Mortality Trajectories at the Very Advanced Ages

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Introduction

The shape of the human mortality trajectory at the very advanced ages (e.g., 95+) is still under debates. Some studies described mortality risk in the eldest elderly as a plateau (SOA, 2000), while other suggested the existence of mortality decline, at age 105+, including analyses based on Medicare Part B claims data (Kestenbaum 1992, 2002; Manton et al. 2008). There is no methodological problems in studying the "downturned mortality" phenomenon in insect populations (Carey et al 2001), however, evaluation of mortality patterns in humans is complicated due to the problems in accuracy of reporting the age at death in death certificates and also because the confirmed survival at ages 110+ is a rare and relatively recent phenomenon (the first documented supercentenarian was registered in 1932). While not all researchers agree that death certificates are not accurate in advanced ages (Rosenwaike and Stone, 2003), the others argued that for being accurate, data required a confirmation of Medicare Part B reports by direct contact with individual (such as survey/interview) (Kestenbaum, 2002). In this study combined approach to data evaluation was used: a direct contact (survey) plus Medicare service use data. So, the data for analysis was improved compared to those used in Manton et al. (2008) by including an additional survey (the NLTCS, 2004-2005).

To analyze rich and reliable data, a model with substantively interpretable parameters should be used. Vaupel et al (1979) suggested that a gamma mixture of individual Gompertz hazard functions, producing an overall logistic for the population hazard function, could explain the mortality plateau in human populations. Later, Steinstaltz and Wachter (2005) stated that the degree of heterogeneity required for explanation of mortality plateau in a gamma mixed Gompertz hazard was too large to be plausible. Recently, Manton et al (2008) proposed a four parameter hazard function to replace the gamma mixed Gompertz, however, this four-parameter hazard models as well as several other population models could not describe the data very well—a significant bias existed in the fit in the age range 80 to 95 years. This is why in this study we proposed more flexible hazard models with six parameters which have biological interpretation and resolve the issue of bias in fit occurring at age 80 to 95.

Data

National Long Term Care Survey (NLTCS), Medicare files of Service Use, and Medical cost. The primary data to be analyzed are the six waves of the NLTCS spanning the period from 1982 to 2004/5 together with the linked Medicare data. The NLTCS uses a sample of individuals drawn from the national Medicare enrollment files. The NLTCS provides reported data on hundreds of variables including age, sex, and activities/instrumental activities of daily living (ADL/IADL) allowing for disability measurements. The U.S. Census Bureau was employed for collecting data over all waves—so, training methods and materials, survey administration and management procedures, field operations, computer processing, and editing procedures are consistent across the surveys. Together with the high (95%) response rates in all NLTCS waves, that minimizes bias in trend estimates. The 1982-2004 NLTCS files include information on 49,258 individuals with roughly 35,000 deaths observed over the 25 years of follow-up. So-called screener weights released with the NLTCS were used in this study to produce the national population estimates. All individuals in the NLTCS are continuously tracked for Medicare Part A and Part B service use. Thus, for all persons we have continuous records of Medicare service use from 1991 (or from the time the person has passed the age of 65 after 1990) until his/her time of death. These records are available for each institutional [inpatient (INP), outpatient (OTP), skilled nursing facility (SNF), hospice (HSP), or home health agency (HHA)] and non-institutional [Carrier-Physician-Supplier and durable medical equipment (DME) providers] claim type.

Methods

The strategy for empiric data analysis included several steps. First, individuals were selected for analysis (27 deaths anomalously reported as occurring before 1982 were excluded). Second, a weight for each individual was assigned to project results for the entire US population and a time period when this weight is valid for an individual was defined; several approaches using the base weights and so-called CDS weights were used. At the third step, two ages were defined for each individual, namely the age of enrollment and age of death/censoring. The age of death was obtained from the Vital Statistics file for the dead persons, and for individuals not marked as dead in the file we supposed that part of these individuals could be dead but information about the death cases was missed from the file. To resolve the issue, a set of approaches was developed to assign the censoring date (or the date of the end of follow-up) for these individuals using available information on these individuals from other sources. Specifically, we determined if one of three types of events occurred: 1) a service event in Medicare Part A (e.g. a hospitalization), 2) a payment - into Medicare Part B (i.e. monthly premiums), and 3) a payment of a monthly premium into an HMO or other managed care plan. We detected 90 persons paying Part B premiums that had no other (Part A) service use and who did not respond to the survey. The detailed analyses and comparison of mortality rates calculated for different approaches were important because they could result in essentially different age patterns of mortality rates. A specific analysis was focused on the effects of non-responders: information on them was collected using the question "Reason for non-response in NLTCS", with the possible outcomes such as "deceased" and "gone abroad".

The careful consideration of the specific groups (e.g., the 90 suspected non-responders who do not appear in Medicare Part A, but paid monthly Part B premiums) is important because of the several reasons. Their contribution is significant, and therefore, if neglected it would significantly contributes to systematical uncertainty in mortality patterns at advanced ages. Note such fraction of individuals could be plausible because roughly 2% of Part B enrolled persons do not participate in Part A benefits. Some small number of eligible individuals was not, however, covered by Medicare Part B (~2%). Additionally, some small proportion of persons would pay Part B premiums but would not be eligible for part A (~3%). A third type of program eligibility would involve enrollment in managed care plans (e.g. HMOs) when the death was recorded. All these benefit categories involve the positive actions to be recorded in the Medicare claims files. The final records are for persons who have responded to the survey which provides a direct confirmation of age reported on the Medicare claims data. All of these persons should be enrolled in the Medicare program some way, with an enrollment necessary for being selected for the NLTCS sample.

Results

Figure 1 presents the empirical results of the mortality suggesting that there is a decline with age in hazard rates at extreme ages. Figure 2 presents the various hazard functions estimated under the different alternative assumptions about data selection. The Basic Approach (marked by 0) is specified as having censoring date as a date of the latest appearance in Medicare part A (in records) or in Part B (in payments). Note, that information about payments comes from the NLTCS Denominator files, and, therefore can be less accurate. In basic approach, the non-responses, gone abroad non-responders, and died non-responders were removed. The approaches 1-5 described below are defined as the basic approach with specific adjustments as follows:

- Approach marked by 1. No cut of the 90 suspected non-responses, i.e., those individuals who are 1) alive according to vital statistics, 2) no Medicare histories, and 3) premium payments till 2005.
- Approach marked by 2. Censoring date is calculated according to Vital Statistics
- Approach marked by 3. If a reason for dead non-responders is deceased then this is the death case.
- Approach marked by 4. The same as in 3, but this is censored, not death case.
- Approach marked by 5. The gone abroad non-responders are not removed.

The sex-specific mortality rates are shown in Figure 3. The plateau in mortality rate is observed for males aged 95+. Female mortality rate declines for ages 100+. Other specific effects not shown in this abstract (but to be presented at the PAA-2011 Annual meeting) include results for stratified populations over disability and comorbidity. Moreover, the evaluated effects of time trends and the results of sensitivity analyses (e.g., effects of age misreporting) will be also presented.

Mortality models representing both genetic heterogeneity and variable rates of ageing. A broad spectrum of models appeared in literature to fit the mortality patterns at old ages were examined for a description of age patterns of mortality for total and stratified population (detailed presentation of this study will be done at the 2011 PAA meeting). Review of the results obtained using these models allowed us to conclude that the best model capable of describing the mortality age patterns is the frailty model with the Gompertz mortality function in which a correction to aging rate (i.e., the shape parameter in Gompertz model typically represented by θ) has to be made resulting in the six-parameter mortality function.

$$\mu = \frac{\alpha_1 e^{(\theta_1+(\alpha_2 Age)^{\theta 2})Age}}{\left(1+n\sigma^2 \frac{\alpha_1}{\theta_1+(\alpha_2 Age)^{\theta_2}}(e^{(\theta_1+(\alpha_2 Age)^{\theta 2})Age}-1)\right)^{\frac{1}{n}}} \tag{1}$$

The six parameters are the two shape parameters for the mixing distribution n and σ^2, the two scale parameters α_1 and α_2, and the two shape parameters θ_1, and θ_2 for the age dependency of the hazard rate. The clear difference between the standard gamma-Gompertz and the six-parameter models are in replacing θ by the function ($(\theta_1+\theta_2 Age)^{\theta_2}$). This suggests that the rate of aging itself is a nonlinear function of age and is not time/age relevant.

Many of considered models are not capable of describing mortality over ages 80-95 and only the six-parameter model does not suffer from this bias (Figure 4). Parameter estimates presented in Table 1.

Table 1. Parameter estimates and standard error for total population using the six-parameter model (1).

	$-\log(\alpha_1)$	θ	σ^2	α_2	θ_2	n
Estimate	4.16	0.100	0.24	0.013	4.14	0.81
Standard Error	0.01	0.002	0.04	0.001	0.38	0.06

From the Table 1, one can see that all parameters are highly significant and precisely estimated; θ_1 is in the range of standard Gompertz estimates (θ= 10%), n is near 1.0 (i.e. 0.84) to suggest that the initial distribution is similar to the gamma distribution and the value of θ_2 suggests that additional acceleration of the rate of aging θ_2 provides additional flexion in the base Gompertz to explain the bias for the mortality rate for ages 80 to 95.

Conclusions. The performed analyses of mortality patterns at old ages included empirical methods and applied demographic models of mortality. Empirical results shows that the increase in mortality rates is stopped at age 95 for males and 100 for females. The decline in mortality rate above these ages is detected for total and female population. The model extends the analysis reported in Manton et al (2008) to include the additional data—the range of date is extended three years including the sixth, 2004, NLTCS which had the benefit of a large over sample (N=1584) of persons aged 95+. The model is generalized to include additional parameters to remove the effects of bias on hazard rates estimated from ages 80-95 and, thereby to reduce the standard error of parameters. The model provides a more transparent biological interpretation of the hazard mechanisms operating at extreme ages. The developed model allows for the aging rate to vary over time/age so that heterogeneity is evident both over individuals (fixed frailty) and in the aging process itself.

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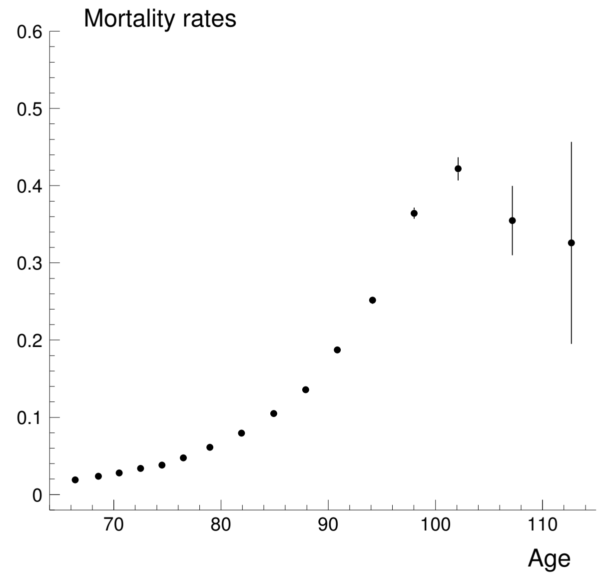

Figure 1. Results of base calculation. 49,123 individuals were selected, i.e., excluding 27 with death before 1982 and 90 non-responders (not appeared in Medicare records, alive according to vital statistics, paid premiums till 2005).

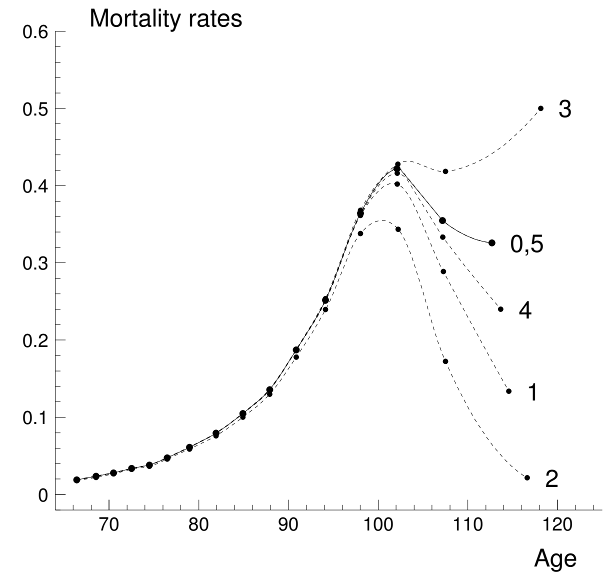

Figure 2. Results of calculation of incidence rates using base (marked by 0) and five alternative approaches (see text for details).

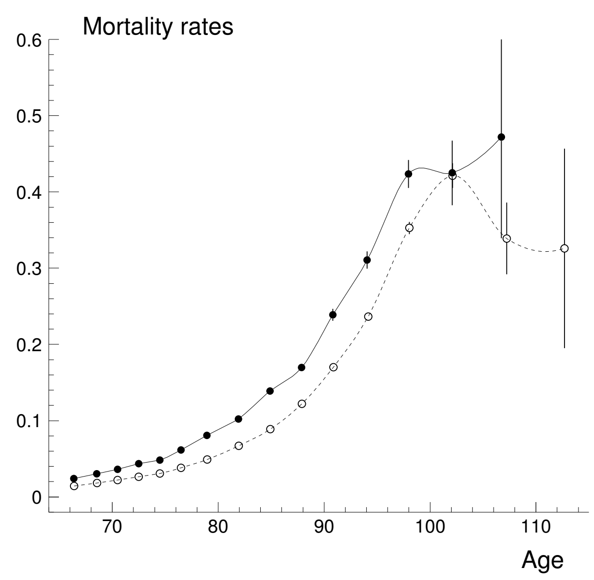

Figure 3. Sex-specific incidence rates, Closed (opened) dots correspond to female (male) populations.

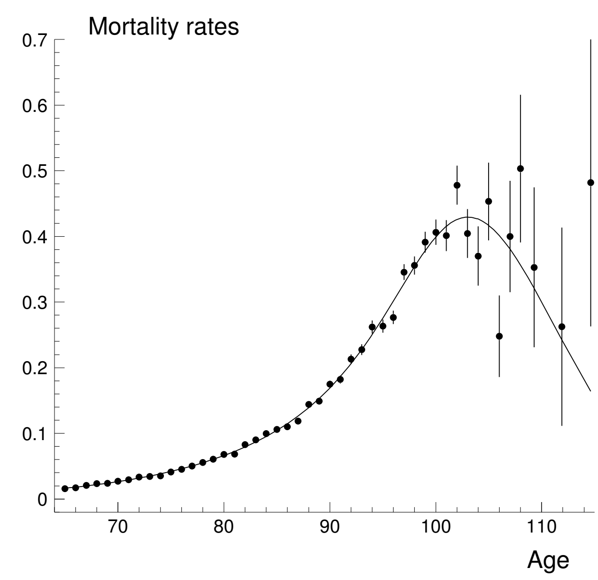

Figure 4. Empiric mortality rate (closed dots) for total population with standard errors (error bars) and the six-parameter model prediction (solid line).