rates estimated using the corresponding mortality rate ratios. In this way, mortality inequality becomes a direct parameter of the model and allows estimating mortality of the total population given various scenarios of inequality levels.

In this study, the regression function is used to parameterise the mortality surface in a manner similar to the Age-Period-Cohort,the Lee-Carter mortality, the Poisson, and the Gompertz models (Lee & Carter, 1992; Wilmoth, 1997; Martikainen, Blomgren, Valkonen, 2007; Kohler et al., 2008). The regression coefficients are considered as parameters of a deterministic function. Thus, throughout the text we do not deal with their statistical errors, which are in any case very low.[3]

Assessing the future

In this section, we show how the observed mortality trend in the vanguard group and dynamics of relative mortality inequalities can be integrated into scenarios of the future mortality change. According to formula (5), temporal changes in the model mortality rates in the vanguard group are determined by dynamics of the age-related beta-coefficients. It can be shown that $\beta_x(t)$ changes are nearly linear in respect to time[4]. This change can be expressed as

$$\beta_x(t) = A_x + B_x t\,,$$

where A_x and B_x are the intercept and the slope of the linear trends in the beta-coefficient for age x. The slopes B_x tend to decrease with age, reflecting a somewhat slower pace of progress

[3] In fact, the maximum likelihood estimates of the regression coefficients obtained in this study are highly statistically significant p<0.0000005. Mortality effects of secondary education in 1971-75, 1976-80, and 1981-85 are the only exceptions with p<0.803620, p<0.004663, and p<0.000589, respectively.

[4] We also obtained nearly linear trends from the equivalent data for Finland, Norway and Sweden (analyses not shown here).

at older ages. The expected future values $\beta_x(t)$ are obtained by continuing the linear trends of 1971-2000 into the future over the period 2001-2030.

Trends in the beta-coefficients related to education and marital status are also nearly linear and can be calculated as:

$$\beta_{ed}(t) = A_{ed} + B_{ed}t \, , \qquad (7a)$$

$$\beta_{ms}(t) = A_{ms} + B_{ms}t \qquad (7b)$$

Changes in the slopes B_{ed} and B_{ms} can be used for generating scenarios of change in the relative mortality inequalities. In this study, we test only two such scenarios.

1. The first scenario assumes continuation of the observed trends toward further widening of inequalities. According to this scenario, A_{ed}, B_{ed} and A_{ms}, B_{ms} values are the least-square estimates of the intercepts and the observed slopes of trends in $\beta_{ed}(t)$ and $\beta_{ed}(t)$.
2. The second scenario assumes that the relative mortality excesses determined by $\beta_{ed}(t)$ and $\beta_{ms}(t)$ do not increase and remain unchanged (frozen) at certain fixed levels. Correspondingly, the slopes B_{ed} and B_{ms} are set to zero.

The future group-specific mortality rates based on these two scenarios produce two different trends in mortality rates, and in the population attributable risk in the total population.

In order to perform hypothetical calculations of the future age-standardised rates for the total population, we have to estimate age-specific population weights of the twelve two-dimensional groups for the period 2001-2030. It is obviously impossible to model the future population composition by education and marital status as dependent on changes in the educational system, nuptiality, international migration, differential mortality, and other real-life factors. Thus we apply a simple linear extrapolation of the shares of the 12 groups at every age of the entire population up to the year 2030. In a few cases (such as the group of widowed with high education at ages below 45), our calculations produce zeros or negative shares. For these cases, we assume that proportions of these groups remain equal to zero until the end of the period covered.

Results

Observed changes in differential mortality

Between 1971-75 and 1996-2000, the total-population age-standardised death rates in Finland decreased by 42% for males and 45% for females. The only slowdown occurred in the second half of the 1980s (Jäntti et al., 2000; Martikainen et al., 2001; Valkonen et al., 2000). During the period 1971-2000, the absolute maximum-minimum mortality ranges by education and by marital status decreased, while the equivalent relative ranges increased.

Figure 1 displays trends in SDRs for the 12 education-marital status groups. Between 1971-75 and 1996-2000, the vanguard group (HM) experienced a steep decrease from 18.1 to 10.0 per 1,000 for males, and from 10.9 to 5.7 per 1,000 for females. During the three decades, no convergence between this group and the total population can be observed. For males and females, the age-standardised death rates experienced by the vanguard group in 1971-75 were reached by the total population only in the mid-1990s.

The group of married with secondary education (SM) show the second lowest mortality after the vanguard group (Figure 1). For males, the SDR trend in this group is nearly parallel to the trend observed in the vanguard group. For females, the SM group tended to diverge upwards from the HM group.

Episodes of mortality stagnation in the 1980s are especially pronounced in the groups of never married and widowed males with low education (LN and LW), and in the group of never married females with secondary education (SN). The highest mortality group of divorced people with low education (LD) experienced a mortality decrease for males, and only a very slow decline for females. The male SDR in this group decreased from 37.5 to 28.0 per 1,000, whereas for females the SDR dropped from 16.7 to 14.0 per 1,000. Between 1981-85 and 1996-2000, female mortality in the LD group did not decrease at all.

Importantly, Figure 1 shows that the vanguard group that had the lowest mortality in 1971-75 also experienced the steepest relative mortality decrease. Indeed, the SDR in this group dropped by 58% for males and 64% for females. Among males, the same proportional reduction is observed in only one group, of divorced men with high education (HD). For females, proportional decreases were slower in all non-vanguard groups.

Figure 1. Trends in age-standardised death rates for 12 education-marital status groups for ages over 30 in Finland in 1971-2000.

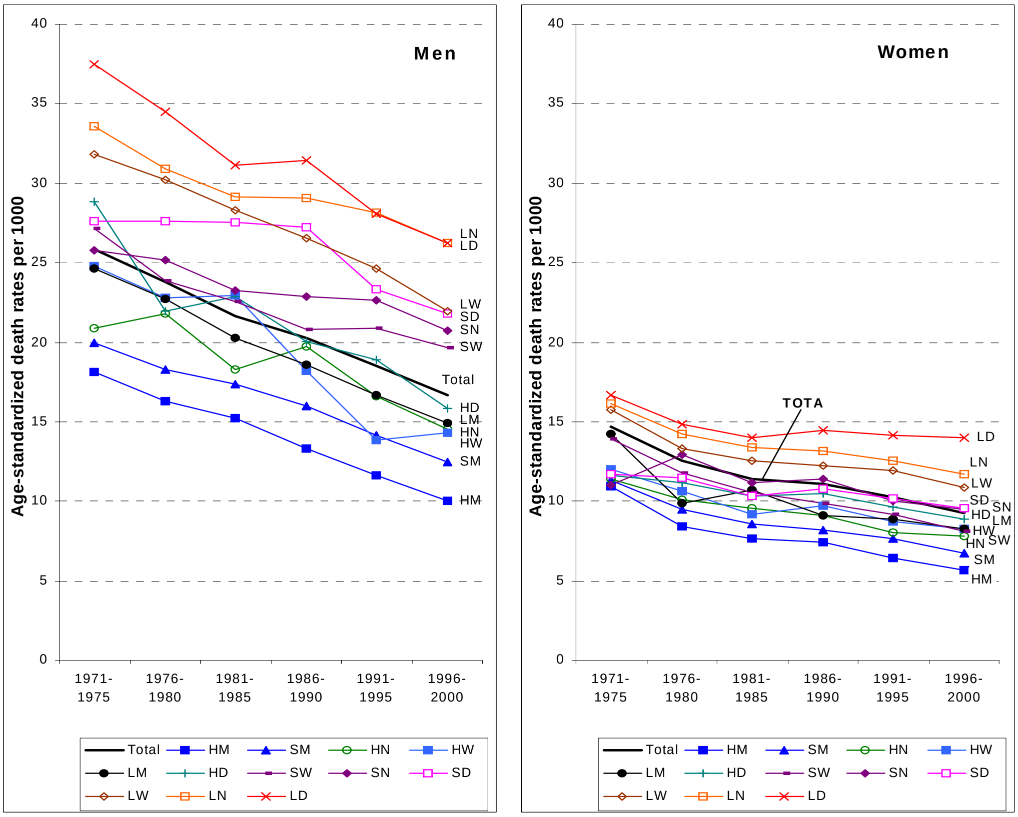


Table 1 presents trends in the average mortality, measures of absolute and relative inequality across the educational and marital status, as well as the changes in these measures according to the combined (two-dimensional) groups between 1971-75 and 1996-2000. As expected, all indicators of relative inequality, including the max-min ratio and the Gini coefficient, increased. For males, the maximum-minimum mortality differences by education, by marital status, and by their combinations decreased. For females, the educational max-min difference decreased, but the max-min difference by marital status, and by the combined groups, increased.

Between 1971-75 and 1996-2000, the average inter-group differences (AID) across the educational, the marital status, and the combined groups increased for both sexes. Unexpectedly, these increases contradict the corresponding decreases in the max-min ranges, and deserve further attention. To assess the components of the AID increases, we apply a general decomposition algorithm (Andreev et al., 2002; Shkolnikov et al., 2003). It appears that, between 1971-75 and 1996-2000, AID grew from 2.234 to 2.816 per 1,000. A positive contribution of 0.635 per 1,000 to this total increase is produced by the growth in diversity of the population composition by the combined characteristics of education and marital status.

The mortality component, as reflected by the contribution of group-specific mortality, is negligible (-0.054). This can be explained by the fact that decreasing educational differentials in mortality contribute towards diminishing AID and outweigh opposite effects of worsening disparities by marital status. For females, AID increased from 0.893 to 1.168 per 1,000. The total increase of 0.275 was formed by two almost equal contributions by the compositional (0.139) and the mortality components (0.136). Again, the inter-group mortality differences decreased in respect to education, and increased in respect to marital status. In case of females, the latter component outweighs the former.

Table 1. Changes in the age-standardised death rate of the total population and in measures of absolute and relative mortality inequality for ages over 30 in Finland in 1971-2000.

	SDR[1] (per 1,000)	Max SDR/ /Min SDR	Max SDR - - Min SDR (per 1,000)	Gini	AID (per 1,000)	PAR
	Males					
	By education					
1971-75	25.40	1.42	7.94	0.047	1.189	0.283
1996-2000	15.90	1.71	7.76	0.091	1.441	0.428
	By marital status					
1971-75	25.51	1.52	12.37	0.059	1.515	0.070
1996-2000	17.51	1.79	10.77	0.141	2.466	0.261
	By education and marital status					
1971-75	25.09	2.07	24.16	0.089	2.234	0.320
1996-2000	16.53	2.62	20.03	0.170	2.816	0.501
	Females					
	By education					
1971-75	14.34	1.32	3.65	0.041	0.589	0.193
1996-2000	8.89	1.44	3.09	0.071	0.635	0.168
	By marital status					
1971-75	14.28	1.14	1.96	0.030	0.430	0.020
1996-2000	9.00	1.55	4.11	0.099	0.892	0.095
	By education and marital status					
1971-75	14.04	1.53	5.79	0.064	0.893	0.244
1996-2000	8.60	2.48	8.38	0.136	1.168	0.325

[1] The population-weighted average of the group-specific SDRs.

Finally, marked increases in population-attributable risks (PAR) demonstrate the public health importance of the mortality inequalities (Table 1). These inequalities are responsible for a rising share of the generally falling total mortality. Between 1971-75 and 1996-2000, the percentage of deaths attributable to excess mortality in the non-vanguard groups increased from 32% to 50% for males, and from 24% to 33% for females.

Fitting the model

Table 2 presents the maximum likelihood estimates of the beta-coefficients for education, marital status, and time period for the model (1) and the slopes of their change *A* and *B* according to (7a) and (7b).

The mortality rate ratios for two-dimensional groups are computed from the beta-coefficients. For example, for the divorced males with secondary education (SD) in 1986-90, the risk score is 0.646+0.252= 0.898 and the mortality *RR*=exp(0.898)=2.456. SDR in the group SD is equal to the vanguard SDR in 1986-90 times RR: SDR=11.9*2.456=29.3. The observed SDR in group SD in 1986-90 is 27.3 per 1,000. Annex 2 presents all values of observed and model group-specific SDRs for the 12 groups from 1971-75 to 1996-2000. The population weighted root mean square errors comparing the model and observed estimates are 6.0% for males and 3.8% for females.

Table 2. Beta-coefficients for education and marital status and their linear trends.

	1971-1975	1976-1980	1981-1985	1986-1990	1991-1995	1996-2000	Linear trend parameters *A*	*B*
	Males							
Education								
(H) High [Ref]	0	0	0	0	0	0	0	0
(S) Secondary	0.123	0.136	0.187	0.252	0.271	0.319	0.318	0.041
(L) Low	0.369	0.394	0.384	0.434	0.464	0.510	0.495	0.028
Marital status								
(N) Never married	0.372	0.382	0.441	0.526	0.597	0.633	0.637	0.058
(M) Married [Ref]	0	0	0	0	0	0	0	0
(D) Divorced	0.523	0.528	0.546	0.646	0.638	0.669	0.674	0.033
(W) Widowed	0.219	0.220	0.238	0.258	0.295	0.305	0.304	0.019
Goodness of fit Chi2	23,764[1]	25,966[1]	27,800[1]	30,021[1]	31,414[1]	33,871[1]	-	-
Pseudo R2	0.7264	0.7337	0.7408	0.7367	0.7378	0.7308	-	-
	Females							
Education								
(H) High [Ref]	0	0	0	0	0	0	0	0
(S) Secondary	0.008	0.091	0.092	0.131	0.139	0.153	0.167	0.026
(L) Low	0.303	0.328	0.303	0.325	0.356	0.369	0.362	0.013
Marital status								
(N) Never married	0.176	0.215	0.228	0.306	0.344	0.432	0.408	0.050
(M) Married [Ref]	0	0	0	0	0	0	0	0
(D) Divorced	0.182	0.245	0.272	0.305	0.319	0.370	0.367	0.034
(W) Widowed	0.138	0.149	0.168	0.225	0.234	0.277	0.271	0.029

Note: Outputs of Poisson regressions linking male and female mortality with education and marital status, and age.

Changing shapes of mortality distributions

Figure 2 shows mortality profiles across the 12 education-marital status groups in 1971-75 and 1996-2000. The groups are sorted in ascending order according to the group-specific SDRs in the second period. Cumulative population shares corresponding to the groups are plotted on the horizontal axis. The group-specific SDRs are shown on the vertical axis.

For each time period, two series of mortality estimates are shown: the observed SDRs (fuzzy lines) and the model SDRs (sharp lines). Closeness of the empirical and model series in Figure 2 illustrates that the model is a good fit, as the empirical and model series of estimates are very close. The figure shows simultaneously mortality decreases in the groups and changes in their population weights over time. Between 1971-75 and 1996-2000, the population composition changed considerably due to the spread of education and increasing numbers of non-married people (Annex 3). Among women, there was also a decrease in the share of widows due to a greater survival of men.

The shares of the vanguard and the highest mortality groups changed considerably (Figure 2). Between 1971-75 and 1996-2000, the proportion of the HM group almost doubled among males and tripled among females, reaching 11% and 9%, respectively. At the same time, there was also an increase in the percentage of males in the highest mortality group (LD) from 2.4% to 5.1%, and a decrease in the share of this group among females from 9.9% to 5.4%.

In 1971-75, large shares of males and females (60% and 51%, respectively) belonged to the married with low education (LM) group. In this period, males and females of this group experienced a 1.3-1.4 fold mortality excess compared to the vanguard group. By 1996-2000, the share of the LM group fell by about one-half, and reached a low of 26% for males and 23% for females. In 1996-2000, the absolute mortality difference between this group and the vanguard group had about the same value as that in 1971-75. Over the observation period, the decrease in population weight of the LM group coincides with an increase in the proportion of the group of married males and females with secondary education (SM). Percentages of this group in the total population increased from 15% to 26% among males, and from 11% to 25% among females.

Figure 2. Age-standardised death rates at the range of ages over 30 across the education-marital status groups in 1971-1975 and 1996-2000 in Finland.

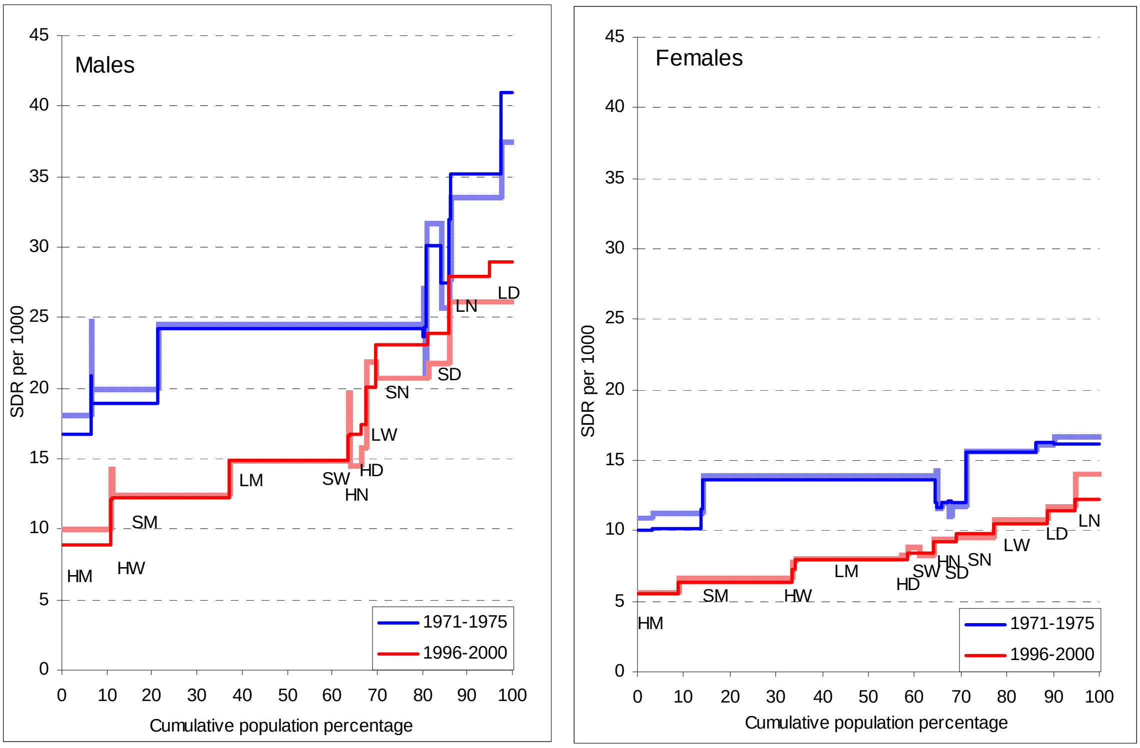


Figure 2 also allows us to compare mortality in non-vanguard groups in 1996-2000 to the mortality in the vanguard group in 1971-75. In 1996-2000, the male model SDRs for the group of widowed with low education (LW), the never married with secondary education (SN), the divorced with secondary education (SD), the never married with low education (LN), and the divorced with low education (LD) were still higher than the corresponding SDR in the HM group in 1971-75. In the case of females, there were only two such groups (LD and LN). The laggard groups with higher model SDRs in 1996-2000 than the HM level in 1971-1975 constituted 36% of male and 23% of female population exposures in 1996-2000.

Inequalities among groups and mortality of the total population

Table 3 compares actual trends in mortality of the total population with the hypothetical trends based on elimination of the increase in the relative inequalities and/or elimination of changes in population composition in 1976-2000. The first two columns of the table simply demonstrate a closeness of the model and observed SDRs for the total population. The next three columns present three types of the hypothetical model mortality rates, which can be compared to the SDRs in the second column.

The SDRs in the third column are based on the assumption that the population composition remains unchanged (as of 1971-75) from 1976 to 2000. It appears that this constraint produces only a minor (unfavorable) impact on the total mortality. Both for males and for females, SDRs of 1996-2000 in the third column are very slightly higher than those in the second column. In the fourth column, the SDRs are based on the assumption that, after 1975, relative mortality inequalities remain unchanged at their initial levels of 1971-75. In this case, mortality decrease becomes considerably steeper than the observed decrease, as shown in the second column of Table 3. In 1996-2000, SDRs appear to be significantly lower than the real values: 13.5 instead of 16.7 per 1,000 for males (a 21% reduction) and 7.6 instead of 9.3 per 1,000 for females (a 20% reduction). The fifth column shows that additional freezing of the population composition does not significantly modify SDRs of the previous column.

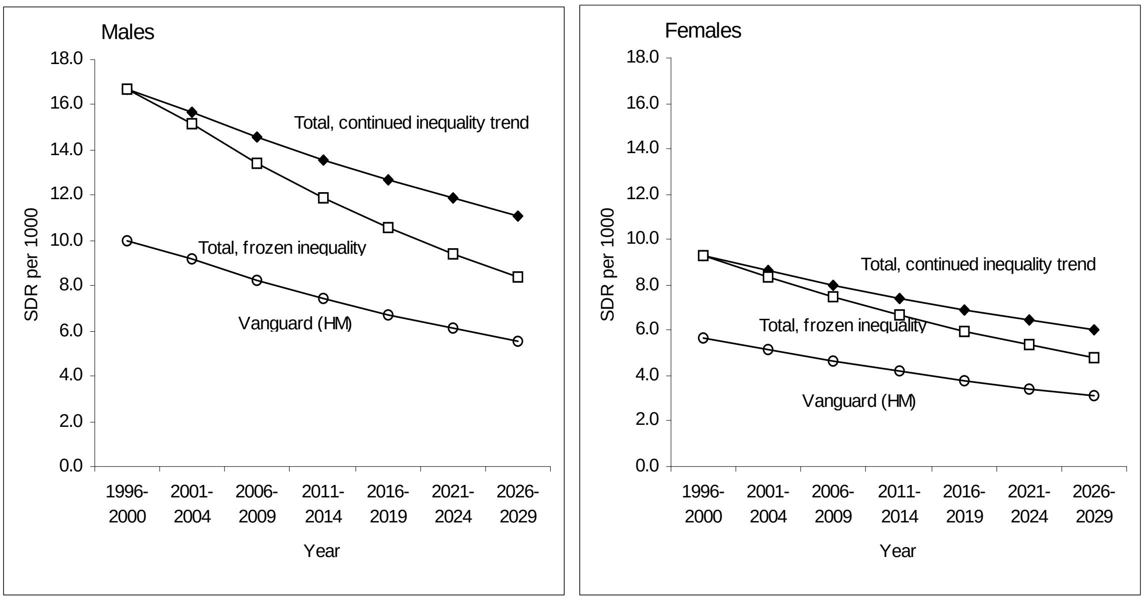
In general, mortality trends in the total population are influenced by the increase in mortality inequalities, but the impact of the population composition is surprisingly minor. This result can be explained by a balance between the positive influence of rising education in the population, and the negative impact of growing numbers of non-married people.

Table 3. Actual and hypothetical age-standardised death rates at ages over 30 in the total population of Finland from 1971-2000 to 1996-2000.

Period	Observed SDRs	Model SDRs	Model SDRs, frozen population composition	Model SDRs, frozen mortality inequalities	Model SDRs, frozen population composition and mortality inequalities
Males					
1971-1975	25.85	25.84	25.84	25.84	25.84
1976-1980	23.76	23.74	23.85	23.17	23.27
1981-1985	21.62	21.60	21.74	20.88	21.04
1986-1990	20.29	20.28	20.41	18.18	18.42
1991-1995	18.48	18.46	18.71	15.81	16.10
1996-2000	16.71	16.70	16.96	13.49	13.82
Females					
1971-1975	14.66	14.65	14.65	14.65	14.65
1976-1980	12.56	12.55	12.62	12.01	12.09
1981-1985	11.41	11.40	11.53	10.98	11.14
1986-1990	11.08	11.08	11.32	9.99	10.23
1991-1995	10.27	10.26	10.63	8.90	9.21
1996-2000	9.27	9.27	9.76	7.63	8.01

Figure 3 shows that, in 2001-2030, the frozen inequalities scenario corresponds to a substantially steeper decline in general mortality compared to the scenario assuming continuation of the trends of 1971-2000. The SDR of the total male population in 2026-30 would be 11.1 and 8.1 per 1,000 (a 28% difference), according to the first and the second scenarios, respectively. For females, the equivalent figures are 6.1 and 4.8 per 1,000 (a 23% difference). The figure makes clear that the frozen inequalities scenario ensures convergence of the total population mortality toward the vanguard group. If the observed inequality increase continues, then the gap between the vanguard and the total population would be sustained.

Figure 3. Future trends in age-standardised death rates at ages over 30 for the vanguard group and the total population, according to the two scenarios of relative mortality inequality, Finland, 1996-2000 to 2026-30.



It should be noted that the changes in differential mortality would also obviously influence the population composition by education and marital status in the future. However, our hypothetical calculations (not shown here) suggest that this influence on the population composition will have only a negligible impact on the age-standardised death rates of the entire population. Such compositional changes may result in a change of up to 1.5% in standardised death rates in 2026-30 compared to the scenario assuming a fixed population composition by education and marital status throughout the prediction period.

Table 4 quantifies the public health impact produced by the elimination of the increase in relative inequalities. Freezing of the mortality inequalities at their 1971-75 levels would lead to a reduction in the male and female SDRs during the subsequent 25-year period of 11% on average. Fixing the mortality inequalities at their levels of 1996-2000 would lead to average reductions of the SDRs over the subsequent 30-year period of 16% for males and 13% for females.

Table 4. Model age-standardised death rates and population attributable risks at ages over 30, with and without increase in inequalities in 1976-2000 and 2001-2030.

	SDR per 1,000		PAR	
	Continuation of actual trends	Frozen mortality inequalities	Continuation of actual trends	Frozen mortality inequalities
	1976-2000			
Males	19.9	17.8	0.408	0.324
Females	10.8	9.7	0.306	0.230
	2001-2030			
Males	13.1	11.2	0.587	0.484
Females	7.2	6.3	0.417	0.324

Table 4 also shows that, if the inequalities are frozen at their values of 1971-75, the male and female PARs in 1976-2000 would decrease by eight percentage points. If the inequalities continue rising after the year 2000, the male and female PARs in 2026-30 are likely to reach the values of 0.65 and 0.47, respectively. On average over the period 2001-2030, the male and female PARs would be 0.59 and 0.42. If the inequalities are frozen at their values of 1996-2000, the equivalent PARs would be 0.48 and 0.32. This corresponds to reductions of 11 percentage points.

Discussion

Our study, based on high quality census-linked data, examines a general pattern of change in the mortality surface formed by 12 two-dimensional education-marital status groups, and its impact on mortality of the total population in Finland from 1971 to 2000. The results show that the vanguard group consisting of highly educated and married people experiences a steeper decline in mortality than all other groups. This well-known but still surprising tendency is reflected in increasing relative mortality inequalities between non-vanguard groups and the vanguard group throughout the period. The findings suggest that the consequence of such uneven progress in reducing mortality was an additional public health burden, on the top of the death toll related to the already existing inequalities in Finland. About half of the total male deaths and about one-third of the total female deaths in 1996-2000 were attributable to mortality excesses of lower educated and non-married people. A substantial part of this burden was built up over decades by continuously rising relative mortality differences by education and marital status.

As expected, we have found that the amount of relative mortality inequality in terms of the Gini coefficient increased between 1971-75 and 1996-2000. However, the amount of the absolute mortality inequality measured by the average inter-group difference has also increased for both males and females with respect to education, marital status, and combinations of both dimensions. This unexpected increase can be attributed to the growing compositional diversity of the population, and to the increasing differences in mortality by marital status. At the same time, educational inequalities contributed to the decrease in the total mortality gap measured by AID. A notable contribution of mortality inequalities by marital status to the rise of AID is also somewhat surprising. One should take into account that, due to increasing shares of the divorced and never married (including cohabitants) within the population, these groups probably became less selective (Fu & Goldman, 1996; Murphy et al., 2007). As argued by Martikainen et al. (2005), the increasing excess mortality of non-married Finns cannot be attributed to selection through a socio-economic position or housing arrangements.

The aforementioned contradictory changes in group-specific mortality were accompanied by notable transformations in the population composition, which became more diverse due to growing shares of better educated and non-married people. The results of this study suggest, however, that the changing population composition by education and marital status in 1971-2000 did not produce a significant effect on the average population mortality. This can be explained by the fact that a positive impact of rising education was counterbalanced by the negative contribution of a growing share of non-married groups within the population.

A simple proportional model has been fitted to the changing surface of the differential mortality over time. The main advantage of this model is that it correctly reflects the principal features of this complex process. This is particularly important for assessment of the impact of the changes in the inter-group inequality on mortality of the total population. The results suggest that the model provides good approximations of the observed group-specific and total mortality rates, even without taking into account possible interactions between the variables under consideration.

The model was applied to estimate both the past and the future trends in mortality of the total population given different scenarios of changes in inequalities. It has shown that, if the mortality inequality across education-marital status groups had remained fixed at the level of 1971-75, mortality of the total population in 1996-2000 would be about 20% lower for both males and females. The mortality reduction for the whole period of 1976-2000 would constitute about 11 per cent on average.

The model has also been used to estimate total mortality up to 2030 given two different scenarios of inequality change. The modeling results suggest that, even the maintenance of mortality inequalities at the current level would lead to a considerably faster decline in the total mortality of the entire population, and would allow for a reduction in the public health burden due to excess mortality among lower socio-demographic groups. If mortality inequalities remain frozen at the level of 1996-2000, it is likely that the age-standardized mortality rates would be 28% lower for males and 23% lower for females in 2026-30 than in the scenario of the continuation of increasing inequalities, as observed during the period 1971-2000. For the whole period 2001-2030, the potential mortality reduction would constitute about 16% for males and 13% for females. In addition, the male and female PARs for the same period can be reduced by about 10 percentage points. Finally, such a scenario would lead to a convergence in mortality trends between the lowest mortality vanguard group and the total population. In general, our results reveal that the widening of mortality inequalities among higher mortality groups is important for total mortality, and that widening mortality inequalities have significant public health implications.

Although we believe that our hypothetical calculations capture the principal features of future mortality trends, several limitations of our approach should be noted. First, we assume that mortality in the vanguard group will continue decreasing at the same speed as during the period of 1971-2000. Given that mortality in this group was already very low in 1996-2000 (lower than in the world longevity leader Japan), it is not clear whether the vanguard mortality will really decrease at a steep pace during the coming three decades. Second, our model ignore interactions between age and socio-demographic characteristics, which may become important predictor of the total mortality in the future. Third, very significant contributions of mortality excesses by non-married groups to the total amount of inequality may decrease if these groups keep growing. It is not clear whether such notable marital status differentials are a temporal phenomenon, or result from some fundamental selection and protection processes (Murphy, 2007) that are likely persist into the future.

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Annexes

Annex 1. Person-years of exposure to risk and deaths by two-dimensional population group in Finland in 1971-2000 (in thousands).

Population group	Person years of exposure to risk		Deaths	
	Males	Females	Males	Females
Total	38076.0	44010.3	683.9	662.4
HM	3392.5	2555	24.6	6.3
HN	500.8	894.7	1.8	6.9
HD	210	291.4	2.2	1.7
HW	57.3	216.3	3.7	7.3
SM	8464.4	8321.6	63.1	22.3
SN	2490.4	2288.6	14.5	15.5
SD	996.7	1234.1	12	6.3
SW	157.5	823	9.1	23.7
LM	15327.9	15780.6	334.6	142.6
LN	3862.9	3168	84	85.9
LD	1637	2349.3	43.7	36.5
LW	978.7	6087.7	90.4	307.4

Annex 2. Observed and model age-standardised death by education-marital status group at ages over 30 in Finland in 1971-2000.

		Observed											
		Males						Females					
Group	Population weights 1971-2000	1971-1975	1976-1980	1981-1985	1986-1990	1991-1995	1996-2000	1971-1975	1976-1980	1981-1985	1986-1990	1991-1995	1996-2000
Total	1.000	25.9	23.8	21.6	20.3	18.5	16.7	14.7	12.6	11.4	11.1	10.3	9.3
HM	0.089	18.1	16.3	15.2	13.3	11.6	10.0	10.9	8.4	7.7	7.5	6.4	5.7
HD	0.013	28.8	22.0	22.9	20.0	18.9	15.8	14.3	9.9	10.7	9.1	8.9	8.3
HN	0.006	20.9	21.8	18.3	19.7	16.6	14.6	12.0	10.6	9.2	9.8	8.7	8.3
HW	0.002	24.8	22.8	23.0	18.2	13.8	14.3	11.4	10.1	9.6	9.1	8.0	7.8
LD	0.222	37.5	34.5	31.1	31.4	28.0	26.2	16.1	14.3	13.4	13.1	12.5	11.7
LM	0.065	24.6	22.7	20.3	18.6	16.7	14.9	13.9	11.8	10.6	9.8	9.2	8.1
LN	0.026	33.6	30.9	29.2	29.1	28.2	26.2	16.7	14.9	14.0	14.5	14.2	14.0
LW	0.004	31.8	30.2	28.3	26.6	24.6	21.9	15.7	13.3	12.5	12.3	11.9	10.9
SD	0.403	27.6	27.6	27.6	27.2	23.4	21.8	11.0	12.9	11.1	11.4	10.0	9.5
SM	0.101	20.0	18.3	17.4	16.0	14.1	12.5	11.3	9.5	8.6	8.2	7.6	6.7
SN	0.043	25.8	25.1	23.2	22.9	22.7	20.8	11.7	11.5	10.3	10.8	10.2	9.5
SW	0.026	27.2	23.9	22.6	20.8	20.9	19.7	11.6	11.1	10.3	10.5	9.6	8.9
		Model											
		Males						Females					
Total	1.000	25.8	23.7	21.6	20.3	18.5	16.7	14.7	12.5	11.4	11.1	10.3	9.3
HM	0.058	16.8	15.1	13.6	11.9	10.4	8.9	10.0	8.3	7.6	7.0	6.3	5.5
HD	0.020	28.3	25.6	23.5	22.7	19.7	17.4	12.0	10.6	10.0	9.5	8.7	7.9
HN	0.007	24.3	22.1	21.2	20.2	18.9	16.8	12.0	10.3	9.6	9.5	8.9	8.4
HW	0.005	20.9	18.8	17.3	15.4	14.0	12.1	11.5	9.6	9.0	8.8	8.0	7.2
LD	0.189	40.9	37.9	34.5	35.1	31.3	28.9	16.3	14.7	13.6	13.1	12.4	11.5
LM	0.052	24.2	22.4	20.0	18.4	16.5	14.8	13.6	11.5	10.3	9.7	9.0	7.9
LN	0.028	35.2	32.8	31.1	31.1	30.0	27.9	16.2	14.2	13.0	13.2	12.7	12.2
LW	0.019	30.2	27.9	25.4	23.8	22.2	20.1	15.6	13.3	12.2	12.1	11.4	10.5
SD	0.359	32.0	29.3	28.4	29.3	25.8	23.9	12.1	11.6	11.0	10.8	10.0	9.2
SM	0.072	19.0	17.3	16.4	15.3	13.6	12.3	10.1	9.1	8.4	8.0	7.2	6.4
SN	0.053	27.5	25.3	25.5	26.0	24.8	23.1	12.0	11.2	10.5	10.9	10.2	9.8
SW	0.138	23.6	21.5	20.8	19.8	18.3	16.6	11.6	10.5	9.9	10.0	9.2	8.4

Annex 3. Percentages of educational and marital status groups in the total population exposure in Finland in 1971-2000 (in percents).

Population group		1971-1975	1976-1980	1981-1985	1986-1990	1991-1995	1996-2000
MALES							
Education	(H) High	7.0	8.6	9.9	11.1	12.5	14.6
	(S) Secondary	17.3	22.0	28.2	34.4	39.2	42.9
	(L) Low	75.6	69.4	61.9	54.5	48.3	42.5
Marital status	(N) Never married	13.5	14.2	16.0	18.0	20.5	23.2
	(M) Married	80.0	77.3	73.9	70.9	67.4	63.2
	(D) Divorced and separated	2.9	5.1	6.9	8.1	9.2	10.7
	(W) Widowed	3.6	3.4	3.2	3.0	2.9	2.8
FEMALES							
Education	(H) High	5.0	6.3	7.5	9.1	10.7	13.7
	(S) Secondary	15.5	19.5	25.0	30.9	36.2	40.4
	(L) Low	79.5	74.2	67.5	60.1	53.0	45.9
Marital status	(N) Never married	14.2	13.4	13.4	13.8	14.9	16.5
	(M) Married	64.2	63.1	61.6	60.6	58.9	56.6
	(D) Divorced and separated	4.6	6.3	8.0	9.3	10.6	12.4
	(W) Widowed	17.0	17.2	17.0	16.4	15.6	14.5