Age-Specific Variation in Adult Mortality Rates in Developed Countries

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Epidemiologic transition and mortality dispersion

- Epidemiologic transition and mortality dispersion
  - Mortality compression (e.g., Fried, 1980; Cheung et al. 2005)
  - Mortality expansion (Myers and Manton 1984; Rothenberg et al., 1991)
- Implications for the limit of human life span
  - However, the relationship between variability of age at death and limits in human life span is indeterminate (Wilmoth and Horiuchi 1999; Wilmoth 1997)
- Implications for health disparities (e.g., Edwards and Tuljapurkar 2005)

Prior research on mortality dispersion

- Measures:
  - Standard deviation around the mean or modal age of death (e.g., Cheung et al. 2005; Myers and Manton 1984; Kannisto 2001)
  - Distance between the lower and upper quartiles of the age distribution of death (Wilmoth and Horiuchi 1999)
  - Gini coefficient of age at death (e.g., Shkolnikov et al. 2003)
- Unconditional mortality dispersion (e.g., Robine 2001) or conditional mortality dispersion (e.g., Edwards and Tuljapurkar 2005)

This study on mortality variation

- Examine variation in single-year-of-age-specific mortality rates around mean rates within age intervals (e.g., age 30-40), period, and cohort.
- More specifically, we focus on the adult ages from age 18 to the end of life, and, within this full age range, partition age into 10-year intervals.
- Within these shorter age intervals, we perform an integrated analysis of temporal trends in both single-year-of-age mortality rates and residual variation in those rates around expected values to filter variability in the single-age mortality rates and variation among the rates into their age, period, and cohort components.

Traditional measures of mortality dispersion and this new measure of mortality variation

- Different,

but both measures are related to variability in the risk of death within a population.

- MD: variability within whole population or subpopulation above a certain age;
- MV: variability within each age group, period, and cohort

- MD: calculated either from period or cohort life tables, so cannot simultaneously disentangle period and cohort effects.

- MD: look exclusively at life tables where the effects of age structure have been removed.
- MV: affected by all three temporal dimensions: age, period and cohort.

Temporal changes in mortality dispersions and implications on mortality variations

- Life course: fixed frailty or cumulative disadvantage
- Time periods: increasing life expectancy or disproportionate benefit among higher SES groups
- Cohorts: the shift from acute to chronic diseases
  - Cohort morbidity phenotype (Finch and Crimmins 2004)
  - Technophysio evolution (Fogel and Costa 1997)
  - Health disparities literature (e.g., Lynch 2003)
  - Theory of heterogeneity and mortality selection (Vaupel et al. 1979)

Data

- Human Mortality Database
- 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-19th century for most other countries.

Data (cont'd)

- Annual, single-year-of-age-and-period-specific mortality rates across the age range from age 18 to 109 with a final open-ended age 110 and over.

- In total, there are 204,414 mortality rates.

Method

- Hierarchical Age-Period-Cohort Variance Function Regression (HAPC-VFR) model (Zheng, Yang, Land 2011)

- The HAPC-VFR model simultaneously assesses the effects of age, period, and cohort in the mean and variance of an outcome by embedding a Variance Function Regression model (Western and Bloome 2009) within the framework of a Hierarchical Age-Period-Cohort model (Yang and Land 2006).

Step 1: Estimate the β regression coefficient vectors for between-group variation across age, period and cohort

Level-1 or "Within-Cell" Model:

$$MR_{ijk} = \beta_{0jk} + \beta_1 age18_{ijk} + \beta_2 age30_{ijk} + \beta_3 age40_{ijk} + \beta_4 age50_{ijk} + \beta_5 age70_{ijk} + \beta_6 age80_{ijk} + \beta_7 age90_{ijk} + \beta_8 age100_{ijk} + e_{ijk}, \quad e_{ijk} \sim N(0, \sigma^2) \qquad (1)$$

Level-2 or "Between-Cell" Model:

$$\beta_{0jk} = \gamma_0 + u_{0j} + v_{0k},\ u_{0j} \sim N(0, \tau_u),\ v_{0k} \sim N(0, \tau_v) \qquad (2)$$

for $i = 1, 2, \ldots, n_{jk}$ age-specific mortality rates within cohort j and period k;

$j = 1, \ldots, J$ birth cohorts;

$k = 1, \ldots, K$ time periods;

Step 2: Estimate the λ regression coefficient vectors for within-group variation across age, period, and cohort

Level-1 or "Within-Cell" Model:

$$\log(\sigma^2_{ijk}) = \lambda_{0\,jk} + \lambda_1 age18_{ijk} + \lambda_2 age30_{ijk} + \lambda_3 age40_{ijk} + \lambda_4 age50_{ijk} + \lambda_5 age70_{ijk} + \lambda_6 age80_{ijk} + \lambda_7 age90_{ijk} + \lambda_8 age100_{ijk}, \quad (3)$$

Level-2 or "Between-Cell" Model:

$$\lambda_{0\,jk} = \pi_0 + \omega_{0\,j} + \varphi_{0k},\ \omega_{0\,j} \sim N(0,\psi_\omega),\ \varphi_{0k} \sim N(0,\psi_\varphi) \quad (4)$$

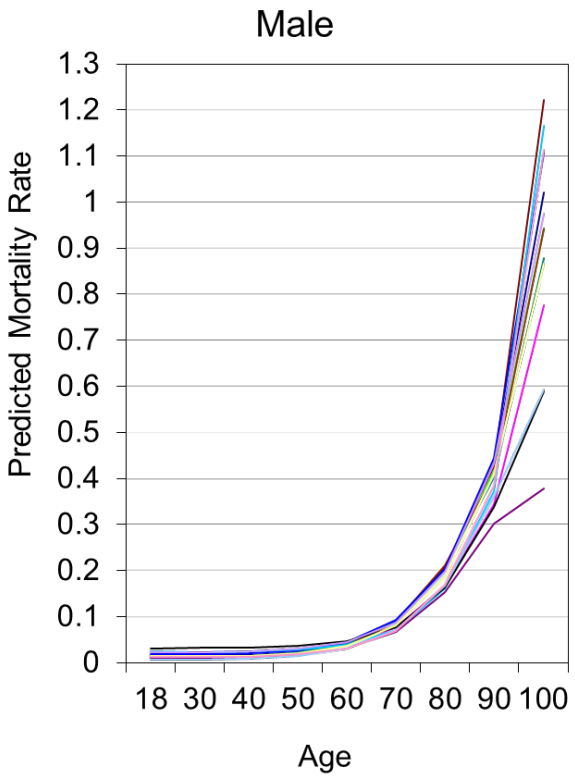
Iteration and Maximum Likelihood Estimation

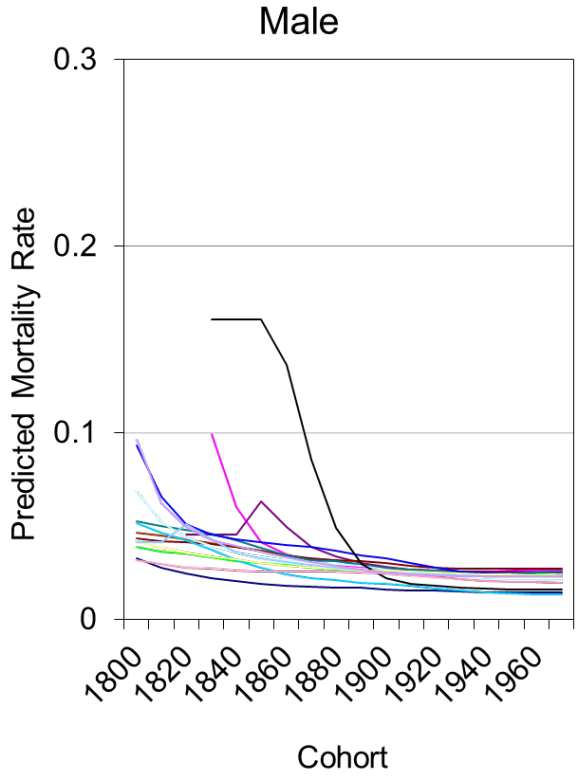
Even though each of these two steps produces restricted maximum likelihood or residual pseudo-likelihood estimators, they must be iterated in order to obtain maximum likelihood (ML) estimators:

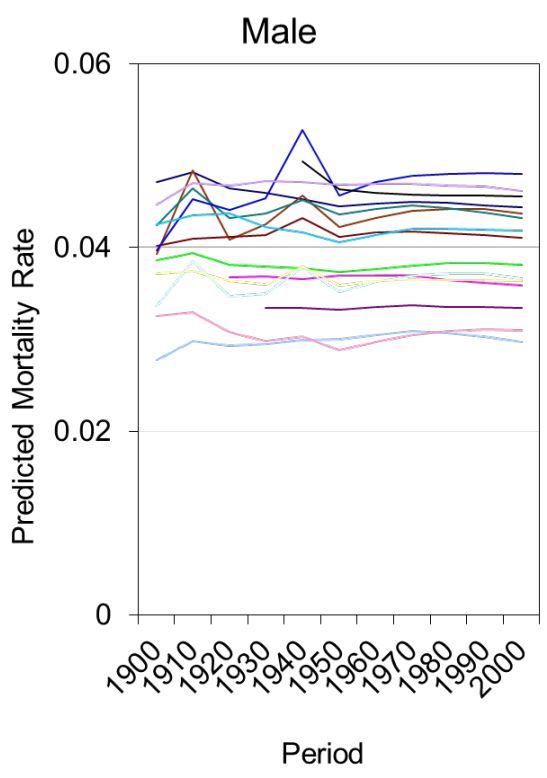
- The fitted values $(\hat{\sigma}_i^2)$ from an application of the two-steps are saved and used in a weighted regression of MR_{ijk} on age group dummies with weights $(1/\hat{\sigma}_i^2)$.

- Estimates of the residuals from Step 1 then are updated, Step 2 is computed, and so forth until convergence.

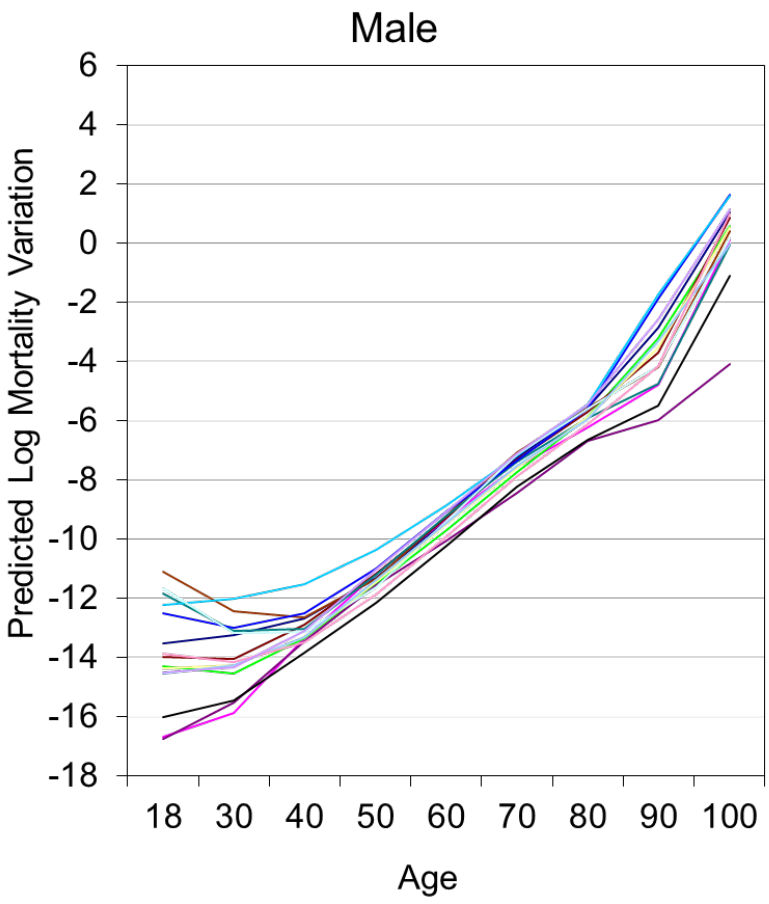
Variability in Mortality Rate across Age, Period and Cohort

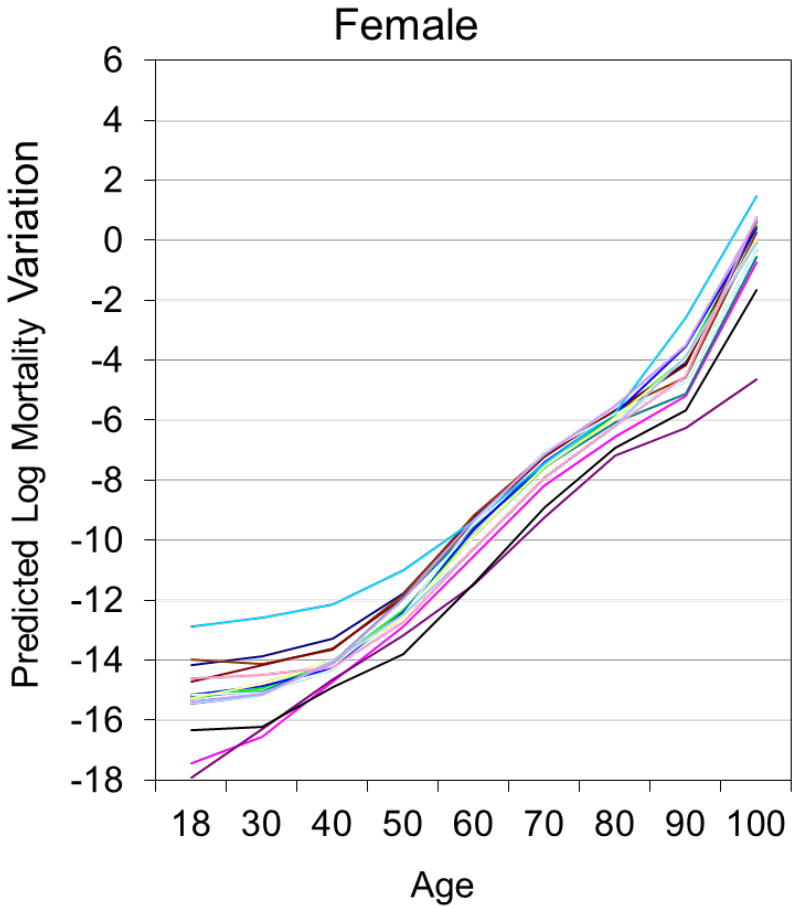




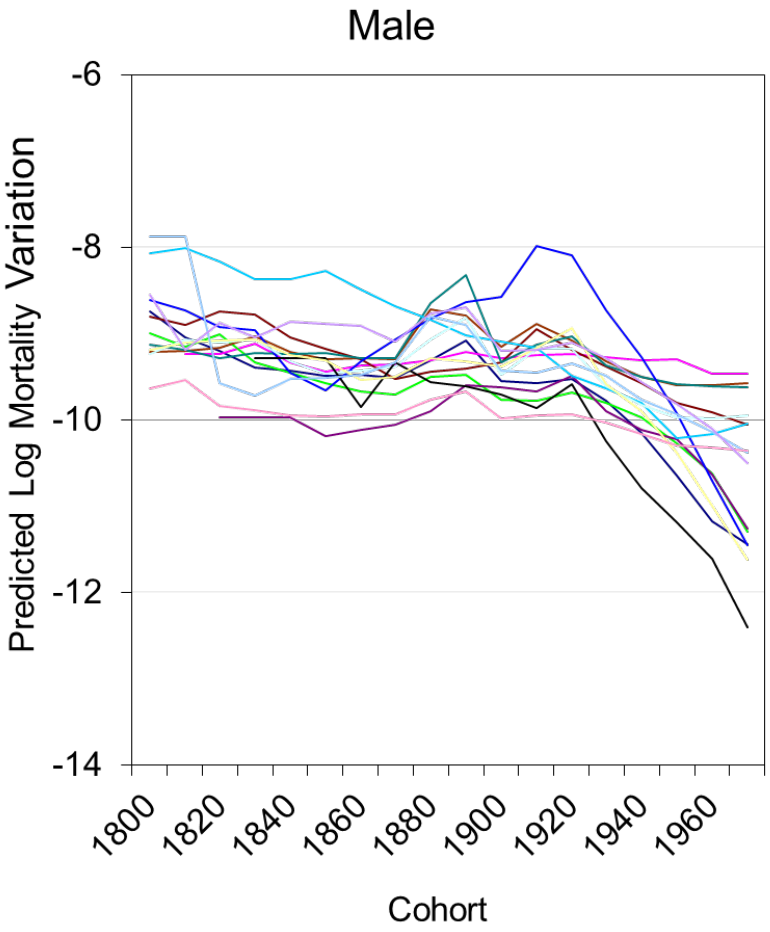


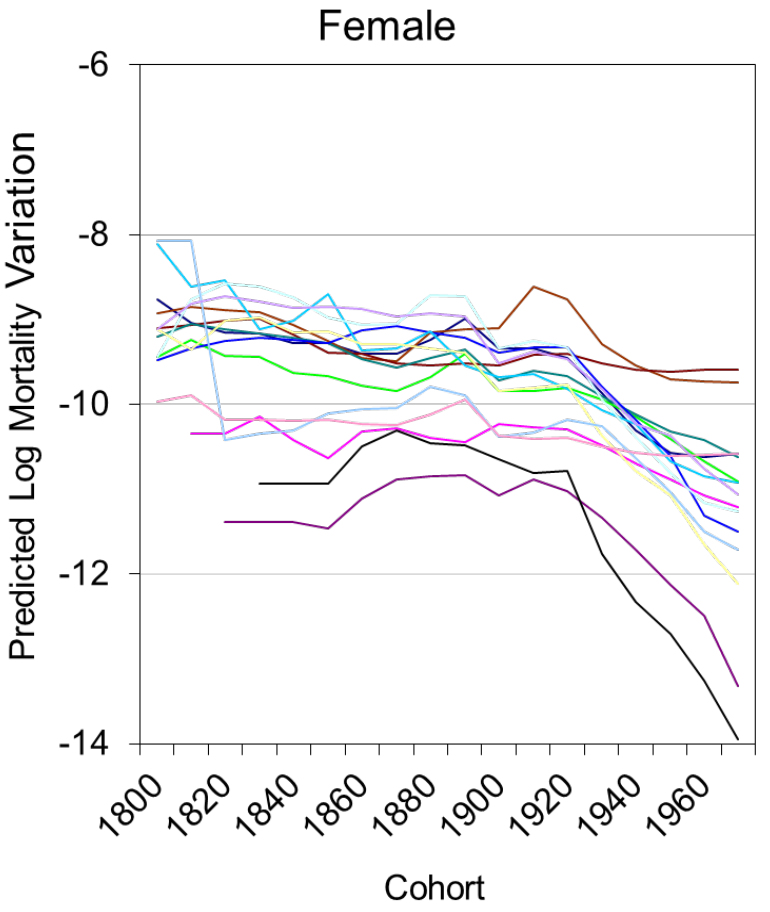
Variability in Residual Mortality Variations across Age



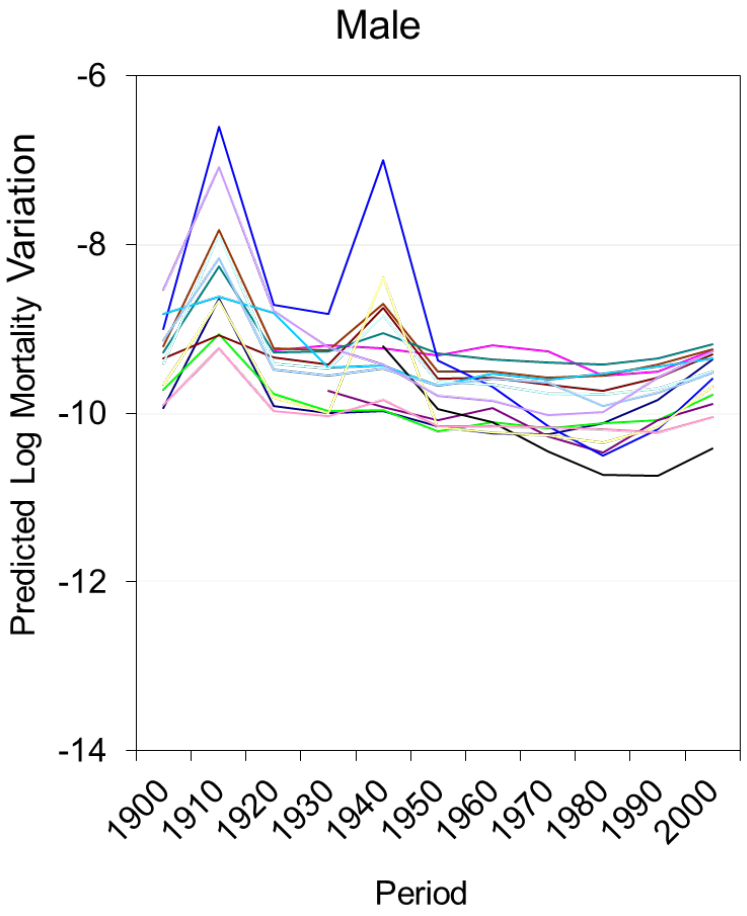


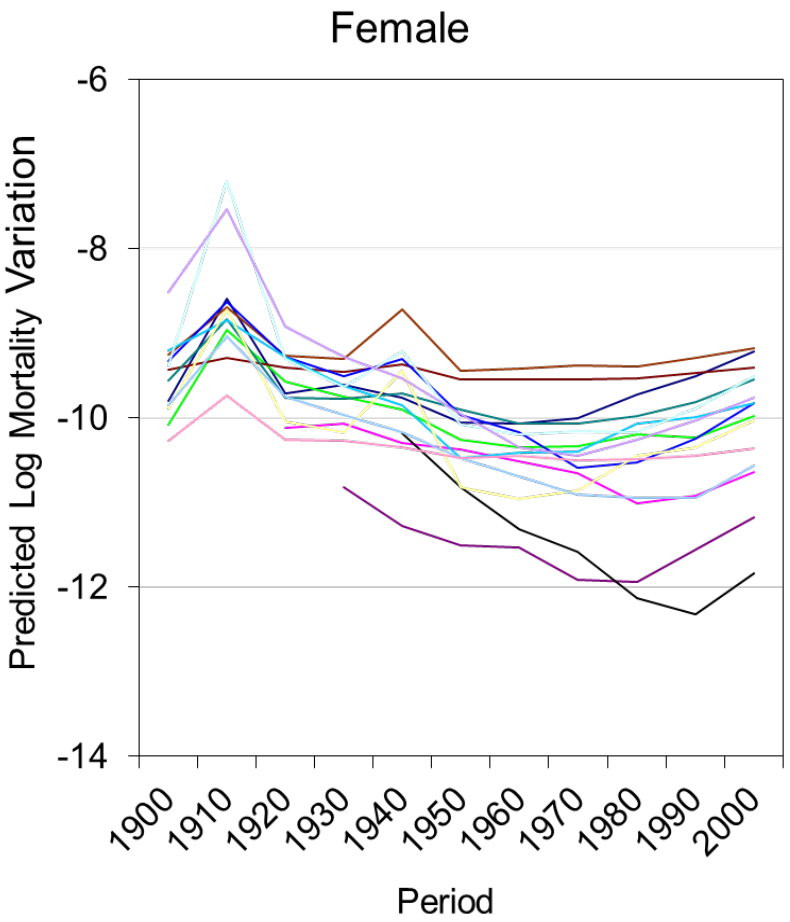
Variability in Residual Mortality Variations across Cohort





Variability in Residual Mortality Variations across Period





Why has mortality variation increased in the recent decades?

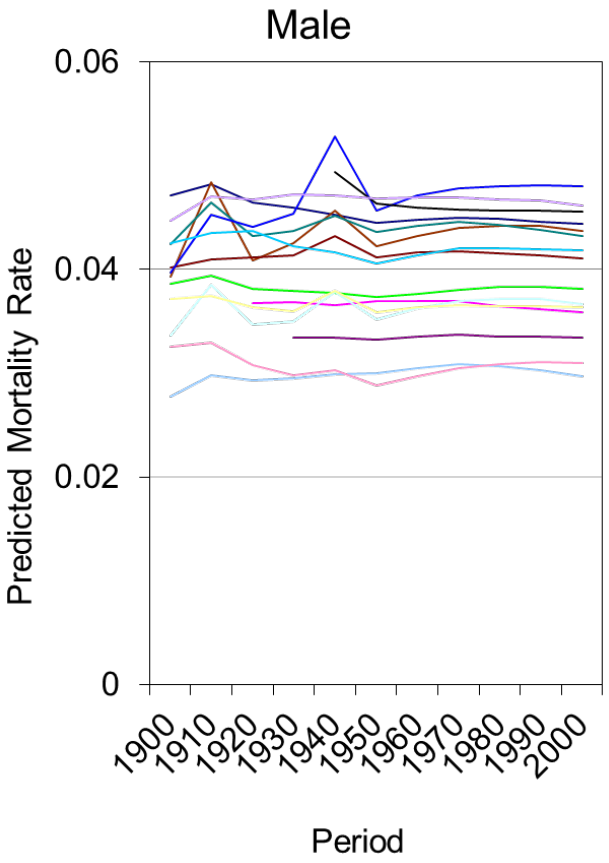
- Aging?
- The intrinsic relationship between mortality rate and mortality variation?
- Epidemiologic transition?
  - Disproportionate delay in deaths from degenerative diseases?
  - Re-emergence of infectious diseases?

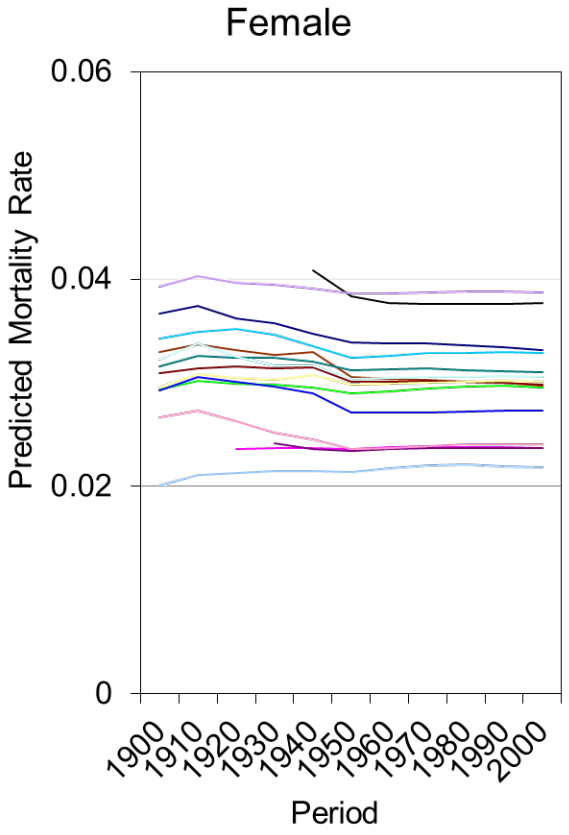
Aging?

Coefficients of the Proportion of Population Age 65 and Over on Mortality Variation by Country and Gender.

Country	Female	Male
Australia	-4.53 ***	-7.12 ***
Belgium	-13.01 ***	-12.05 ***
Denmark	-12.17 ***	-15.96 ***
England	-12.17 ***	-12.22 ***
Finland	-11.94 ***	-17.24 ***
France	-10.12 ***	-8.37 ***
Iceland	-4.75 ***	-31.53 ***
Italy	-16.79 ***	-16.50 ***
Japan	-8.12 ***	-5.02 ***
Netherlands	-3.91 ***	-1.94 **
New Zealand	-6.22 ***	-20.29 ***
Norway	-14.51 ***	-13.87 ***
Sweden	-10.16 ***	-18.75 ***
Switzerland	-24.45 ***	-36.09 ***
USA	-8.20 **	-8.69 *

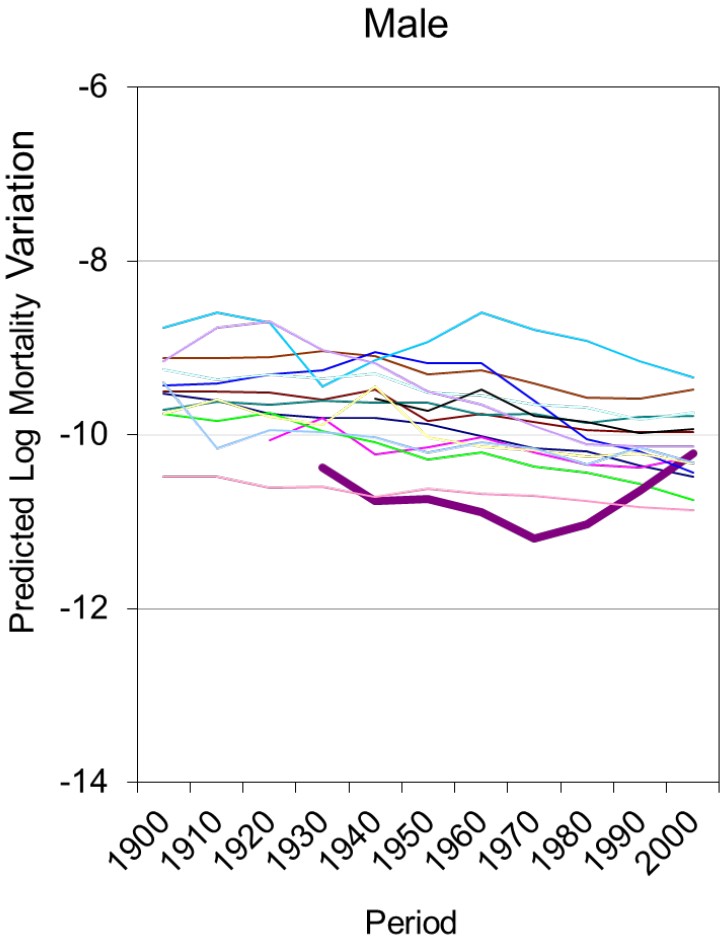
Increasing mortality rate?

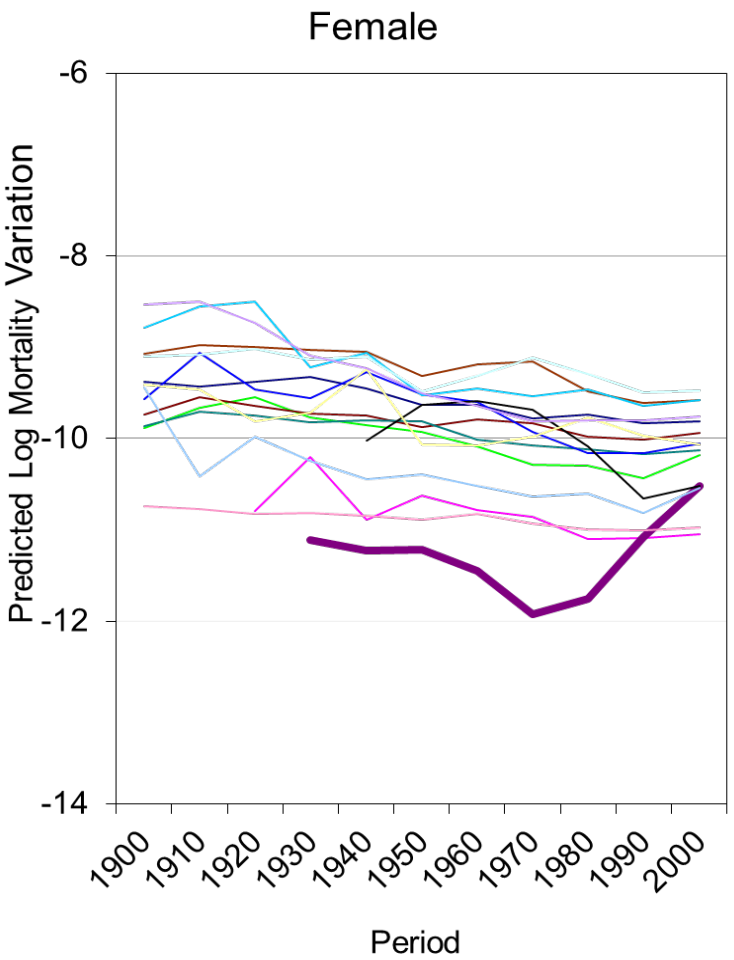




Disproportionate delay in deaths from degenerative diseases?

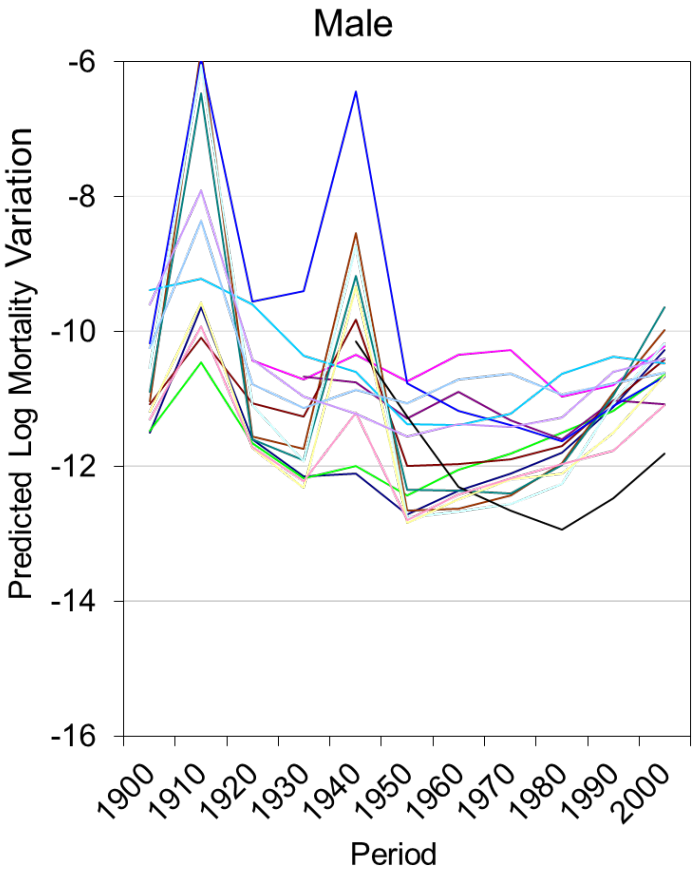
Variations in Predicted Mortality Varitions across Period for aged 65 and Older

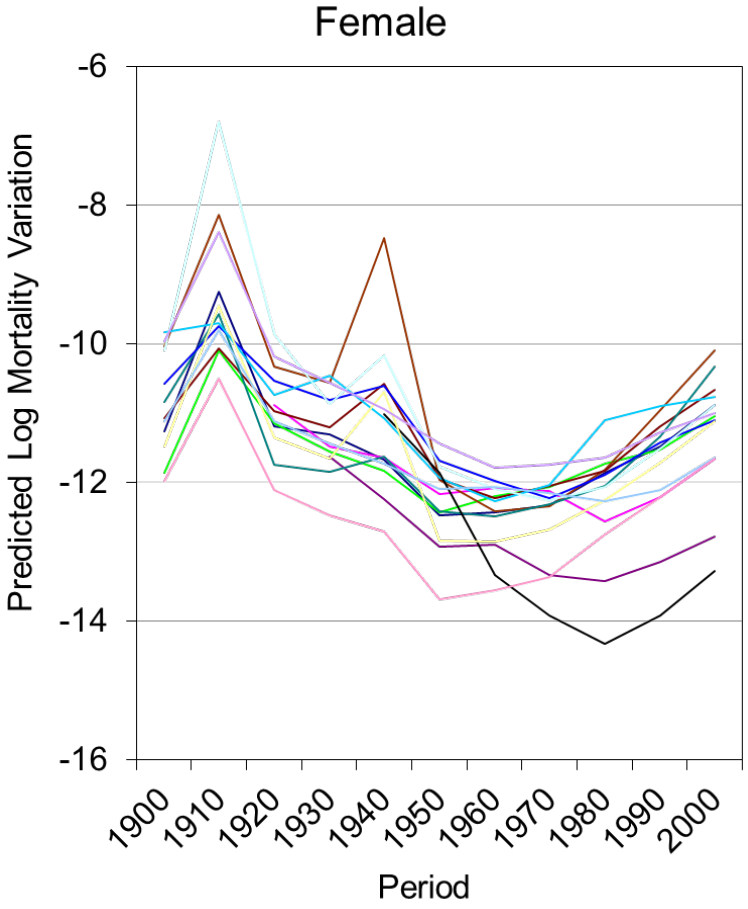




Re-emergence of infectious diseases?

Variations in Predicted Mortality Variations across Period for aged 18-64





Conclusion

- 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
- U.S. men and women have substantially lower mortality rates than other countries after age 90
- 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

Conclusion (cont'd)

- Mortality variations increase over the life course for all countries, but slow down at age 90 and then increase again after age 100 for some countries
- Mortality variations significantly declined across cohorts born after the early 20th century
- Mortality variations continuously declined over much of the last two centuries but have substantially increased since 1980

Conclusion (cont'd)

- Recent increases in mortality variations are not due to increasing proportions of older adults in the population, trends in mortality rates, or disproportionate delays in the deaths from degenerative and man-made diseases, but rather due to increasing variations in young and middle-age adults.