Trends in modal length of life by occupational class in Finland, 1971-2010

Viorela Diaconu[*], Alyson van Raalte[*], and Pekka Martikainen[**]

[*]Max Planck Institute for Demographic Research
[**]Population Research Unit, Department of Social Research, University of Helsinki

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1 Introduction

The remarkable longevity extension made since the 1970s in many industrialized countries were mainly attributed to the unprecedented and unexpected decline in mortality at older ages (Meslé and Vallin, 2006; Vallin and Meslé, 2001; White, 2002; Wilmoth et al., 2000), with ages 60 and above being the most prominent contributor (Barbieri and Ouellette, 2012; Mazui et al., 2014; Payeur, 2011). However, these gains were not equally distributed across individuals from different social strata. Individuals from higher socioeconomic classes reaped most of the benefits. Hence, a mortality gradient running from top to bottom of the socioeconomic spectrum is observed in most advanced economies.

In the past years, mortality differentials by socioeconomic status have been monitored over a broad range of adult ages using mortality rates or life expectancy at birth or at younger adult ages, generally ranging from 25 to 35 (Blanpain, 2011; Mackenbach et al., 2016, 2008; Permanyer et al., 2018; Sasson, 2016; Shkolnikov et al., 2012; Tjepkema et al., 2012, 2013; van Raalte et al., 2014). These studies have also revealed a widening over time of the mortality gap by social class, findings which go in line with Link and Phelan's "fundamental cause" theory (Phelan et al., 2004). While these indicators give account of the changes that have occurred within and between different socioeconomic groups, they do not solely focus on mortality at older ages. In fact, because they take into account changes in mortality that have occurred over a broad range of adult ages, they are strongly influenced by ages associated with premature mortality, i.e. 35-64. Deaths at these ages are heavily influenced by changes in externally-caused factors such as traffic accidents, alcohol and drug abuse, homicides, and infections such as HIV/AIDS (Remund et al., 2018).

Growing interest has been given recently to mortality inequalities related to the socioeconomic status of the elderly (Cambois, 2004; Currie and Schwandt, 2016; Huisman et al., 2005, 2013; Wenau et al., 2019; Wilmoth et al., 2010; Zarulli et al., 2012). These inequalities have been assessed using mortality rates at older ages or conditional life expectancies at some selected early old age such as e_{50} or e_{65}. Most of these studies have found that social inequalities persist into old age and that they decrease with increasing age. The few studies examining trends in social mortality gradient showed mixed results (Huisman et al., 2013; Shkolnikov et al., 2012; Wenau et al., 2019; Zarulli et al., 2012).

More recently, studies have also demonstrated that the late mode is solely determined by old-age survival and that the pattern of trends and differentials in M can differ greatly from those in life expectancy, at birth, or at some early old age (Canudas-Romo, 2008; Cheung et al., 2009; Horiuchi et al., 2013; Office of National Statistics, 2012). Conditional life expectancy, unlike M, tend to underestimate age shifts in old-age mortality (Horiuchi et al., 2013). This feature gives a special meaning to M in an era where the extension of human life in developed countries is primarily due to the reduction of old-age mortality.

During the past two decades, a growing number of researchers have been monitoring longevity gains in low mortality countries through the lens of the late modal age at death (Brown et al., 2012; Canon, 2017; Canudas-Romo, 2008; Cheung and Robine, 2007; Cheung et al., 2008, 2009, 2005; Diaconu et al., 2016; Kannisto, 2001; Ouellette and Bourbeau, 2011; Ouellette et al., 2012; Robine, 2001; Thatcher et al., 2010). Therefore, M has become increasingly recognized as an informative lifespan indicator and has been proven useful in the parameterization of well-known mortality models (Horiuchi et al., 2013; Missov et al., 2015). However, this old-age mortality indicator has been rarely used for monitoring socioeconomic inequalities in mortality among the elderly. In the current literature, only three cross-sectional studies have focused on socioeconomic differentials in mortality using M (Brown et al., 2012; Canon, 2017; Zarulli et al., 2012). While these studies revealed that socioeconomic differences in mortality still persist into old-age, they could not account for how these disparities evolved over time.

The objective of this paper is twofold. First, it aims to analyze long-term trends in mortality inequality at older ages by occupation in Finland since the 1970s using the late modal age at death, M, and to determine how these inequalities have evolved over time. Second, it aims to assess if the pattern and differentials in M-trends by occupational class are systematically different than those of more widely-used measures of old-age survival such as e_{50}, e_{65}, and e_{75}. Our study will provide insight on the direction and the magnitude of occupational inequalities in mortality at older ages over the past 40 years in Finland. The comparative analysis of M with e_x trends will allow to identify the socioeconomic groups for which these trends are more different/similar.

2 Data and Methods

2.1 Data

The data used in this paper consists of observed death counts and population exposure by single year of age (31 and above), sex, occupational status and underlying cause of death covering the period 1971-2010 in Finland. Mortality and population exposure series by socioeconomic status and cause of death were obtained from linking the individual-level register data of all Finns to death records using personal identification codes. Before releasing any information to researchers, Statistics Finland aggregated death and exposure counts by sex, calendar year, occupational status, and single year of age. In the resulting data set, deaths and person-days for a given calendar year were assigned into one-year age intervals between exact birthdays.

We used occupation-based social class as our socioeconomic indicator which was measured at the time of each census and updated every fifth year. Women and men were allocated into the following classes based on their current or previous occupation: 1) upper non-manual (e.g. doctors and teachers), 2) lower non-manual (e.g. shop salespersons and nurses), 3) manual workers (e.g. construction workers, bus drivers, and cleaners), and 4) others (e.g. farm and forestry workers, students, entrepreneurs, unknown occupational status). We focus on mortality differences between the three first classes only given the significant heterogeneity and large compositional changes that have occurred over time within the fourth group. For retired and unemployed individuals as well as for those with unknown occupation at the time of the census information was gathered from earlier censuses. Those whose main activity was household work were classified according to the occupation of the head of the household. Immigrants were removed from the data set since there was no information on their occupational class and emigrants were censored at emigration.

2.2 Methods

For a given sex and occupational class,

- life expectancy at age x in calendar year y is given by:

$$e_x(y) = \int_x^\omega exp\Big[-\int_x^a \mu(x,y)du\Big]da, \tag{1}$$

  and

- the modal age at death, M, defined as the age at which the highest proportion of deaths occur, is obtained as:

$$M_s(y) = \max_x \ f_s(x,y) = \max_x \mu(x,y)exp\Big[-\int_0^x \mu_s(u,y)du\Big], \tag{2}$$

where $f(x,y)$ represents the density function and describes the distribution of deaths across ages for a given sex and occupational class. This function is solely obtained from corresponding sex and occupational hazard functions, $\mu(x,y)$ (equation (2)).

The hazard function, $\mu(x,y)$, also known in demography as the force of mortality, represents the instantaneous risk of dying. It is defined as:

$$\mu(u,y) = \lim_{\Delta x \to 0} \frac{Pr\big(x < X < x + \Delta x | X > x\big)}{\Delta x}. \tag{3}$$

As illustrated by equation (1) and (2) the estimation of $e_x(y)$ and $M(y)$ relies solely on the estimation of $\mu(x,y)$. Generally, $\mu(x,y)$ can be estimated by the central death rate $m_i = d_i/e_i$ where d_i and e_i represent observed death counts and population's amount of exposure to the risk of dying by single year of age, sex, and occupational class. Although this straightforward approach is quite simple, it does not allow deriving with great precision the density functions and associated modal ages at death. To overcome these limitations, we smooth death rates in order to retain the continuity of the age patterns of mortality presented above.

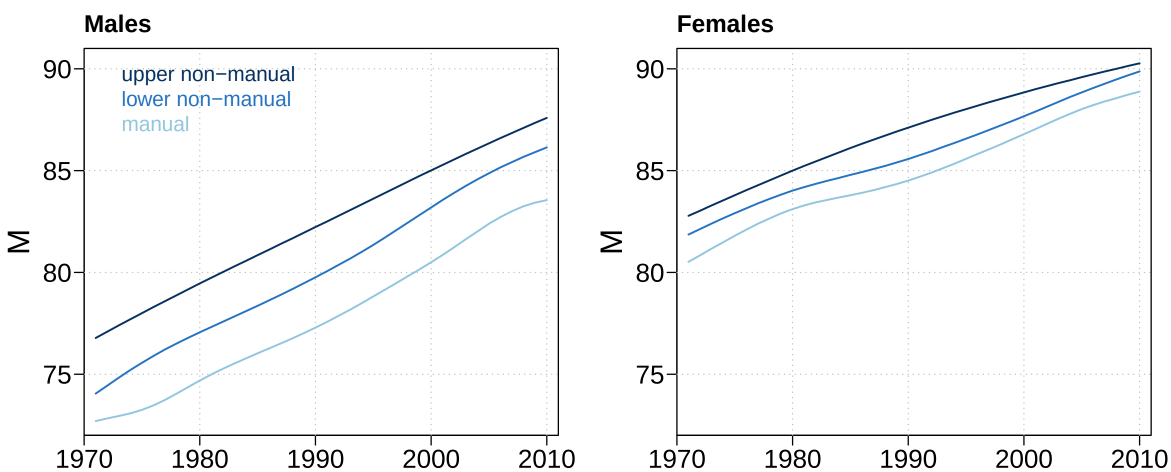
Among the various nonparametric smoothing techniques, we opted for the P- splines method in two dimensions. The attractiveness of this approach is that it uses information on neighboring ages and years and therefore random variation due to small counts are less likely to occur (Camarda, 2012). More details on the P-spline smoothing in two dimensions can be found in the Appendix of Ouellette et al. (2012). Compared to the competing techniques available, P-splines is the smoother that features the most desirable properties simultaneously (see Table 1 in the Rejoinder section of Eilers and Marx (1996) on p.121, and Appendix A, notably, of Eilers, Marx, and Durban (2015) for a comparison with O-splines). Moreover, this method has been proven highly effective for smoothing mortality rates and hence for obtaining smooth forces of mortality (Camarda 2008, 2012, Currie, Durban, and Eilers 2004).

3 Results

Figure 1 shows trends in modal age at death, M, by occupational class and sex over the 1971-2010 period in Finland. The modal age at death increased for all occupational classes and for both sexes. In 1971, M for males in upper nonmanual occupations was 76.8 years but was 4.1 years lower for those in manual classes (72.7 years). Most lower nonmanual male workers lived until 74.1 years, therefore outliving their peers in manual occupations by 1.4 years. In 2011, M for the upper and lower nonmnaual classes reached 87.6 and 86.1 years respectively compared with 83.5 years for the manual classes. Over time, mortality inequalities among older Finnish males declined between all groups, except among lower nonmanual and manual male workers who experienced an increase. The M-gap almost halved between males in the nonmanual groups (from 2.7 to 1.4 years), increased by more than one year between workers in the lowest occupational categories (from 2.4 to 2.6 years) while it remained unchanged for males at the opposite end of the occupational spectrum (at about 4 years).

Compared to males, the occupational mortality gradient was less steep for females. In addition, mortality differentials between all occupational groups were smaller in 2010 than 1971. In the early 1970s, females in upper nonmanual classes typically lived 2.3 years more than their counterparts in manual classes (82.8 vs 80.5). In 2011, the gap between the two occupational classes was only 1.4 years as females in upper nonmanual and manual classes registered a modal age at death of 90.3 years and 88.9 years respectively. The decline in the gap between the remaining occupational classes was more modest (less than half a year). Over the study period, M for females in lower nonmanual classes went from 81.9 to 89.9 years.

Figure 1: Adult modal age at death (M) by occupational class for Finnish males and females, 1971-2010



How do trends in M by occupational class compare with those of more conventional measures of old-age mortality, such as conditional life expectancies at age 50, 65, and 75 (i.e. e_{50}, e_{65}, e_{75})? Figure 2 illustrates trends in modal age at death M and conditional life expectancies e_{50}, e_{65} and e_{75} by occupational class and sex over the 1971-2010 period in Finland. It shows that over the 40-year period M increased at a faster pace than the three conditional life expectancies studied. This is the case for all occupational classes and for both sexes. Since 1971, M for nonmanual and manual workers increased by almost 11 years and by 12 years for the lower nonmanual ones. The pace of increase of the various e_x's was more modest. The gain in e_{50} was of about

8.5 years for each nonmanual class and 7.9 years for the manual class. Conditional life expectancies at ages 65 and 75 registered smaller gains. The increase in e_{65} and e_{75} was quite similar for the two nonmanual classes (6.2 and 3.7 years) and slightly lower for the manual classes (5.9 and 3.3 years). These results suggest smaller gains in the various e_x's as one moves down through the occupational spectrum while the gains in M for the upper nonmanual and manual classes are similar and slightly lower compared to the lower nonmanual classes.

Similar to males' results, M for females increased at a faster pace than the three conditional life expectancies under study, with higher increases in M as one moves down the occupational spectrum. Over the study period, the increase in M for the upper nonmanual, lower nonmanual, and manual females workers was respectively of 7.5, 8.0, and 8.4 years. The increase in e_{50}, e_{65}, and e_{75} was similar for all three occupational groups; oscillated around 6.5, 5.7 years and 4.2 years respectively.

Figure 2: Adult modal age at death (M) and *total* life expectancies at age 50, 65, and 75 ($50 + e_{50}$, $65 + e_{65}$, $75 + e_{75}$) by occupational for Finnish males and females, 1971-2010

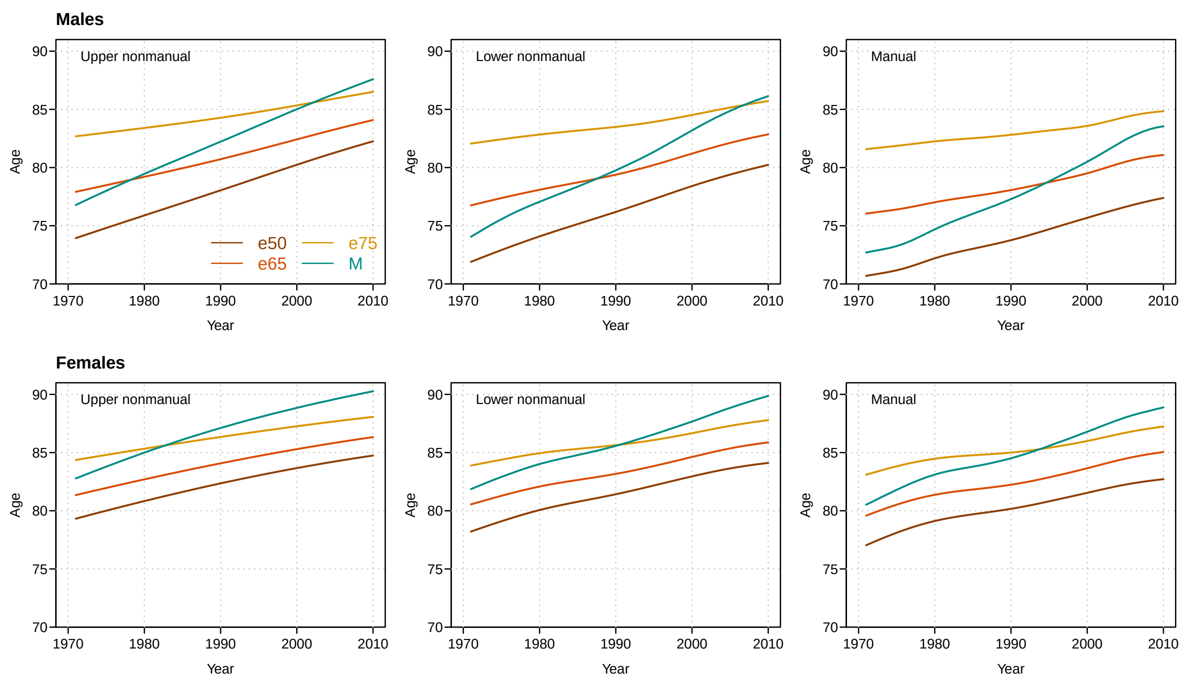


Figure 3 illustrates trends in lifespan differences by occupational class among older Fins from 1971 to 2010, monitored using M, e_{50}, e_{65}, and e_{75}. It reveals that patterns of trends in M-gap by occupational class differ from those in e_{50}, e_{65}, and e_{75}.

For males, the e_x-gap increased between the three occupational classes throughout the study period and more steeply at younger than older ages. Trends in M-gap by occupation fluctuated upwards and downwards throughout the period. Compared to 1971, the 2010 M-gap remained the same between the upper nonmanual and manual classes (at about 4 years), increased between the lower non-manual and manual classes (from 1.4 to 2.6 years) and decreased between the upper and lower nonmanual classes (from 2.7 to 1.4 years). In contrast, occupational differences in the various e_x's reveal an increase of almost 2 years in e_{50}, almost

1 year in e_{65} and 0.5 years in e_{75} between the nonmanual classes and manual classes. The gap between the two nonmanual classes changed very slightly over time. The M-gap was in general higher than the one in e_50 for most of the study period; until the late 1990s for males in upper nonmanual classes and their peers in the lower two classes and until the early 1990s between males in lower nonmanual and manual classes.

Occupational differences at older ages for females are quite different than those observed for males. Patterns of trends in M- and e_x-gap by occupation followed a bell-shaped curve over the period studied, especially true when looking at the lifespan difference between the upper nonmanual and manual classes. The decline in M was steeper compared to that in e_{65} and e_{75} during the period following the 1990s-peak. For instance, the difference between the upper nonmanual and manual classes in M-levels in 1990, year when the M-gap was at it's highest level, was 2.6 years. In 2011, the difference between the two groups amounted to 1.4 years - a decline of 1.2 years. The narrowing in e_{65}-gap was more modest (0.5 years) going from a level of 2.1 years in 1994 (peak-year) to a level of 1.6 in 2011. Compared to the other classes, old-age differences in lifespan between the lower nonmanual and manual classes followed a different pattern. Trends in M-gap exhibited a reduction of mortality inequalities between the two classes during the 1970s and 1990s and early-2000s and an increase during the 1980s and late 2000s. Similar trends are observed in the three conditional life expectancies trends until the late 1970s. However, trends in these three indicators differ from those in M as of the beginning of the 1980s. Occupational differences measured with e_{50} suggest an increase in mortality inequalities throughout the 1980-2010 period. Trends in e_{65}- and e_{75}-differentials indicate that the mortality gap between the lower nonmanual and manual female workers decreased very slightly in the first years of 2000 and remained unchanged since the mid-2000s. Compared to the various e_xs, the M-gap between the upper nonmanual and manual female workers was higher throughout the 1980s and reached lower levels than e_50 in the early-1990s and than e_{65} in the mid-2000s. Mortality inequalities were also larger between females in upper and lower nonmanual occupations when measured with M than conditional life expectancy - observed throughout the 1980s and 1990s. We notice the same for females in lower nonmanual occupations, however the difference in the number of years lived by these two groups is more similar when measured with M or e_x.

Figure 3: Occupational differences in M and e_{50}, e_{65} and e_{75} for Finnish males and females, 1971-2010

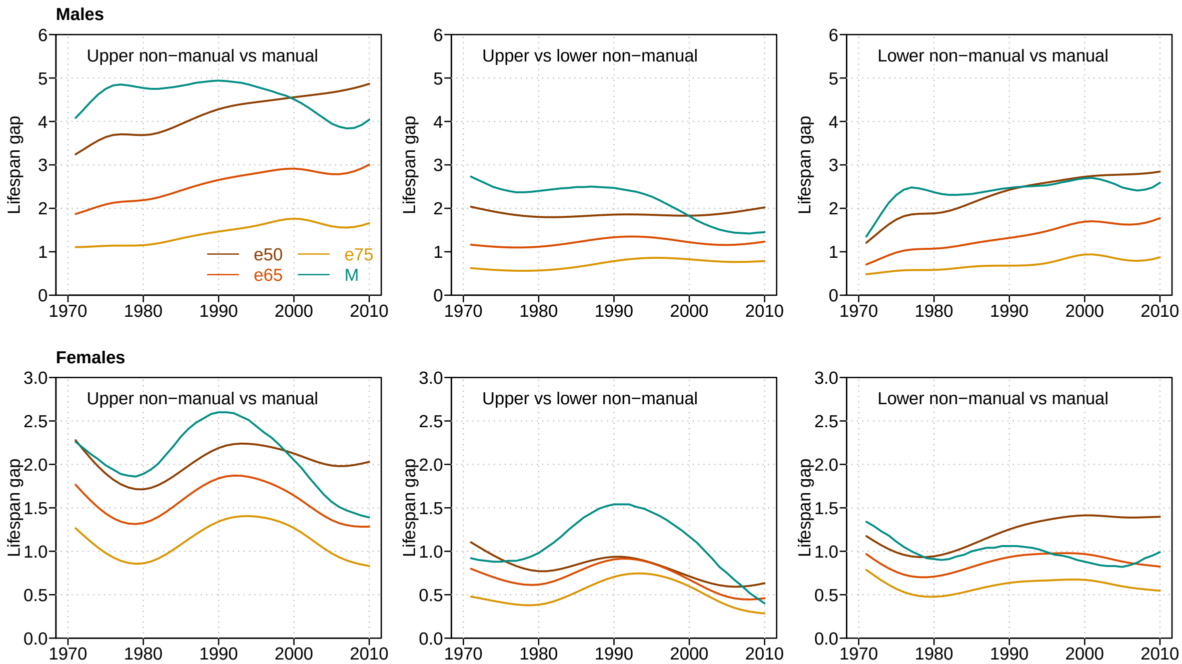
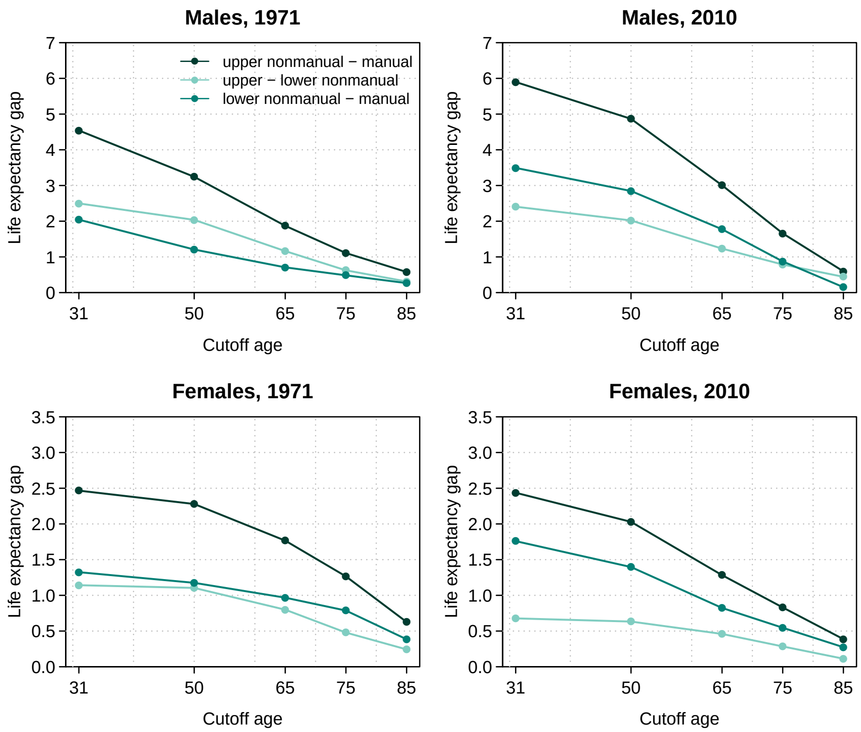


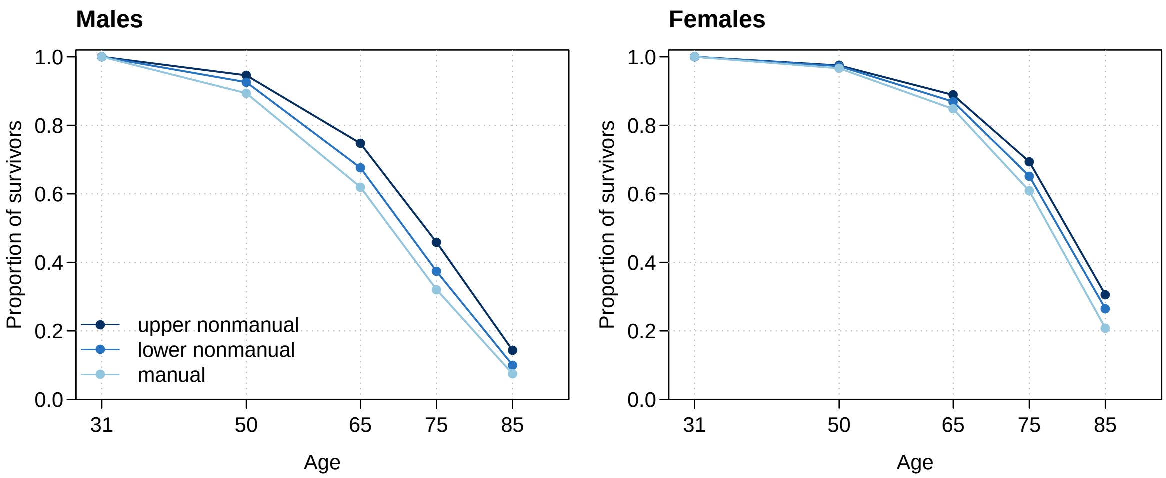
Figure 3 revealed greater differences in conditional life expectancies by occupational class at younger than older ages. That is, mortality inequalities by occupation are larger at age 50 than 65 and 75 with larger disparities at age 65 than 75. This phenomenon is observed for both males and females. The decline in the mortality gradient with increasing age is illustrated in Figure 5; the gap in conditional life expectancy between the three occupational classes narrows as the cutoff age, x, from which conditional life expectancies are calculated is increasing. The largest reduction in mortality disparities with increasing age is experienced by nonmanual and manual workers and the smallest between the two lowest occupational classes (i.e. lower nonmanual and manual). In 1971, life expectancy at age 31 was almost 5 and 2.5 years higher for males and females in the upper nonmanual classes than their peers in the manual classes. This advantage gradually faded reaching less than 2 years at age 65 and less than one year at age 85 for both sexes. In 2010, the life expectancy gap is larger for males younger than 75 and for females aged under 50, especially between the nonmanual and manual classes.

Figure 4: Differences in e_x by occupational class at age x, Finnish males and females, 1971



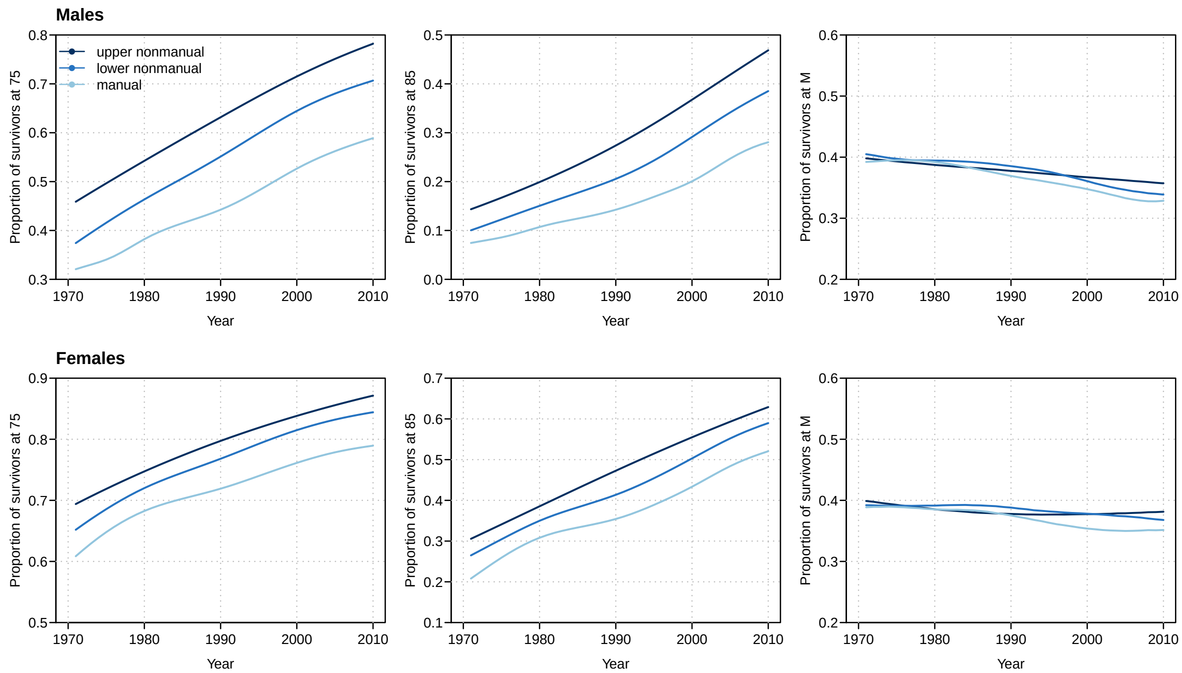
The greater mortality inequalities observed at younger than older ages (Figure 5) may be explained by a smaller proportion of males and females from lower occupational groups surviving to older ages. Figure 6 illustrates the proportion of individuals still alive at a certain age by occupational class. It shows a smaller proportion of survivors at all ages as one moves down the occupational hierarchy. In 1971, 74% of nonmanual male workers survived to age 65 compared to 62% of the manual workers. For females, the difference in the percentage of survivors is more modest compared to males: 89% of females nonmanual workers survived until the age of 65 compared to 86% for those in manual classes.

Figure 5: Proportion of survivors to a particular age x by occupation Finnish males and females, 1971 and 2010



As illustrated in Figure 6, males and females in all occupational classes aged 75 and 85 experienced a survival improvement over the 40-year period. However, the survivorship-gap widened between males in the nonmanual and manual classes but remained quite stable for females. It therefore suggests a change in the composition by occupational class at the oldest ages, with a higher advantage in 2010 than in 1971 for the higher than lower occupational classes. This compositional change resulted in a slower increase in conditional life expectancies for the lower occupational groups. In contrast, the proportion of survivors at M by occupational class remained quite constant over time. However, a small gap is observed between the lower nonmanual and manual workers since the early 1980s. A small difference in the proportion of survivors at M emerged in the late-1980s between the upper nonmanual and manual classes (3 percentage points) and since the late 2000s between the two nonmanual groups workers (2 percentage points). For females, a gap in the proportion of survivors at M is observed since the early 1980s between the two lower occupational classes and since the 1990s between the upper nonmanual and manual classes. However this gap is negligeable; at the end of the study period it was at most 3 percentage points.

Figure 6: Proportion of survivors at age 75, 85 and M by occupational class, Finnish males and females, 1971-2010



4 Discussion

Since its reintroduction to contemporary demography by Kannisto in the early 2000s, the modal age at death (M) has gained increasing scientific interest for monitoring survival improvements at older ages in economically advanced countries. Despite this, studies of M trends by socioeconomic status remain scarce. Direction and magnitude of changes in the socioeconomic gradient are usually assessed with mortality rates or life expectancy conditional on survival to a certain age. Accordingly, this study is the first to analyze long-time trends in mortality inequalities at older ages by occupation in Finland since the 1970s using the late modal age at death, M. The results showed that M increased steadily for all occupational classes and for both sexes throughout the 1971-2010 period. Moreover, the increase occurred at a parallel or even faster pace in low occupational groups than high occupational groups. Therefore, mortality differentials at older ages were smaller at the end of the study period than in the early 1970s, except for males in lower nonmanual and manual classes for which differences widened. These findings suggest, on one hand, that individuals from all social classes benefited from the technological advancements in preventive and curative medicine as well as the adoption of healthier lifestyles brought about the cardiovascular revolution since the 1960s. On the other hand, the results suggest that individuals from lower social classes reaped most of these benefits and became even more successful than their peers in higher classes in fighting against the multiple pathologies present in old age. This finding does not go in line with the "fundamental cause" theory which stipulates that mortality inequalities by socioeconomic status will persist and continue to increase because social status "embodies an array of resources, such as money, knowledge, prestige, power, and beneficial social connections" (Phelan et al., 2004). Our results may suggest however that the increase in the general level of education of the population should not be undermined. As the general level of education in population's level increases, individuals from all social strata acquired the ability to understand the benefits of health-related behaviors, how to avoid occupational health hazards, and the importance of early screening and treatment. This may be exemplified by the different attitudes and beliefs in regard to the harmful effects of smoking between younger and older cohorts following educational compositional changes in the United States. As highlighted by the author, the lower-educated individuals of the 1900s became over time more able to understand the risks associated with smoking, more health conscientious as not to engage in such behavior, and more willing to deprive themselves from the immediate satisfaction of smoking; characteristics that their college-educated counterparts of the 1970s did not appear to posses ((Link, 2008)).

The comparative analysis of M trends with those in conditional life expectancies e_{50}, e_{65}, and e_{75} revealed, firstly, larger gains in lifespan among the elderly in all occupational classes with the mode-based than mean-based measure. As mathematically proven by Horiuchi and colleagues (2013), when the mortality curve makes a parallel shift to older ages, M increases at exactly the same pace as the old-age mortality shift. However, conditional life expectancies, such as e_{50}, e_{65}, and e_{75}, increase more slowly. In addition, by contrast with M, old-age survival improvements were more modest when monitored with the various e_xs and the lower social classes registered lower gains than their peers in favorable social situations. This finding may suggest e_x trends do not accurately capture the old-age mortality improvements made by the lower classes. This group has in fact experienced larger declines in absolute mortality than higher groups over the 1990-2010 period (Mackenbach et al 2016), which may have therefore translated into more pronounced mortality shifts to older ages.

Secondly, the direction and the pattern of changes in mortality inequality depend on the measure used. Compared to their 1971-level, occupational disparities in 2010 were in general smaller when monitored with M but larger or remained unchanged when assessed with the various e_xs. In addition, the evolution over time of mortality disparities monitored with M followed a different pattern than with e_x especially for males. For instance, the difference in modal age at death between the upper nonmanual and manual classes stagnated in the 1970s and 1980s, suggesting similar survival improvements among the two groups at ages older than M. In fact, M shifts to older ages when changes in mortality occur at ages above M (Horiuchi et al., 2013; **?**). In contrast, the upper nonmanual and manual difference in conditional life expectancy became increasingly wider and even more so at ages 50 than 65 or 75, resulting from higher gains in the upper nonmanual than manual classes. Alcohol misuse among middle aged Finnish men contributed to slower mortality regression among the lower social groups, and consequently to the widening of social inequalities (Makela et al., 1997). Pattern of change was also different for females when monitored with M or with e_x, especially with e_{50}. The gap in the number of years lived by females in upper nonmanual and manual classes sharply declined since 1990s as showed by trends in M. However, the decrease in the various e_xs studied was less considerable, particularly those in e_{50}. The narrower disparities suggest that most of the improvements occurred in the manual classes. One possible explanation may be that absolute declines in mortality in many European countries over the 1990s and 2000s, including Finland, were larger in lower than higher socioeconomic groups, particularly in mortality from ischaemic heart diseases and amenable to medical intervention (Mackenbach et al., 2016). Another explanation may be that individuals in lower socioeconomic classes surviving until M were more similar in regards with health-related behaviors to individuals in higher classes in the 1990s and 2000s than in the early 1970s. The difference in the speed at which the decline occurred may imply that most of the mortality improvements were concentrated at ages above M, ages on which e_{65} and e_{75} are less dependent. In fact, saving the life of a 65 year old individuals adds more years to e_{65} than saving the life of a 85 or 90 year old individual.

Finally, the magnitude of mortality inequalities by occupational class were in general larger - particularly between the upper nonmanual classes and the other two classes - for most of the study period when measured with M than with conditional life expectancy at older ages. It is possible that the differences observed between M and e_x during specific time periods may be related to the heterogeneity in frailty. Frailer individuals have lower chances of survival to older ages which generates a compositional change in the surviving population, i.e. the robust survivors make up the older population. This phenomenon is amplified by socioeconomic status. Biological risk increases with age more rapidly among individuals in lower social strata than higher social strata (Crimmins et al., 2009). As a larger number of individuals are claimed at younger ages and only the fittest survive to older ages, mortality inequalities decline with age. This phenomenon is reflected by differences in the proportion of survivors at a particular age x by occupational class (Figure 5). As occupational differences in the proportion of survivors increased over time, so did the difference in conditional life expectancy therefore suggesting that these mean-based indicators are tainted to some extent by the selection effect. By contrast, M seem to be free from this problem; the proportion of survivors at M was similar across occupational groups and did not widen over time. This feature gives an advantage to M over conditional mean-based measures of survival in studies of mortality inequalities.

5 Conclusion

Long-term trends in modal age at death M by occupational class in Finland revealed a decline in mortality inequalities among the elderly since the early 1970s, which resulted from larger old-age survival improvements in the lower than higher socioeconomic classes. The rise in the general level of education within a population may have played a more important role than the resources, i.e. money, prestige, beneficial social connections, to which the more privileged have access to. The diffusion of education within the population has provided individuals from all social strata, and not only the most affluent ones, with the skills and resources necessary to adopt healthier lifestyles and to reduce their exposure to harmful risk factors. These changes at the individual level combined with the population wide improvements in prevention and treatment, contributed to the faster extension of their length of life.

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