Socioeconomic differences in the most common age at death: An analysis by leading causes of death 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

1 Introduction

Socioeconomic differences in mortality are found in all countries around the globe. Individuals of lower occupational status, with less education and with lower income, generally experience on average shorter lives. While individuals from all social classes benefited from the progress made in life expectancy over the course of the last century, the increase in length of life has not been equally experienced across social groups. Life expectancy differences between socioeconomic groups have in fact widened in some countries, for instance in Finland (van Raalte et al., 2014) and the United States (Sasson, 2016), but remained unchanged in others, like in France (Blanpain, 2011). In Finland, for instance, life expectancy at age 31 increased for individuals from all occupational classes over the 1971-2010 period. However, occupational disparities in mortality widened over time.

In general, differences in average length of life across the socioeconomic spectrum have been monitored using indicators such as life expectancy at a particular age, i.e. e_{25} (Sasson, 2016), e_{31} (van Raalte et al., 2014), and e_{35} (Blanpain, 2011). While these indicators give account of the changes that have occurred over time 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).

Old-age mortality, on the other hand, is more strongly influenced by an accumulation of life course stressors as well as improvements in the medical treatment of chronic conditions (Edwards et al., 2005; Ford et al., 2007; Hass, 2008; Hayward and Gorman, 2004; Naes et al., 2012; Palloni et al., 2009; Shields and Wilkins, 2009; Unal et al., 2004; Wilmoth, 2000). These trends could be captured by conditional life expectancies at some selected early old age, for instance e_{50} or e_{65} (Barbieri and Ouellette, 2012; Bosworth et al., 2016; Glei et al., 2010; Wilmoth et al., 2010), however the choice of such an age is arbitrary. As a partial remedy, the late modal age at death, M, is increasingly recognized as an informative lifespan indicator because it is solely influenced by improvements in old-age survival (Canudas-Romo, 2008; 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. Indeed, the increase in life expectancy since the 1970s is increasingly attributed to the faster decline in death rates at older than at younger ages and to the reduction in deaths occurring at ages 80 and above (Barbieri and Ouellette, 2012; Kannisto et al., 1994; Mazui et al., 2014). Under a given mortality regime, the modal age at death, M, represents the most common (i.e., most frequent) or 'typical' length of life among adults.

In the current literature, only two studies have focused on socioeconomic differentials in mortality using M (Brown et al., 2012; Canon, 2017). In the United States for instance males and females with higher education 'typically' lived about five years more than their counterparts with lower levels of education (Brown et al., 2012). The gap between the most and least educated was somewhat smaller in Canada, as males and females from higher education groups outlive their counterparts from lower education groups by about two and four years respectively (Canon, 2017). 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 or by cause of death.

The first objective of this paper is therefore to answer the following question: Did socioeconomic differences in all-cause and cause-specific mortality at older ages increase, decrease or stagnate over time? To answer this question we examine all-cause and cause-specific trends in the modal age at death, M, by socioeconomic status in Finland over the 1971-2010 period. We focus on six broad leading causes of death, that is heart diseases, cerebrovascular diseases and four types of cancers, namely colorectal cancer, lung cancer, prostate cancer (males), and breast cancer (females). Our study is the first to document trends in modal age at death by cause of death and by social class. The contribution of an analysis on socioeconomic differences in mortality along a cause-of-death dimension is two-fold. First, it allows to determine the magnitude of the social gradient in mortality for each cause and to examine whether this magnitude has amplified, attenuated, or remained unchanged over time. Second, it will indicate which causes are responsible for the trends observed in all-cause mortality disparities between socioeconomic groups at older ages.

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.

In this data set the causes of death are classified according to the World Health Organization International Classification of Diseases (ICD). Because the period covered by our study extends from 1971 to 2010 we bridge three revisions of the international classification, ICD-8, ICD-9, and ICD-10. To ensure the consistency of categories throughout the three revisions of the ICD and to minimize the impact of successive revisions on our results we restricted our analysis to large groups of causes of death (Table A, Appendix).

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 occupational class, the modal age at death for a given cause of death k and calendar year y is given by:

$$M_k(y) = \max_x \ f_k(x, y) = \mu_k(x, y)S(x, y) \tag{1}$$

where $f_k(x, y)$ and $\mu_k(x, y)$ are the density function and the force of mortality for cause k and $S(x, y)$ is the all-cause survival function.

The cause-specific density function, $f_k(x, y)$, a continuous function of age x and time y, is obtained by multiplying the force of mortality for cause k, $\mu_k(x, y)$, and the all-cause survival function, $S(x, y)$ which are also continuous functions over age and time.

The all-cause survival function, $S(x, y)$ can be obtained from the all-cause force of mortality, $\mu(x, y)$, as:

$$S(x, y) = exp\Big[-\int_0^x \mu(u, y)du\Big]. \tag{2}$$

Under the assumption that the causes of death are mutually exclusive and mutually exhaustive (Preston et al., 2001), the all-cause force of mortality, $\mu(x, y)$, can be obtained from cause-specific forces of mortality through summation. Therefore, the density function of cause k can be expressed solely in terms of cause-specific forces of mortality. For more details on the application of the P-spline method within a cause of death context see Diaconu et al. (2016).

For a given occupational class, the forces of mortality for each leading cause of death studied are estimated from observed cause-specific death counts and population exposure using the flexible smoothing P-spline 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).

3 Preliminary results

Figure 1 depicts trends and levels in the most frequent age at death as measured by $\hat{M}$ for Finnish males from 1971 to 2010. It reveals important differences in $\hat{M}$ levels between the various occupational classes.

Throughout the 40-year period, males in upper non-manual occupational classes enjoyed a longer life than their peers in lower non-manual classes who survived more years than those in the manual classes. In 1971 the most common age at death for males in upper non-manual classes was about 77 years while for those in lower non-manual and manual categories it reached a level of about 74 and 73 years respectively. Over the last 40 years, $\hat{M}$ increased steadily in an almost parallel and linear manner for all occupational classes. Males at the high end of the occupational ladder saw an increase of about ten years in their modal age at death while the middle and bottom classes gained respectively about 12 and 11 years in their 'typical' length of life. Compared to its 1974 level, the 2010-gap in $\hat{M}$ was smaller between males in the two non-manual classes and larger between those belonging to the two lowest occupational groups. However, the difference in the modal age at death between males in the upper non-manual and manual classes remained unchanged.

Figure 2 illustrates trends and levels in modal age at death, $\hat{M}$, by occupational class for five leading causes of death among males, namely heart diseases, cerebrovascular diseases, colorectal cancer, lung cancer, and prostate cancer, in Finland from 1971 until 2010. It reveals an important occupational gradient in mortality for all leading causes of death which has persisted throughout the 40-year period. The upper non-manual occupational class 'typically' dies at older ages compared to the other two occupational classes while lower non-manual workers enjoy a few additional years of life than their peers with manual jobs. However, the old-age survival advantage of the higher occupational classes varied by cause of death.

At the beginning of the study period, the largest gap in $\hat{M}$ between males in upper non-manual and manual groups was observed for heart diseases and lung cancer. For these two diseases, the manual class' modal age at death was respectively about 69 and 67 years, which is approximately about four years lower than the modal age at death for males with upper non-manual occupations. For the remaining causes of death, the difference in $\hat{M}$ was more modest; about 2.5 years for cerebrovascular diseases and prostate cancer and a little more than 1.5 years for colorectal cancer. The most common age at death for the males in the manual class dying from cerebrovascular diseases was about 77 years, which is about a year higher than that that for prostate and colorectal cancer.

Males dying of heart diseases, lung cancer, and prostate cancer with lower non-manual jobs appear to die around the same age as manual workers rather than upper non-manual workers. The M-gap between the lower non-manual and manual groups for these particular causes varies between 0.8 years (prostate cancer) and 1.6 years (lung cancer) while the one between the two non-manual groups amounts to 3.5 years for heart diseases and to around two years for the two types of cancers. In contrast, for cerebrovascular diseases and colorectal cancer, the most frequent age at death for males with lower non-manual jobs was closer to the one observed in the upper non-manual class.

Despite the steady increase in cause-specific modal age at death for all occupational classes over the 40-year period, disparities in $\hat{M}$ between males at the opposite end of the occupational spectrum are still noticeable. In 2010, prostate and colorectal cancer exhibited the largest difference in $\hat{M}$ between the upper non-manual and manual classes, a finding different from the beginning of the study period. The most common age at death in the manual class for these two malignancies was respectively about 82 and 79 years, which is about four and three years lower than the upper non-manual class. Substantial social differences in mortality at older ages were also observed for heart diseases, cerebrovascular diseases, and lung cancer. Upper non-manual workers enjoyed about 3.5 more years of life than manual workers, who 'typically' lived between 85 and 77 years observed for two main subcategories of heart diseases and lung cancer respectively. A substantial difference, of almost 2.5 years, was also observed for prostate and colorectal cancer, when comparing the most common age at death of the non-manual classes, and for lung cancer, between males in the two lowest occupational groups.

4 Conclusion

Our preliminary results on all-cause mortality revealed that the modal age at death increased for all occupational classes at a similar pace in Finland over the 1971-2010 period and that disparities in mortality remained stable, particularly between the upper non-manual and manual classes. These findings seem to suggest that lower social classes experience mortality improvements at older ages almost at the same rate as higher social groups. Our results also revealed that the modal age at death increased for all occupational classes and for all leading causes of death among males in Finland since the early 1970s. However, over time, disparities in the 'typical' length of life between males at the opposite end of the occupational social class spectrum narrowed for heart diseases and barely decreased for lung cancer, following a faster increase in M in the lower occupational groups, particularly in the lower non-manual group, than in the highest group. The narrowing of the social gap for these particular causes of death, could be associated with the decline in smoking among middle social class males. However, the gap widened for cerebrovascular diseases, colorectal cancer, and prostate cancer. This was due to the fact that the upper non-manual class' M increased at a faster pace than that of the other two classes. This may suggest that individuals in the highest social group were the first to reap the benefits brought about by the introduction of major breakthroughs in health technologies and care strategies and that these benefits diffused more slowly to the lower social classes. Our results have also revealed a shift over time in the causes of death displaying the largest differences in M between upper non-manual and manual workers, from causes strongly related to change in smoking behavior (heart diseases and lung cancer) to causes which are more depended on medical intervention (prostate cancer and colorectal cancer). Nevertheless, the divergence and convergence in M were smaller than those for life expectancy. The overall stability of socioeconomic differences in M provides a fresh perspective to debates about widening inequalities in mortality, and contradicts predictions of increasing advantages of the upper classes.

5 Future work

This is an ongoing project and we intend to run the same analysis for females and verify how the results obtained with respect to trends in cause-specific socioeconomic differences in mortality compare to those for males. We also plan to estimate M for post-2010 calendar years in order to examine the evolution of socioeconomic differences in mortality by cause of death over the past decade. Could it be that in recent years the mortality gradient narrowed for some causes of death? In fact, we are currently in talks with Statistics Finland to have access to data spanning from 2011 to 2018. Another future goal is to determine how our results fit in with the literature focusing on whether socioeconomic differences in mortality decline over age and if examining trends in the modal age at death is more informative as it gives a better idea of the changes in the distribution of ages at death by cause of death and socioeconomic status.

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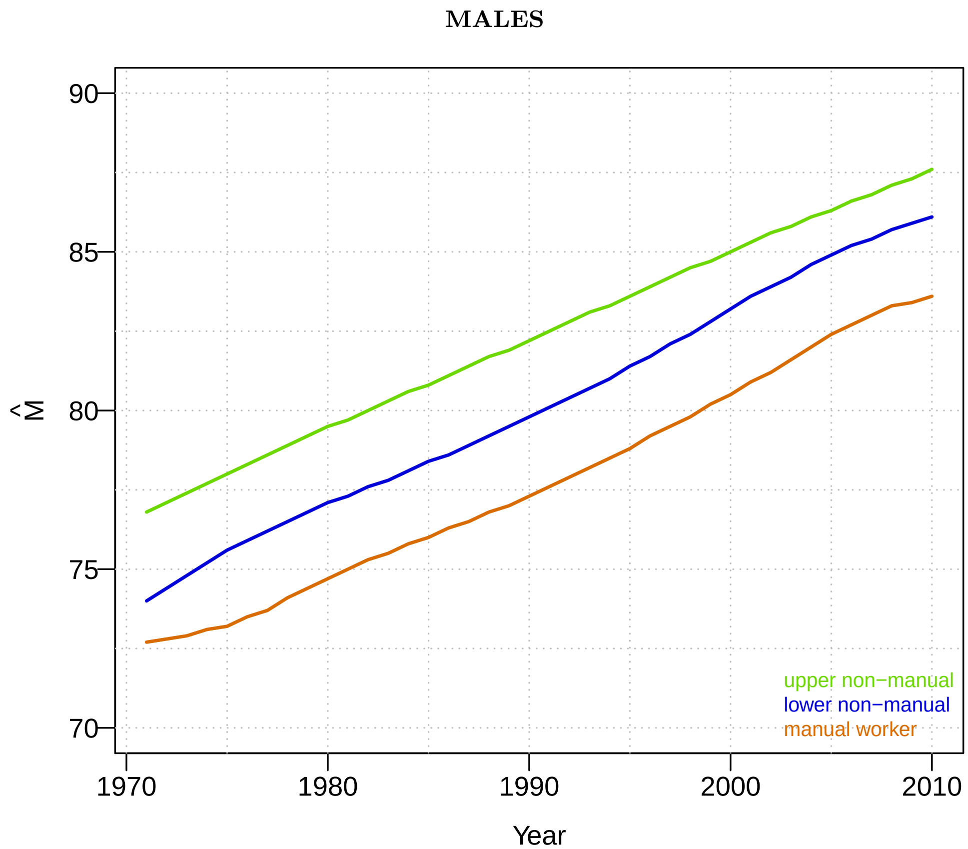
Appendix

A: International Classification of Diseases (ICD) codes for the leading causes of death under study

Table A-1: Concordance table for bridging revisions 8, 9, and 10 of the ICD for leading causes of death in Canada

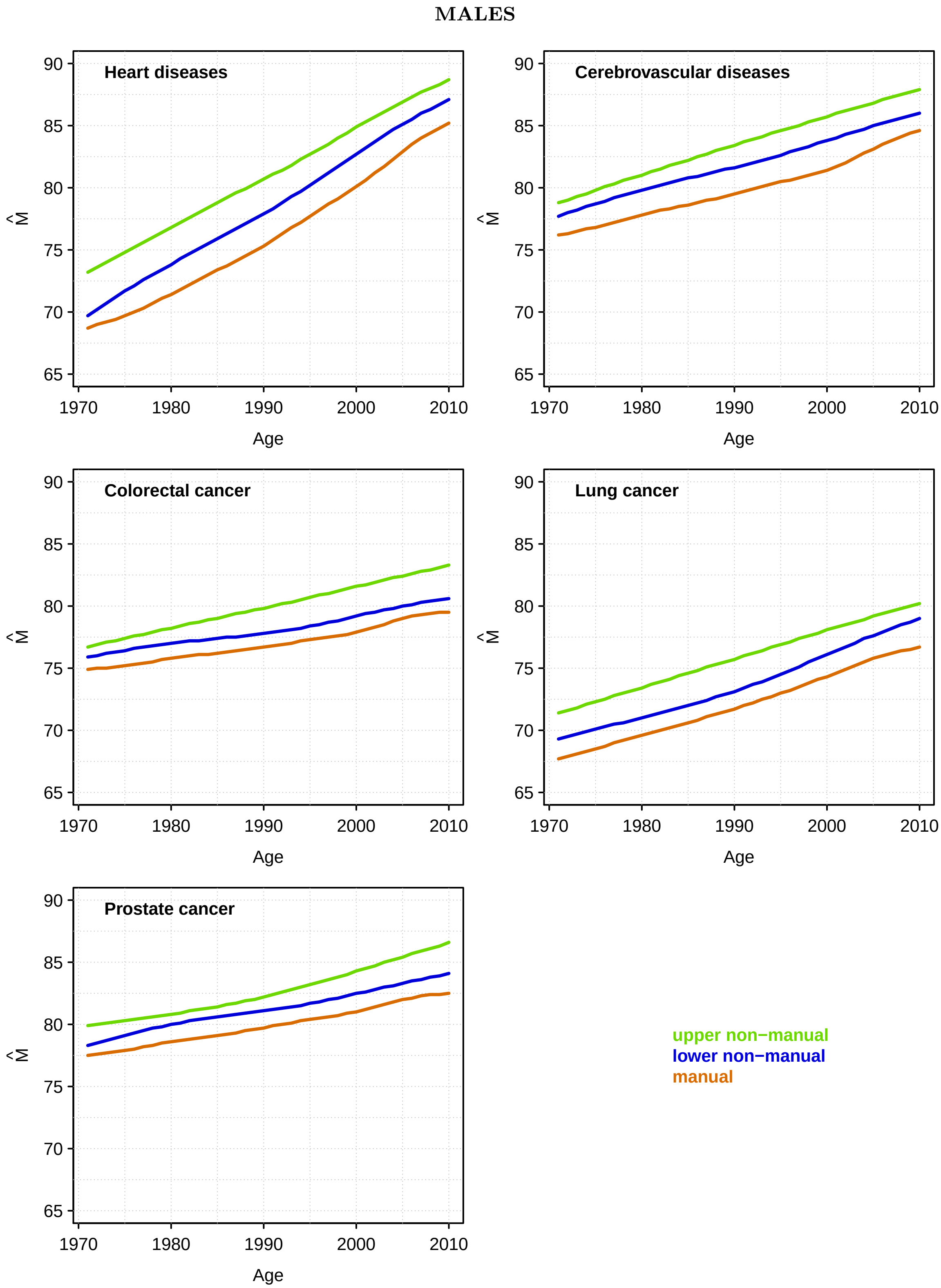
Causes of death	ICD-8	ICD-9	ICD-10
Circulatory diseases	**390-458**	**390-459**	**I00-I99**
Cerebrovascular diseases	430-434, 436-438	430-434, 436-438	I00-I69
Heart diseases	390-398, 402, 404, 410-429	390-398, 402, 404, 410-429	I00-I09, I11, I13, I20-I51
Cancers (malignant neoplasms)	**140-208**	**140-208**	**C00-C97**
Breast cancer	174	174	C50
Colorectal cancer	153-154	153-154	C18-C21
Prostate cancer	185	185	C61
Lung cancer	162	162	C33-C34

Figure 1: Estimated modal ages at death for all causes combined among Finnish males by occupational class, derived from two-dimensional smoothed age-at-death distributions, 1971-2010



Source: Authors' calculations

Figure 2: Estimated modal ages at death by occupational class and leading causes of death, derived from two-dimensional occupational- and cause-specific smoothed age-at-death distributions, Finland, 1971-2010



Source: Authors' calculations