# Increasing Mortality Dispersion in the Developed Countries:

# Aging, Epidemiologic Transition, or Other Mechanisms?

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*This paper investigates historical changes in mortality rates and mortality dispersions over the past two centuries in 15 developed countries using an integrated Hierarchical Age-Period-Cohort—Variance Function Regression Model. We find that (1) mortality rates accelerate across the adult ages among all countries except in the U.S. where mortality rates increase at a slower rate after age 90; (2) U.S. men and women have substantial lower mortality rates than other countries after age 90; (3) mortality rates substantially declined across cohorts for all countries, while they are relatively flat across time periods after controlling for confounded age and cohort effects. We also find that (4) mortality dispersions increase over the life course for all countries, but slows down at age 90 and then increases again after age 100 for some countries, e.g., the U.S; (5) compared to other nations, U.S. men and women generally had smaller mortality dispersions across all age groups, especially after age 80; (6) mortality dispersions significantly declined across cohorts born after the early 20$^{th}$ century; (7) mortality dispersions continuously declined over much of the last two centuries but have substantially increased since 1980. Further analysis suggests the recent increases in mortality dispersions are not due to increasing proportions of older adults in the population, or disproportionate delay in the deaths from degenerative and man-made diseases, but due to increasing dispersions in young and middle adults. These findings are discussed in the context of American exceptionalism, the welfare state, compression of mortality, limits to the human life span, and health disparities.*

Most developed countries have experienced substantial mortality declines and continuous life expectancy increases over the past two centuries. Initial mortality declines resulted from the decreasing mortality risks from infectious and parasitic diseases among young people as a result of exposures to better nutrition, hygiene, vaccines and medical advances. During the late 19th century and early 20th century, individuals saved from infectious disease-related deaths survived into middle and older ages when they faced an elevated risk of dying from "degenerative or man-made diseases" (Omran 1982), which caused the death distribution to progressively shift from the young to the old. Beginning in the late 1960s, the United States and other developed nations experienced unexpectedly rapid declines in mortality rates for the major degenerative diseases (e.g., heart disease, cancer and stroke) (Olshansky and Ault 1986), which caused the death distribution to further expand to the older ages.

This widespread demographic and epidemiologic transition trend is the subject of an intense debate about the consequences of mortality declines and their implications for limits to the human life span. Fries (1980) argued that increasing survival to older ages may compress the death distribution curve as human beings are close to the limit of life span. Other scholars (e.g., Myers and Manton 1984a; Engelman, Canudas-Romo and Agree 2010), however, documented an increasing mortality dispersion trend in older ages over time, which is termed as "expansion of mortality" by Rothenberg, Lentzner, and Parker (1991). Although demographers tend to infer the limit of human life span from the death distribution curve, sociologists prefer using mortality dispersion as an indicator of health disparities. This paper uses recently developed integrated Hierarchical Age-Period-Cohort Variance Function Regression (HAPC-VFR) Models (Zheng, Yang, and Land 2011) to filter variations in mortality rates and dispersions into their age, period and cohort components.

Extant studies of mortality dispersion tend to focus on two dimensions: age and period. Some scholars (e.g., Robine 2001) suggested including deaths of all age groups to calculate the mortality dispersion and examining the all-life-span mortality dispersion over time, while others found the trend of mortality dispersion over time may depend on the age groups. For example, Myers and Manton (1984b) found all-life-span mortality dispersion is negatively correlated with the level of life expectancy, but mortality dispersion over age 60 is positively correlated with the level of life expectancy. These findings are echoed in Engelman et al. (2010).

These studies, however, do not take into account the interplay among age, period and cohort in the trends of mortality dispersion. An increase in mortality dispersion across time periods may result from either cohort replacement in which cohorts with larger within-cohort mortality dispersion succeed cohorts with smaller within-cohort mortality dispersion or an aging society wherein the elderly, who usually have larger within-age mortality dispersion than younger people, increase their proportionate share in the population structure, or from some combination of the two. Similarly, a widening mortality dispersion with age may be confounded with other temporal patterns. That is, period patterns in mortality dispersion may affect age variations in mortality dispersion. And a widening mortality dispersion across age groups may also be influenced by cohort patterns.

Zheng et al. (2011) developed an integrated HAPC-VFR model that simultaneously assesses the effects of age, period, and cohort in the mean and variance of an outcome. This model embeds a Variance Function Regression model (Western and Bloome 2009) within the framework of a Hierarchical Age-Period-Cohort model (Yang and Land 2006). More specifically, this model estimates the conditional mean and conditional variance equations of the variance function regression model by treating cohort and period as random effects in the context

of a repeated cross-section survey research design across a broad range of ages—so that the question of the relative contributions of the age, time period, and birth cohort temporal dimensions to the mean and variance of an outcome variable are relevant. In the context of the present paper, the first step regression estimates variations in the conditional mean of mortality rates across age, period, and cohort, and the second step regression estimates variations in the mortality dispersions across age, period, and cohort.

Data are from Human Mortality Database which includes reliable and complete life table and time series of mortality data. Analysis is based on 15 developed countries: Australia, Belgium, Denmark, England and Wales, Finland, France, Iceland, Italy, Japan, Netherlands, New Zealand, Norway, Sweden, Switzerland, and U.S.A. Mortality data date back to 1750 for Sweden, and to mid- or late-19$^{th}$ century for most other countries. We cross-classified gender-age-specific mortality rates by 10-year period and cohort groups for each country and then applied HAPC-VFR model to each country's gender-age-specific mortality rate time-series data separately.

We find mortality rates accelerate with age over the life course for both men and women in all the countries, except for the U.S., where mortality rates increase at a lower rate after age 90. These findings suggest the deceleration of mortality increases in extreme old ages may not be a universal biological phenomenon as previously assumed (e.g., Horiuchi and Wilmoth 1998; Vaupel 1997). Mortality rates are very similar in young and middle adulthoods across countries but differences widen in older adulthood, and U.S. men and women have substantial lower mortality rates than other countries after age 90. We also find mortality rates substantially decline across cohorts for all the countries, while they are relatively flat across time periods after controlling for confounded age and cohort effects.

By comparison, mortality dispersion increases over the life course for all the countries, but slows down at age 90 and increases again after age 100 for some countries, e.g., the U.S. These findings generally support the "cumulative disadvantage" hypothesis in health disparities literature (e.g., Ross and Wu 1996; Lauderdale 2001; Lynch 2003; Dupre 2007). National differences in mortality dispersion are small during adulthood from age 40 to 80, but large at both the lower and upper ends of age range. Compared to other nations, U.S. men and women generally have smaller mortality dispersion across all age groups, especially after age 80.

Mortality dispersions are generally flat, slightly decrease, or have random variation for cohorts born before the 19th century, but significantly decline across cohorts born after the early 20th century. This is generally consistent with Myers and Manton (1984b)'s finding that mortality dispersion with all deaths included is negatively correlated with the level of life expectancy. While the Myers study pertains to a period pattern, our finding distinguishes the period and cohort components of the change.

Mortality dispersions continuously declined from the mid-18th century in Sweden and the mid-19th century in other countries. This downward trend is disturbed by two upward spikes during period 1910-1919 and 1940-1949, which may be due to WWI, 1918 influenza epidemic and WWII. Surprisingly, this long term downward trend is reversed since 1980 in all these 15 countries, which has not been documented in the extant literature.

We propose and test several possible explanations for the increasing mortality dispersion in the recent decades. First, aging national populations may contribute to this phenomenon. The elderly have larger within-age mortality dispersion than younger people, therefore increases in their proportionate shares in population structures will increase the mortality dispersion in the

whole society. We created a variable, the proportion of population age 65 and over, and entered it as an explanatory variable in the integrated HAPC-VFR model. We found this variable explained the downward period trend of mortality dispersion, but did not explain the increasing mortality dispersion in recent decades as this variable is negatively correlated with mortality dispersion. This is consistent with Myers and Manton (1984b)'s finding as the proportion of population age 65 and over is an indirect indicator of life expectancy.

Second, a disproportionate delay in deaths from degenerative diseases may contribute to the increasing mortality dispersion in recent decades. Since the beginning of the twentieth century, infectious and parasite diseases receded and degenerative diseases (e.g., cancer, heart diseases) became the leading causes of death for all the people, which narrowed the mortality dispersion. But since 1960, public health measures and medical advances have especially benefited the higher SES groups, which may have led to the increasing mortality dispersion afterwards. If this is true, we should observe an even larger increase in mortality dispersion among the elderly in recent decades as degenerative diseases tend to kill people at old ages. In order to test this hypothesis, we disaggregate the analysis by the elderly (age 65 and over) and young- and middle-aged adults (age 18 to 64). We find that mortality dispersion among the elderly decreased in recent decades in the 14 developed countries except for the U.S. which experienced a large increase in mortality dispersion since 1970. In contrast, the mortality dispersion among the young- and middle-aged adults substantially increased since 1980 among all these 15 countries. In fact, the whole period trend in mortality dispersion is driven by the trend within young- and middle-aged adults rather than within older adults.

Therefore, the recent increases in mortality dispersion are not due to increasing proportions of older adults in the population, or disproportionate delays in deaths from

degenerative and man-made diseases, but due to increasing mortality dispersion in young- and middle-aged adults. Olshansky, Carnes, Rogers, and Smith (1997) documented that re-emerging infectious diseases (e.g., HIV), which have disproportionately affected and caused death among people at different socioeconomic statuses (e.g., Rubin, Colen and Link 2009), may contribute to the increasing mortality dispersion among young- and middle-aged adults although additional explanations should be explored and examined.

We discuss these findings in the context of American exceptionalism, the welfare state, the compression of mortality, the limit to human life span, and health disparities.

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