Patterns of Aging-Related Changes on the Way to 100: An Approach to Studying Aging, Mortality and Longevity from Longitudinal Data

Anatoliy I. Yashin
Konstantin G. Arbeev
Svetlana V. Ukraintseva
Igor Akushevich
Alexander Kulminski

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Abstract

Objective. To investigate dynamic properties of age trajectories of physiological indices and their effects on mortality risk and longevity using longitudinal data on more than 5,000 individuals collected in biannual examinations of the Framingham Heart Study (FHS) original age group during about 50 subsequent years of follow up.

Methods. First, we performed empirical analyses of the FHS longitudinal data. We evaluated average age trajectories of indices describing physiological states for different groups of individuals and established their connections with mortality risk. These indices include body mass index, diastolic blood pressure, pulse pressure, pulse rate, level of blood glucose, hematocrit and serum cholesterol. To be able to investigate dynamic mechanisms responsible for changes in the aging human organisms using available longitudinal data, we further developed a stochastic process model of human mortality and aging (Yashin and Manton 1997), by including in it the notions of "physiological norms," "allostatic adaptation and allostatic load," "stress resistance" and other characteristics, associated with the internal process of aging and effects of external disturbances. In this model, the persistent deviation of physiological indices from their normal values contributes to an increase in morbidity and mortality risks. We used the stochastic process model in the statistical analyses of longitudinal FHS data.

Results. We found that different indices have different average age patterns and different dynamic properties. We also found that age trajectories of long-lived individuals differ from those of the shorter-lived members of the age group for both sexes. Using methods of statistical modeling, we evaluated "normal" age trajectories of physiological indices and the dynamic effects of allostatic adaptation. The model allows for evaluating average patterns of aging-related decline in stress resistance. This effect is captured by the narrowing of the U-shaped mortality risk (considered a function of physiological state) with age. We showed that individual indices and their rates of change with age, as well as other measures of individual variability, manifested during the life course, are important contributors to mortality risks. The biological mechanisms, which might contribute to the age patterns corresponding to exceptional health and/or longevity are discussed.

Key Words: Mortality, Life Span, Longitudinal Data, Statistical Modeling, Healthy Aging, Survival Improvement