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Lifespan Variation by Occupational Class: Compression or Stagnation Over Time?

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Abstract Cross-sectional analyses of adult lifespan variation have found an inverse association between socioeconomic position and lifespan variation, but the trends by social class are unknown. We investigated trends in lifespan variation over four decades (1971–2010) by occupational social class (manual, lower nonmanual, upper nonmanual, other) using Finnish register data. We performed age and cause-of-death decompositions of lifespan variation for each sex (a) by occupational class over time and (b) between occupational classes at a shared level of life expectancy. Although life expectancy increased in all classes, lifespan variation was stable among manual workers and decreased only among nonmanual classes. These differences were caused by early-adult mortality: older-age lifespan variation declined for all the classes, but variation in early-adult mortality increased for all classes except the highest. The manual class's high and stagnant lifespan variation was driven by declines in circulatory diseases that were equally spread over early mortality-compressing and older mortality-expanding ages, as well as by high early-adult mortality from external causes. Results were similar for men and women. The results of this study, which is the first to document trends in lifespan variation by social class, suggest that mortality compression is compatible with increasing life expectancy but currently achieved only by higher occupational classes.

Keywords Lifespan variation · Life disparity · Life expectancy · Mortality compression · Socioeconomic inequality

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Introduction

Socioeconomic differences in mortality exist in every modern population where they have been examined.[1] Research has shown that lower socioeconomic status (SES) groups, on average, not only have shorter lives but also higher variability about their age at death in the United States (Brown et al. 2012; Edwards and Tuljapurkar 2005) and in Europe (Shkolnikov et al. 2003; van Raalte et al. 2011). Greater lifespan variation[2] means higher inequality and higher uncertainty about the age at death for the lower-SES groups.

Reducing lifespan variability and the uncertainty about age at death can factor into life course decisions, such as retirement planning and the adoption of healthy behaviors. The value of public and private investments in education and training increases when individuals are more likely to survive to older ages (Edwards 2008). Moreover, the existence of substantial socioeconomic inequalities in lifespan variation may point to the failure of social protective policies (van Raalte et al. 2011). For this reason, trends in lifespan variation by SES should be understood and monitored alongside trends in life expectancy.

Until now, studies that have focused on socioeconomic inequalities in lifespan variation have been limited to cross-sectional analyses (Brown et al. 2012; van Raalte et al. 2011) or to two points in time (Shkolnikov et al. 2003). We fill this void by examining how lifespan variation has changed since the 1970s for different socioeconomic groups. Using Finnish register data, we test whether occupational social classes experienced similar or diverging trends in adult lifespan variation and life expectancy. We use occupational social class (hereafter, "occupational class") as our socioeconomic dimension because unlike education, its composition within the population has remained relatively stable. The stability of the occupational class distribution is particularly important because with a stable SES classification, changes in lifespan variation can be attributed to group-specific changes in health exposures and health rewards rather than being driven by compositional changes of the groups. We measure life expectancy and lifespan variation conditional on survival to age 31, so as to be old enough to contain useful information on occupational status yet young enough to capture most adult mortality. We compare the age and cause-of-death distribution of mortality for each occupational class over time and at similar levels of remaining life expectancy. Over time, we expect the cardiovascular revolution[3] to have driven changes in the age-at-death distribution; however, at the shared level of life expectancy for different occupational classes, we expect to see a larger role from behavioral-driven causes of death.

Our findings reveal stark differences by occupational class: increasing lifespan variation among manual workers and mortality compression among nonmanual workers. These differences were due to diverging trends in early-adult mortality. At a shared level of life expectancy, manual workers had higher lifespan variation at

[1] Generally, higher-status individuals have lower mortality, but in some populations, a reverse gradient has been observed (Rosero-Bixby and Dow 2009).

[2] Lifespan variation goes by many different names and is also called mortality compression/expansion, (de-)rectangularization of the survival curve, and variation or inequality in age at death or length of life.

[3] We refer here to the successful fight against cardiovascular diseases which has been the major source of life expectancy improvement in western countries since the 1970s (Vallin and Meslé 2004).

early-adult ages owing to higher mortality from external causes, yet differences in lifespan variation at older ages were negligible. These results show that continued declines in lifespan variation are possible alongside increases in life expectancy, as evidenced by the trends observed for the higher occupational classes. Tackling the high early-adult mortality of the lower occupational classes would help these groups also achieve both increasing life expectancy and decreasing lifespan variation.

Background

Lifespan variation increases or decreases with increasing life expectancy, depending on the balance between saving lives at early ages, which compresses the age-at-death distribution, and saving lives at old ages, which expands this distribution. Conceptually, lifespan variation should be split into these early-adult and old-age components, which have different causes and theoretical implications (Vaupel et al. 2011). Generally, age decompositions have shown that differences in the number of deaths over early-adult ages (and infancy, when included) drive differences in lifespan variation between populations, with mortality differences at older ages being relatively unimportant (Shkolnikov et al. 2003, 2011; van Raalte et al. 2011; Vaupel et al. 2011; Wilmoth and Horiuchi 1999). However, this is not always the case. Kibele (2012) demonstrated that throughout much of the 1970s and 1980s, the former East German states had lower lifespan variation (over ages 0–90) than West German states at similar levels of life expectancy, owing to not only the East's lower young-adult mortality but also its higher old-age mortality. Meanwhile, examining lifespan variation at older ages is often done to determine whether mortality is being further compressed at these ages, which might signal a looming limit to the human lifespan in the absence of corresponding increases in the modal age at death—or, alternatively, to establish whether the entire older-age distribution of death is shifting to the right, known as the "shifting mortality" hypothesis (Bongaarts 2005; Canudas-Romo 2008; Kannisto 1996).

At the country level, lifespan variation over all adult ages (i.e., excluding infant and child mortality) has either been stagnant or shown only minor compression since the 1960s, despite continued increases in life expectancy. This was first shown by Edwards and Tuljapurkar (2005) for a small group of high-income countries and has since been found for a number of other high- and middle-income countries (Edwards 2011: Smits and Monden 2009). Meanwhile, cross-sectional analysis of adult lifespan variation and life expectancy in European countries by education, both conditional on survival to age 35, was strongly negatively correlated over the 1990s (van Raalte et al. 2011). Why life expectancy should be predictive of adult lifespan variation in the cross-section at the educational subgroup level but not at the national level over time has created a paradox that longitudinal studies of lifespan variation by SES group might help to unravel.

Numerous theories have been advanced to explain how social inequalities in mortality might change over time (for a recent overview, see Mackenbach 2012). Depending on the age pattern of mortality change by SES group, these could be applied to form hypotheses regarding changes in SES differences in lifespan variation over time. On the basis of this literature, we put forward three scenarios.

A *diffusion scenario* in lifespan variation would be possible if the highest-SES groups acted as a vanguard group. This scenario could present itself if higher education, income, or social status provided a pathway to adopting better health habits or to taking earlier advantage of medical breakthroughs: behaviors that eventually were transmitted down to lower-SES individuals (Rogers 1962; Victora et al. 2000). If such modified behaviors proved particularly favorable to reducing early-adult mortality, mortality compression would occur for all SES groups but with the lower-SES groups lagging behind in time. At a shared level of life expectancy, however, we would expect lifespan variation to be similar across all occupational groups. The magnitude of inequalities in lifespan variation by SES group at any time point would be related to the speed of health improvement; in times of greater innovations, inequalities might first diverge before eventually converging to previous levels during slower periods. This diffusion scenario could explain van Raalte et al.'s (2011) cross-sectional finding that within countries, higher-educated groups have lower lifespan variation; but this scenario could not explain the stagnation in lifespan variation at the country level unless mortality change were evenly split between early-adult and old-age components.

Another possibility is a *divergence scenario* in lifespan variation trends by social groups, with upper classes experiencing compression and lower classes showing increases in lifespan variation. Increasing income inequality since the 1980s, the decline of low-skilled manufacturing jobs as a share of the economy, and other social and technological processes might have disproportionately affected the ability of the lower classes to secure stable employment and enact control over their lives. These psychosocial processes could have caused growing inequalities in health and mortality (Aldabe et al. 2011; Ferrie et al. 2003; Wilkinson 1997). Selection effects from social mobility may also account for some of these divergences: for instance, if health problems led directly to downward mobility. On the other side, the expansion of a merit-based higher education system could have led to the upward mobility of individuals with enhanced cognitive abilities and other health-favorable personal characteristics, which in turn could have led to indirect health-selective sorting of the social classes (West 1991). These mechanisms could in whole or in part drive an increasing homogeneity of bad behavior among the lower classes, leading to increasing SES disparities in mortality (Mackenbach 2012). When aggregated over the different occupational groups, the divergences in lifespan variation by occupational class could appear as a stagnating trend at the national level but would not explain the cross-sectional correlation between lifespan variation and life expectancy by SES in Europe.

Finally, a *stagnating scenario* could have occurred if lifespan variation stagnated over time for all socioeconomic groups (i.e., absolute differences in lifespan variation between socioeconomic groups remained fixed), despite increases in life expectancy. Such a scenario would imply that individuals with lower education faced greater lifespan variation at all levels of life expectancy. This could be due to persisting differences in environmental conditions, lifestyle and behavior, or the psychosocial environment. Brown et al. (2012) noted that over the course of the twentieth century, the widespread expansion of education and health care led in part to the redistribution of deaths from younger to older ages, and enhanced the ability of individuals to differentially control the length of their lives according to their own social capacities. This theory draws from the fundamental cause framework (Link and Phelan 1995), where individuals of higher social strata always have access to greater material resources, beneficial social connections, and cutting-edge knowledge. As such, individuals of higher social strata are consistently in a better position to avoid health risks and to seek more timely and effective health interventions. Thus, although the proximate causes of inequalities in health and mortality may change over time, the differences in survival by social position persist. This scenario would be able to explain both the stagnation in lifespan variation at the country level and the inverse association between life expectancy and lifespan variation in the cross-section by country and education.

Few countries have reliable data on social differences in mortality covering several decades. We present analyses of Finnish longitudinal data linking population registers with a mortality follow-up using unique personal identification codes. The data include a consistent measurement of socioeconomic characteristics over four decades with practically no loss to follow-up.

Finland is a country characterized by egalitarian-oriented social welfare policies. The 40 years under analysis were marked by mostly steady economic growth, apart from a particularly bad recession during the early 1990s, which was followed by rapid economic growth fed by a boom in high-skilled industries. The economic and welfare state policy restructuring following the recession particularly adversely affected the lower economic strata, who have since faced increasing job insecurity, long-term unemployment, and social exclusion (Hamnett 1996). This restructuring was also shown to coincide with stagnating mortality among the lower income quantiles (Tarkiainen et al. 2013).

Cross-national comparisons from the 1980s onward show that Finland is characterized by average to large social differences in mortality (Mackenbach et al. 2008). In particular, despite contextual differences, broadly similar social differences in mortality are observed in Finland and the United States at a roughly comparable level of life expectancy (Elo et al. 2006; Kohler et al. 2008). Therefore, we believe that the results obtained using the Finnish data can provide insight and inform future analysis of trends in lifespan variation in other high-income countries of North/Western Europe and North America.

Data and Methods

Data

Our analytical data consist of death and exposure counts by age (31–99+), sex, occupational class, and cause of death, covering the 1971–2010 period in Finland. The data set is based on individual-level register data of all Finns that are linked to death records by means of personal identification codes in the period 1971–2010. The data were organized in eight subsets based on census and population registration information for years 1970, 1975, 1980, 1985, 1990, 1995, 2000, and 2005. These records were linked with cause-of-death records for periods 1971–1975, 1976–1980, 1981–1985, 1986–1990, 1991–1995, 1996–2000, 2001–2005, and 2006–2010, respectively. Immigrants were dropped because we did not have any baseline information on occupational class, and emigrants were censored at emigration because their death records after emigration may be missing.

These individual-level data were then aggregated by sex, year, occupational class, and age by Statistics Finland before being delivered to the researchers. In each year, person-days and deaths were allocated to one-year age intervals between exact birthdays. The overall death rates and occupational class differences in mortality obtained from these data are the same as those published elsewhere (e.g., Martikainen et al. 2001; Valkonen 1993).

Occupation-based SES was measured at the time of each census, updated every fifth year. Four groups were distinguished: (1) upper nonmanual (e.g., doctors and teachers), (2) lower nonmanual (e.g., shop salespersons, nurses), (3) manual worker (e.g., construction workers, bus drivers, cleaners), and (4) other. The last group comprises farmers, entrepreneurs, students, and those whose occupational status was unknown. The classification is retroactive for pensioners and unemployed persons; and for those whose occupational status was unknown, information was retrieved from earlier censuses. Those whose main activity was household work were classified according to the occupation of the head of the household. With internationally high labor force participation rates for women,[4] both women and men are mainly allocated to socioeconomic classes on the basis of their own current or previous occupations. Socioeconomic status becomes relatively stable at age 30 or so (Bihagen et al. 2010; Breen and Jonsson 2007), and in these data, about 80 % of men and women aged 40–45 were in the same category in a 10-year follow-up.

We considered four major cause-of-death categories: circulatory diseases, neoplasms, external causes, and other causes. Circulatory diseases were included because of their obvious importance in mortality decline over the time frame examined. We considered neoplasms because a high contribution from this cause might signal a strong role from smoking-related causes. Finally, external causes are known to be socially patterned and relatively high in Finland (Kunst et al. 1998). These causes were grouped from Statistics Finland's 54-class cause-of-death categories that have been harmonized over the different versions of the International Classification of Diseases (ICD).[5] The high quality of the cause-specific death register in Finland has been demonstrated in international comparisons of death registration (Mathers et al. 2005).

Because of the small size of some of these occupational subgroups, data were aggregated over five-year time intervals to increase the statistical power of the life table estimates used in all analyses. This aggregation lowered the 95 % confidence intervals around the remaining life expectancy of the smallest subpopulation from about ±0.6 years to ±0.3 years[6] and led to smoother age-at-death distributions. The proportion of the population, the number of person-years, and the deaths from each of the four causes per period and occupational class are presented in Tables S1 (for men) and S2 (for women) in Online Resource 1.

Life tables were constructed by the methods described in the Human Mortality Database (Wilmoth et al. 2007) for each five-year period, sex, and occupational group. This included smoothing observed death rates from the age at which the male death counts in the smallest occupational group (upper nonmanual) first fell below

[4] For example, in the 1990s and early 2000s, only about 12 % of women aged 30–35 were household workers (Haataja 2006).

[5] Details are found online (http://www.stat.fi/til/ksyyt/2005/ksyyt_2005_2006-10-31_luo_002_en.html)

[6] Confidence intervals were estimated by bootstrapping using Monte Carlo simulation methods, assuming a binomial distribution of death counts.

100 deaths by fitting a Kannisto model (Thatcher et al. 1998). For each five-year period, the same ages were smoothed for both sexes and all occupational classes. This also made it possible to extend the upper age limit from 99+ to 110+. By smoothing, we compromised information on causes of death among the elderly. However, at these ages, the interaction of multiple underlying causes of death makes determining a single cause less reliable (Manton 1986; Minaker and Rowe 1985). Thus, we do not carry out any cause-of-death comparisons over ages where mortality was smoothed, ranging from age 80 in the first period to age 94 in the last.

Measurement of Lifespan Variation

Lifespan variation was measured using the life disparity conditional on survival to age 31 index ($e_{31}^{\dagger}$) (Vaupel and Canudas Romo 2003; Zhang and Vaupel 2009). Life disparity is the sum of remaining life expectancy at each age, weighted by the number of deaths at that age:

$$e_{31}^{\dagger} = \frac{\int_{31}^{\omega} f_x e_x dx}{\ell_{31}}, \tag{1}$$

where f_x is the life table death density at age x; e_x is remaining life expectancy; ℓ_{31} is survivorship at the starting age of the integral (here, 31 years); and ω is the open-aged interval, which is 110+ in our case.[7] Age 31 was the earliest age available in our data set. It is an age young enough to capture most of the early-adult mortality yet old enough to contain useful information on occupational class.

Life disparity can be interpreted either as the average years of life lost to death or, alternatively, as the average remaining life expectancy at death. When death is highly variable, some individuals will die well before their actuarial expected age at death, contributing many lost life-years. As individuals survive to more similar ages, the difference between the actual age at death and the expected remaining life years diminishes, and life disparity becomes smaller. If everyone were to die at the same age, remaining life expectancy would be zero, and hence $e_{31}^{\dagger}$ would equal zero as well.

We used life disparity because of its easy demographic interpretation and because it can be divided into additive age components. This allowed us to separate the contributions of ages that compress mortality from ages that expand mortality. The threshold age separating these two components can be determined analytically, by methods that Zhang and Vaupel (2009) developed. In recent years, this index has become a popular option for measuring lifespan variation (Beltrán-Sánchez and Soneji 2011; Kibele 2012; Nusselder and Mackenbach 1996; Popham et al. 2013; Shkolnikov et al. 2011; Vaupel et al. 2011; Zhang and Vaupel 2009).

Life disparity is also related to a commonly used index in public health research: the person-years of life lost because of death up to a certain age from a certain cause (PYLL). Many variants of PYLL have been proposed over the years, most often examining the PYLL up to age 65 or 70. An earlier variant instead proposed using the

[7] These calculations were also performed for each period. For notational simplicity, we dropped the subscript t denoting time.

remaining life expectancy at the age when death occurred (Dublin and Lotka 1949; Greville 1948; Horm and Sondik 1989). Under this definition, the sum of PYLL from all causes of death is exactly $e_x^\dagger$. Thus, although PYLL is usually conceived as a measure of premature mortality, it can also be thought of as the contribution of a certain cause of death to the total variation in lifespan.

Finally, life disparity is the numerator of Keyfitz's life table entropy measure H (Goldman and Lord 1986; Vaupel 1986; Vaupel and Canudas Romo 2003), which Keyfitz himself noted was related to lifespan variation (Keyfitz 1977). The H measure gives the proportional response in life expectancy to a proportional change in mortality.

Compared with other indices of lifespan variation examined over adult ages, life disparity is sensitive to changes in mortality at later ages (Shkolnikov et al. 2011; van Raalte and Caswell 2013). Use of another measure would probably show wider differences in lifespan variation by occupational groups given that socioeconomic inequalities in lifespan variation tend to be driven by differences in early-adult mortality to which life disparity is less sensitive (van Raalte et al. 2011). However, the high correlations between measures of lifespan variation mean that broad conclusions would likely be the same regardless of the measure chosen (van Raalte and Caswell 2013; Vaupel et al. 2011; Wilmoth and Horiuchi 1999).

Lifespan Variation at Early and Old Ages

Zhang and Vaupel (2009) showed that so long as $e_x^\dagger$ at a given age is less than remaining life expectancy at that age, there exists one unique age ($a_x^\dagger$) that separates deaths that compress the age-at-death distribution from deaths that expand this distribution. Using our starting age of 31, we then define *early-adult* mortality as deaths occurring before age $a_{31}^\dagger$, with deaths occurring after this age defined as *old-age* mortality. Under these definitions, a death considered to be early-adult will differ depending on the underlying mortality conditions. Intuitively, this makes sense: when mortality is low, deaths at (for example) age 70 are more unusual and early than in middle- and high-mortality populations which more commonly experience deaths at age 70 and younger.[8] Generally, the threshold age sits just below the life expectancy (Vaupel et al. 2011). We divided $e_{31}^\dagger$ into its additive early-adult and old-age components to see which component was driving the changes to lifespan variation.

The close correspondence between lifespan variation and life expectancy has led some to argue that one should be examined within the context of the other (Smits and Monden 2009). For this reason, we not only compared lifespan variation over time but also at similar levels of remaining life expectancy, regardless of the time period in which it happened.

[8] However, this definition also means that early-adult deaths are different across social groups within a country so that some deaths that are considered old-age among the lower social classes are early-adult among the upper classes. Thus, we consider "early-adult mortality" to be a technical definition and not to have any normative meaning.

Decomposing a Difference in Lifespan Variation by Age and Cause of Death

We decomposed a difference in $e^{\dagger}_{31}$ by single year of age and cause of death by stepwise decomposition (Andreev et al. 2002; Shkolnikov et al. 2011) using the Visual Basic for Applications (VBA) program developed by Shkolnikov and Andreev (2010). This general decomposition method can be applied to changes in any aggregate measure (including e_{31} and $e^{\dagger}_{31}$) that depend only on the vectors of age-specific death rates, $\mathbf{M}$ and $\mathbf{M}'$, from the two populations being compared. $\mathbf{M}$ itself is simply all-cause mortality, or the sum of age-specific death rates m_x for all n of the i underlying causes (external, circulatory, neoplasms, or other):

$$\mathbf{M} = \left[\sum_{i=1}^{n} m_0^i, \sum_{i=1}^{n} m_1^i, \ldots, \sum_{i=1}^{n} m_\omega^i\right]. \tag{2}$$

We stepwise replaced each m_x^i with that of the comparative population $m_x^{i\prime}$, and recalculated $\mathbf{M}$, e_{31}, and $e^{\dagger}_{31}$ to determine the contribution, δ_x^i, from each elementary age interval $[x, x + 1)$ for cause i.[9]

We decomposed both differences over time for each occupational class as well as differences between occupational classes at the same level of remaining life expectancy. This allows us to determine whether the same age groups and causes of death that were driving differences over time were also driving differences between occupational classes at a given mortality level.

Results

Comparisons Over Time

Figure 1 shows the life table age-at-death distributions conditional on survival to age 31 by occupational class and sex in 1971–1975 (the first period) and 2006–2010 (the last period). For all occupational categories and for both sexes, the distribution of deaths as a whole has moved to higher ages, suggesting that life expectancy increased in all groups. However, for both men and women in the manual class, a considerable lingering left tail of the age-at-death distribution is seen despite the overall shift to the right. In contrast, visual inspection of the age-at-death distributions suggests that upper nonmanual workers experienced a marked compression in the distribution of mortality while early-adult deaths declined. The change for the lower nonmanual groups appears to be between the manual and upper nonmanual groups.

Figure 2 shows the time trends in remaining life expectancy and life disparity at age 31 by occupational class for men and women. The results shown in Fig. 2 confirm what visual inspection of the age-at-death distributions shown in Fig. 1 suggests. Remaining life expectancy at age 31 increased for all occupational classes for both men and women

[9] Small differences can arise when choosing to replace m_x^i with $m_x^{i\prime}$, or vice versa. Thus, we performed the same procedure in reverse and averaged the elementary contributions from each age and cause, as suggested by Shkolnikov et al. (2011).

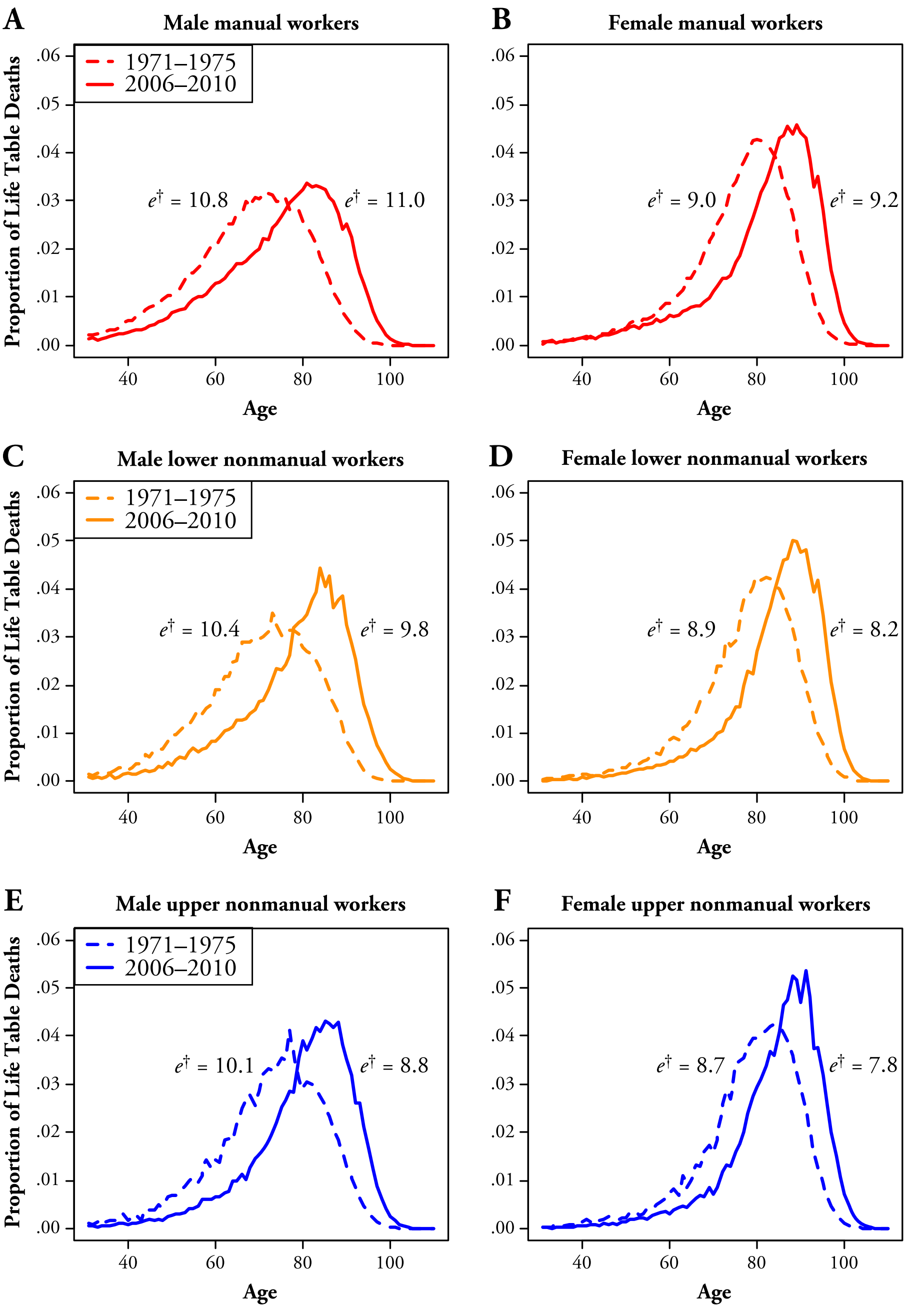

Fig. 1 Life table age-at-death distributions conditional on survival to age 31 in 1971–1975 and 2006–2010 by sex and occupational class, Finland

in an almost parallel linear manner over the last 40 years (Fig. 2, panels A and B), with some increase of differentials, given that the pace of increase was somewhat faster in the higher occupational classes. Lifespan variation, however, showed strongly diverging

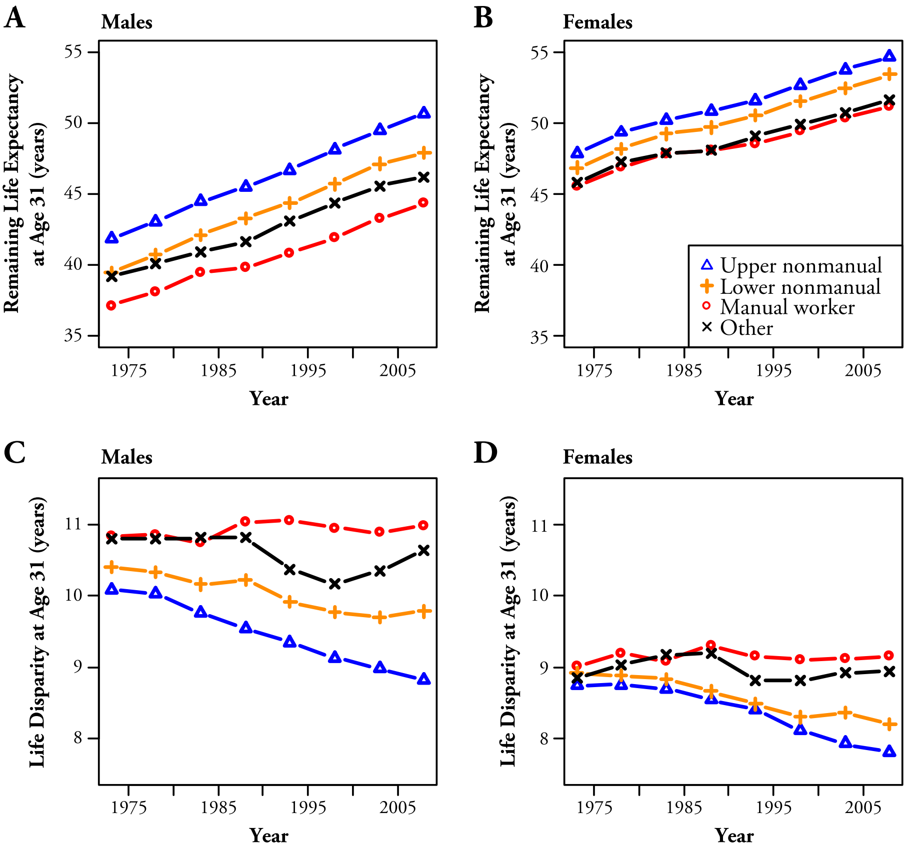

Fig. 2 Trends in remaining life expectancy (upper panels) and life disparity (lower panels) at age 31 by sex and occupational class, Finland, 1971–2010

trends by occupational class (Fig. 2, panels C and D). Among males, the upper nonmanual class experienced adult mortality compression during the entire period of study, and the lower nonmanual and other class experienced mixtures of stagnation and compression. The manual class showed no reduction in lifespan variation over the period. Among females, mortality compression was less pronounced. The manual class experienced stagnation, and the other classes experienced a mixture of stagnation and compression.

Figure 3 shows trends in early-adult and old-age components of life disparity. The figure shows that the diverging trends in lifespan disparity were entirely driven by early-adult mortality. Among both men (panel A) and women (panel B), the early-adult component of lifespan variation slowly decreased for upper nonmanual workers, increased sharply for manual workers, and occupied varying intermediate positions for the other two subgroups. The old-age component of lifespan variation, however, decreased over the time examined in all occupational classes for both men (panel C) and women (panel D). Despite similar trends, the level of old-age disparity for men varied by occupational class, being highest for lower classes.

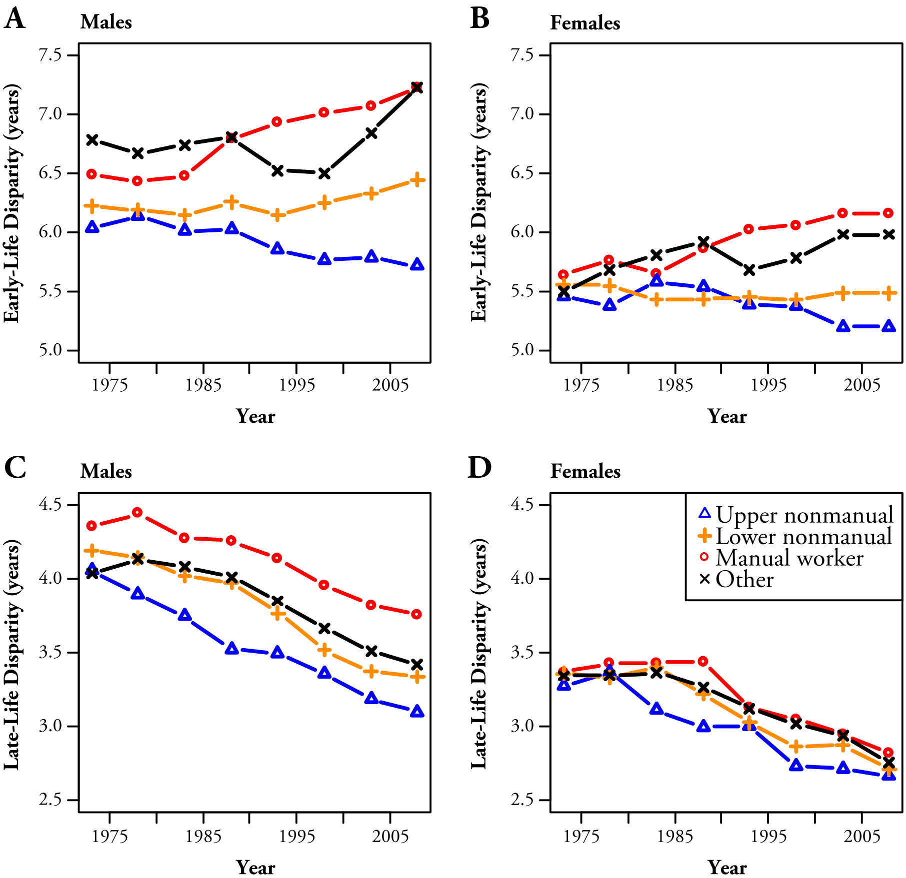

Fig. 3 Trends in early-life disparity (panels A and B) and late-life disparity (panels C and D) at age 31 by sex and occupational class, Finland, 1971–2010

Contributions of Different Causes of Death to Time Trends

Figure 4 shows what causes of death have contributed to the changing lifespan variation at different ages by decomposing the change in life disparity from 1971–1975 to 2006–2010 into age- and cause-specific components for the manual and upper nonmanual classes. Bars that are above the zero line correspond to ages at which mortality change increased lifespan variation over the observation period; bars below the zero line correspond to ages at which mortality change decreased lifespan variation. Among male (panel A) and female (panel B) manual workers, lifespan variation stagnated because the magnitude of compression in lifespan variation from reductions in early-adult mortality roughly cancelled the expansion in lifespan variation from mortality improvement at older ages. In the upper nonmanual classes (panels C and D), the early-adult mortality compression outpaced the expansive contribution from old-age mortality reduction, leading to the overall compression. Overall, the temporal changes in lifespan variation overwhelmingly came from reductions in

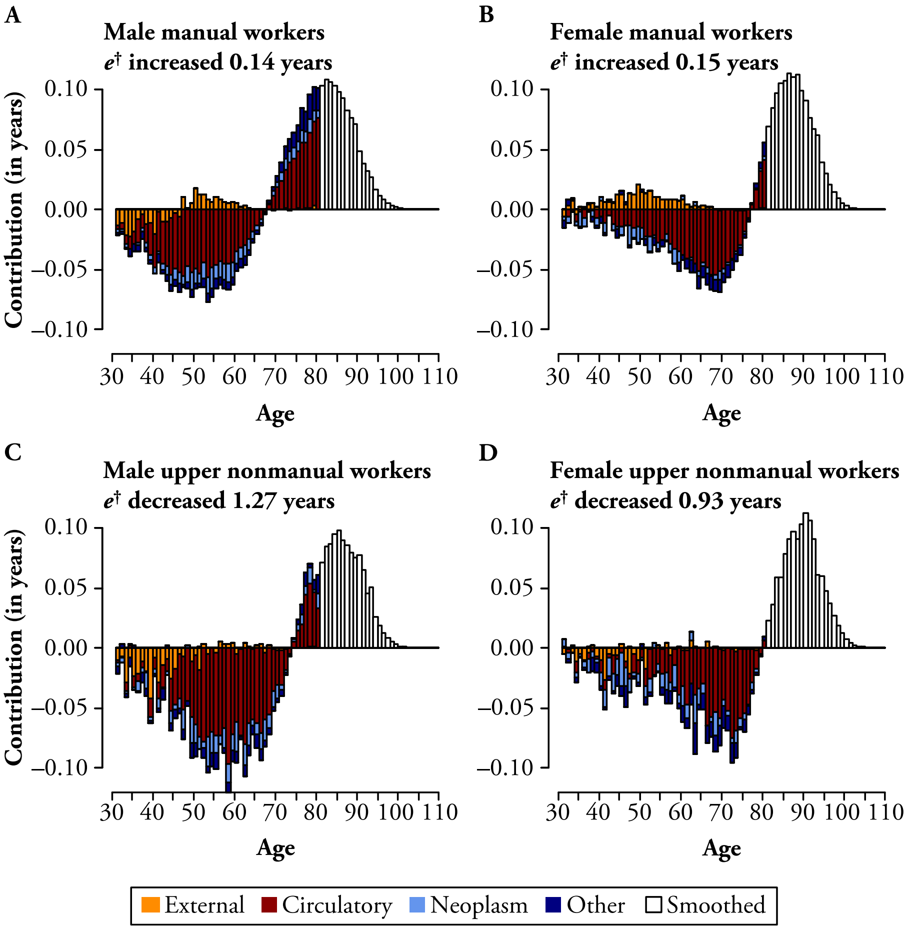

Fig. 4 The change in life disparity decomposed into age and cause-specific components (in years), from 1971–1975 to 2006–2010, by sex and occupational class. *Manual workers*: external mortality –0.05 years (males), 0.23 years (females); circulatory diseases –0.63 years (males), –0.88 years (females); neoplasms –0.18 years (males), –0.16 years (females); other causes –0.02 years (males), –0.16 years (females). A positive contribution implies that the cause of death at that particular age led to an increase in life disparity over the period and vice versa. The white bars begin at ages that were smoothed in the earlier distributions; as such, we do not estimate the contribution of different causes over these ages

circulatory diseases because this was a leading cause of death and because mortality rates dropped substantially from this cause over the time frame under examination. This effect was strongest in the nonmanual classes, owing to their later threshold age, which was above the age at which most of the effect from reductions in circulatory diseases took place, and to a greater intensity in circulatory mortality reduction at all ages. In the manual class, reductions in circulatory disease were also substantial but balanced over early-adult and older ages because of this group's younger threshold age. External-cause mortality increased the lifespan variation of the manual class over ages 40 to 70 for both men and women but contributed relatively little to the overall change in lifespan variation in comparison to other causes of death.

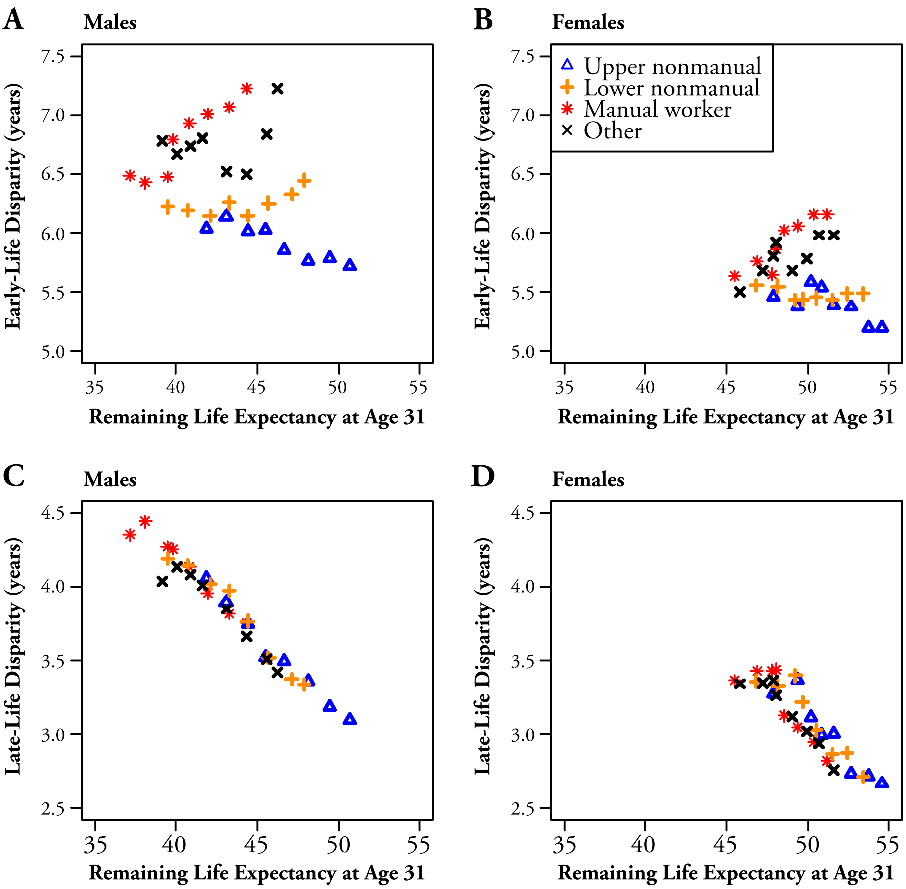

Fig. 5 Trends in early- and old-age disparity (at age 31) at different levels of remaining life expectancy (at age 31) by sex and occupational class, Finland, five-year periods, 1971–2010

Comparisons at the Same Level of Remaining Life Expectancy

At the same level of remaining life expectancy, the nonmanual occupational classes always had lower levels of lifespan variation than the manual and other classes. These differences widened over the observation period. Figure 5 shows trends in early-adult and old-age components of lifespan variation at different levels of remaining life expectancy at age 31. The figure shows that the differences in the relationship between e_{31} and $e_{31}^{\dagger}$ were driven by different levels of early-adult mortality, which widened with increasing e_{31}. On average, the manual class had an early-adult life disparity that was approximately one full year higher (males, panel A) and one-half year higher (females, panel B) than the nonmanual classes at similar remaining life expectancies. Among males, the old-age mortality patterns were astonishingly similar across all occupational groups. Among females, the nonmanual classes actually had higher older-age life disparity at each level of remaining life expectancy.

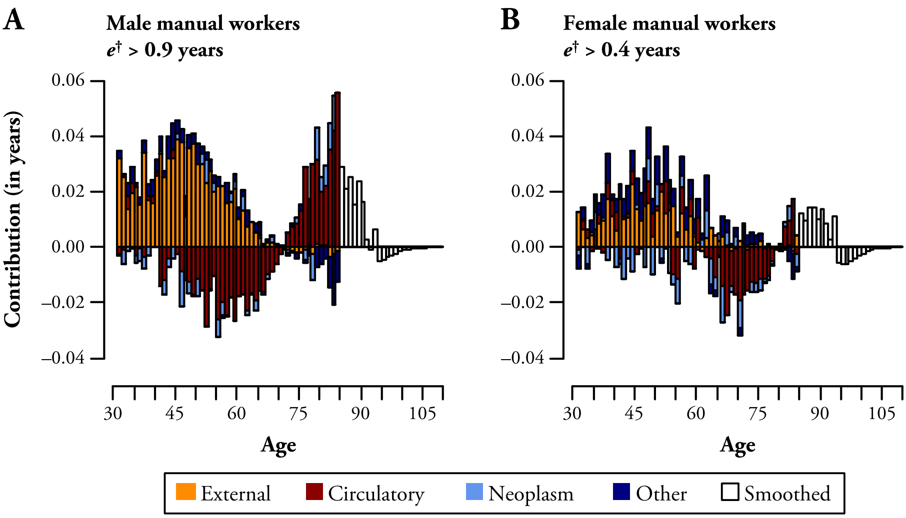

Fig. 6 Age and cause-of-death decomposition of life disparity at age 31 between the upper nonmanual and manual classes when remaining life expectancy at age 31 was similar (about 43 years for males and 50.5 years for females). The total contributions from each cause of death (up to ages where smoothing took place) to the higher lifespan variation of manual workers when compared with upper nonmanual workers: external mortality 0.78 years (males), 0.34 years (females); circulatory diseases –0.11 years (males), –0.10 years (females); neoplasms –0.01 years (males), –0.10 years (females); other causes 0.08 years (males), 0.20 years (females). A positive contribution implies that the cause of death at that particular age led to higher lifespan variation for manual workers compared with the upper nonmanual workers at this level of remaining life expectancy and vice versa

Contributions of Different Causes of Death to Social Class Differences

Next, we performed age and cause-of-death decompositions of life disparity between the manual and upper nonmanual classes when remaining life expectancy was similar but life disparity was higher for the manual classes.[10] We used the upper nonmanual class as the reference. The results are shown in Fig. 6.

Differences in external-cause mortality, especially below age 60, explained a substantial portion of the overall higher life disparity levels of manual workers. This held for males and females. For males older than 45, mortality from circulatory disease was lower for most ages in the lower nonmanual and manual classes than it was in the upper nonmanual class at the same level of life expectancy.[11] This points to strong advances against circulatory conditions that took place between when the upper nonmanual class had an e_{31} of 43 (1976–1980) and when this average mortality level was reached by the manual class (2001–2005). Overall, however, mortality from circulatory diseases had little net effect on the life disparity differences between the two classes; these declines were spread over ages that both compressed and expanded

[10] Males: upper nonmanual (1976–1980) e_{31} = 43.1 years, $e^{\dagger}_{31}$ = 10.0; manual workers (2001–2005), e_{31} = 43.3 years, $e^{\dagger}_{31}$ = 10.9. Females: upper nonmanual (1981–1986) e_{31} = 50.2, $e^{\dagger}_{31}$ = 8.7; manual workers (2001–2005) e_{31} = 50.4 years, $e^{\dagger}_{31}$ = 9.1

[11] Bars above the zero line *before* the threshold age signify that mortality from that age and cause of death was higher among manual workers than nonmanual workers. Bars above the zero line *after* the threshold age signify that mortality from that age and cause of death was lower among manual workers than nonmanual workers.

the age-at-death distribution. The pattern was less clear among females; circulatory disease mortality was higher for manual workers at the youngest ages (31–60) and lower for manual workers at older ages. Mortality from other causes, including neoplasms, was relatively unimportant in explaining the differences in life disparity between occupational classes at similar life expectancy levels.

Sensitivity Analysis

We studied the robustness of our key findings to our starting age, to our choice to stratify early/late mortality by the threshold age, and to our index of lifespan variation (results not shown here). First, we calculated early- and late-life disparity trends using the mode rather than threshold age as a separator. Use of the mode resulted in trends in lifespan variation below and above the mode that were less smooth because the mode itself changes in a less smooth way than the threshold age. However, the diverging trends by occupational class in early mortality as well as the similar trends in late-life mortality were still clearly visible. Second, we reran our analysis using a starting age of 40 rather than 31. The later starting age produced slightly larger divergences in the life disparity levels over time for the occupational subgroups, driven by sharper differences in early-life disparity. Third, we replaced life disparity with the Gini coefficient and standard deviation, both conditional on survival to age 31, in order to verify the group-level trends (i.e. Fig. 2). In all cases, the results were qualitatively similar to our main findings.

Discussion

Summary of the Main Findings

We found diverging trends in lifespan variation across occupational groupings over the period 1971–2010. The lower occupational classes experienced stagnating lifespan variation while the higher occupational classes experienced mortality compression, owing to diverging trends in early-adult mortality. Although circulatory diseases were driving trends in lifespan variation over time for all occupational classes, differences in external-cause mortality explained much of the differences between occupational classes at the same level of remaining life expectancy.

This result most closely matches the divergence scenario outlined in the Background section. In this scenario, we argued that widespread social and technological change might have resulted in changing health gains to occupational group membership, possibly exacerbated by indirect health-selective social mobility (although direct evidence for the latter is nonexistent). Consistent with this theory, we found that differences in causes of death with stronger behavioral components strengthened over time, resulting in SES-based divergences in lifespan variation.

Early-Adult and Older-Age Components of Lifespan Variation

An advantage to our study is the ability to disentangle the changes in lifespan variation by an early-age component leading to mortality compression and an old-age mortality component leading to mortality expansion. Of the two, trends in lifespan variation by occupational class in Finland were driven by the early-adult component, which is in line with most macro-level studies (Vaupel et al. 2011; Wilmoth and Horiuchi 1999). Thus, the lower occupational groups experienced increasing lifespan variation resulting from stagnation in early-adult mortality, and the higher occupational groups experienced comparatively greater reductions in mortality over ages that compress the age at death distribution.

At any given time, the nonmanual occupational classes had lower lifespan variation at old ages than the manual classes. However, the downward time trend was similar for all groups. When measured at similar life expectancy levels, the nonmanual classes did not have lower lifespan variation at these ages. The only other study to examine old-age mortality compression along a socioeconomic dimension was Brown et al.'s (2012) study of the United States, which found a positive association between education and old-age mortality compression. Unfortunately, Brown et al. were unable to examine trends in this relationship in order to determine whether the more compressed old-age mortality of the higher-educated groups was associated with their higher overall life expectancy, as we have found here for Finland.

We found no evidence of shifting mortality among males or among the middle to lower female occupational classes, using either the mode or threshold age to separate early- and late-life mortality.

Comparisons With Previous Studies of Socioeconomic Differences in Lifespan Variation

Longer-term trends in lifespan variation along a socioeconomic dimension are unknown for other countries, and only a few studies have examined this dimension in the cross-section, most of which used older data sets. Shkolnikov et al. (2003) found higher lifespan variation among lower-educated Russians (ages 20 to 65), with widening differences by educational group between the two years examined (1979 and 1989). Although the age groups are not directly comparable to our own, all subgroups in Russia experienced some early-adult mortality compression during this time, which the authors attributed to a decrease in alcohol-related mortality resulting from Gorbachev's anti-alcohol campaign. In Finland, trends were opposite during this period: the manual occupational class experienced increasing early-adult lifespan variation throughout the 1980s while the nonmanual classes experienced early-adult mortality compression.

Socioeconomic inequalities in lifespan variation have also been shown in the United States. Edwards and Tuljapurkar (2005) found a 10 % to 15 % difference in lifespan variation (ages 10+) by either income or education using 1980 data from the National Mortality Longitudinal Survey. Brown et al. (2012) conducted a more recent examination of the United States using data from the Health and Retirement Study (aggregated over 1992–2006) for the population aged 50+. Unfortunately, they calculated lifespan variation only at ages above the mode, hampering direct comparison with our study. Visual comparisons of their depicted death densities by levels of education, however, reveal socioeconomic differences in lifespan variation that are similar in magnitude to those depicted for Finland in Fig. 3. Finally, van Raalte et al. (2011) compared lifespan variation (ages 35+) in 10 European countries over the 1990s. Finland had larger socioeconomic inequalities in lifespan variation than other northern and western European countries (apart from males in Switzerland) but smaller inequalities than in eastern Europe. These larger inequalities were due in part to the large external mortality component in Finland found among younger adults.

Although little is known about socioeconomic trends in lifespan variation, a vast literature covers socioeconomic inequalities in mortality, mostly as regards adult mortality over ages that we defined here as early-adult ages. Finland had moderately high levels of educational inequality in all-cause mortality in the 1990s (Mackenbach et al. 2008), comparable to levels found in the United States (Mackenbach et al. 1999). In part, these trends could be attributed to greater widening of occupational inequalities in mortality over early-adult ages (30–74) in Finland during the 1980s. Faster declines in mortality among higher occupational groups, especially from cardiovascular diseases, drove the diverging trends (Mackenbach et al. 2003). Given that this is the age range driving changes in lifespan variation, we would also expect a greater widening of socioeconomic differences in lifespan variation to have taken place in the 1980s in Finland than in the other northern European countries.

In addition to cardiovascular disease, a higher contribution from external causes of death also played a role in the moderately high socioeconomic inequalities in Finland (Kunst et al. 1998). Binge drinking was particularly problematic (Simpura et al. 1995) and was associated with 47 % (males) and 17 % (females) of all external-cause mortality cases (Mäkelä et al. 1997). Although the high external-cause mortality in Finland among manual classes may in large part be related to its binge-drinking culture (Kauhanen et al. 1997), a socioeconomic gradient for external-cause mortality was found across Europe (Kunst et al. 1998) but was less pronounced among females (Mackenbach et al. 1999). In the United States, Edwards and Tuljapurkar (2005) found that external-cause mortality accounted for a little less than one-tenth of the total standard deviation in lifespan conditional on survival to age 10 in the United States (both sexes combined)—results that are very similar to our own. In light of these studies, we expect that external-cause mortality likely plays a larger role in Finland in explaining socioeconomic differences in lifespan variation than in other western European countries, especially at similar levels of life expectancy, but that its contribution to lifespan variation may be similar to or smaller than that in the United States and in eastern Europe.

The Contribution of Causes of Death to Socioeconomic Differences in Lifespan Variation

We are not the first to notice that between-population differences in lifespan variation in the cross-section arise from different causes than within-population differences over time. Reductions in chronic conditions, such as circulatory diseases and certain cancers, were found to have played a greater role in explaining within-country changes in lifespan variation over time than they did in cross-country or cross-sex comparisons at any given time (Shkolnikov et al. 2011; Zureick 2010).

The finding that the old-age mortality component of lifespan variation is similar across occupational classes at the same level of life expectancy is good news. Although at a higher risk from early-adult mortality, especially from external causes, those in the lower classes who survive to a certain age experience mortality processes that are similar to those of the upper classes—but with a lag. This result is consistent with speculation that much of the particularly rapid widening of socioeconomic inequalities in Finland over the 1980s resulted from the earlier uptake of coronary surgeries and new methods of treatment for cardiovascular diseases by the nonmanual classes (Martikainen et al. 2001; Valkonen et al. 2000).

Methodological Considerations

We used occupational class as our measure of SES because compared with education, there was less compositional change over the 40 years of observation. In particular, the reduction of the male manual class from 49 % to 43 % of the population was minimal. Among females, this reduction was a little stronger, from 39 % to 28 % (see Online Resource 1, Tables S1 and S2). Thus, it is unlikely that the stagnating or even increased lifespan variation over time of manual workers was due to this class becoming exclusively composed of an increasingly selected group of individuals. Nevertheless, although none of the groups experienced large changes in absolute terms, the proportion of nonmanual workers nearly doubled on a relative scale. This expansion could have led to indirect health-selective sorting, as described earlier in the divergence scenario in the Background section.

This study employed a traditional period-based approach to examine trends in mortality compression. Identifying whether temporal changes in mortality are to the result of period or cohort effects remains widely debated (Finch and Crimmins 2004; Gjonça et al 2000; Hayward and Gorman 2004; Masters 2012: Masters et al. 2012; Murphy 2010; Myrskylä 2010; Ouellette et al. 2012; Vaupel et al. 2003; Yang 2008). Although the evidence is mixed, we take the view that period and cohort studies complement one another and that both types of studies can inform policy. However, in interpreting our results, remember that this is a period setup: in each period, the occupational status of individuals was measured according to their current position (or last position before retirement). It is possible that individuals change occupational status when transitioning through the life course, although this was observed for only one-fifth of 40- to 45-year-olds, in a 10-year follow-up study using these data. Over any given period, whether individuals' mortality risks are more likely to resemble the current or future social groups to which they belong is a matter of debate. Moreover, each occupational group is made up of a mixture of birth cohorts that have experienced differences in diet, occupational hazards, and environmental exposures as well as educational systems. Compression or expansion of mortality in the period dimension will not necessarily translate into similar trends across cohorts, just as trends in period life expectancy cannot be translated to cohort life expectancy trends with certainty. With a longer time series or by forecasting incomplete cohorts, it would be interesting to examine how mortality compression is evolving for different birth cohorts along a socioeconomic dimension.

The period we studied covered several revisions to the ICD coding of disease, which can introduce breaks in the time series for certain diseases that might artificially inflate the change in contribution of certain diseases to lifespan variation over time. Any bias this might introduce should be minimal because changes are likely to be within each broad category of disease that we created rather than between categories. Likewise, we did not notice any jump in trends in moving between ICD codes. More generally, given the high quality of the Finnish data set, we expect our results and conclusions to be robust.

Our study has many advantages over other similar studies that have examined lifespan variation along a socioeconomic dimension. Unlike American studies, which have had to rely on survey data (Brown et al. 2012; Edwards and Tuljapurkar 2005), this study made use of the Finnish population registry, which included the institutionalized population and could give a more accurate profile of mortality compression or expansion among the elderly. To date, the European studies have been census-based and either examined trends between two censuses (Shkolnikov et al. 2003) or aggregated data over an intercensal period (van Raalte et al. 2011). We were fortunate to have yearly data by single year of age, which allowed us to more carefully disentangle differences in mortality compression and expansion. Finally, this study contained the longest time frame under examination and was the first to examine time trends in lifespan variation along a socioeconomic dimension in a country with continually improving life expectancy.

The social differences in mortality in Finland are similar to that observed in other high-income countries. For example, when compared with the United States, the social gradient in mortality at a roughly comparable level of life expectancy is very similar (Elo et al. 2006; Kohler et al. 2008). Other cross-national comparisons show that Finland is characterized by average to large social differences in mortality (Mackenbach et al. 2008). Therefore, future research should be directed at uncovering whether the diverging trends in lifespan variation observed in the Finnish context are also present in other high-income countries of northern/western Europe and North America.

Conclusion

Examining the variation in lifespans complements studies that monitor trends in life expectancies. That lower socioeconomic classes experience higher lifespan variation at all levels of life expectancy is a further reminder of the hardships they face. The results from this study suggest that policies to reduce lifespan variation should address the high mortality from accidents and violence of the lower occupational classes. This should be coupled with continued efforts to reduce disparities in access to new medical treatments and campaigns to discourage self-deleterious behavior.

This study shows that continued mortality compression can be compatible with increases in life expectancy, as the example of the upper nonmanual class shows. To continue to do so requires tackling the high early-adult mortality of the lower-SES groups, especially the high mortality from external causes.

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