The semi-supercentenarian mortality plateau in Sweden (abstract)

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1 Background

The question whether human life has an absolute upper limit or not has been in focus lately. Dong et al. (2016) claimed to have found evidence for the existence of such a limit, but their arguments were soon demolished (Lenart and Vaupel, 2017; Rootzén and Zholud, 2017). Rather, Barbi et al. (2018) confirms the conclusions of Rootzén and Zholud (2017): Life is short but unlimited. In fact, no evidence so far (mid 2018) contradicts the hypothesis that human mortality above age 105 is *constant* (albeit on a high level), that is, the aging process has come to an end at age 105.

2 Research questions

The present research concerns circumstances for Swedish centenarians the last 50 years:

- Are there differences in centenarian mortality between
  - sexes,
  - birth cohorts,
  - time periods, or
  - social groups?
- Is centenarian mortality (above age 100) constant?

3 Data

Data are extracted from the Linnaeus database (Malmberg et al., 2010), which is based on different linked national population registers from 1960 to 2013 (censuses, LISA from Statistics Sweden and cause of death registers) and is used within the aging program at CEDAR, Umeå University.

Our sample consists of all individuals in Sweden, 820 women and 136 men, who reach the age of 105 between 1 January 1976 and 31 December 2013, that

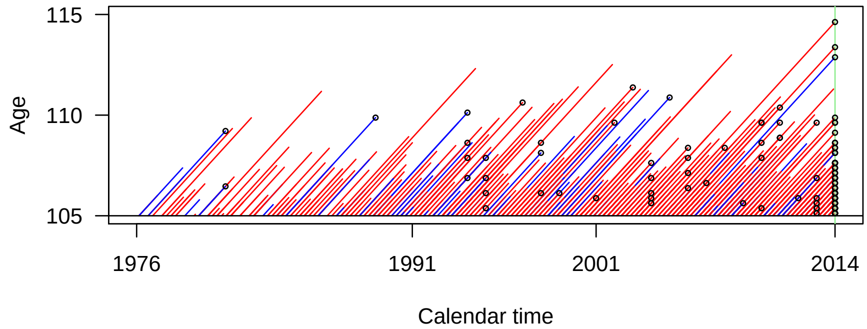

Figure 1: Swedish data: females (red) and males (blue). The small circles marks censored observations.

is, the birth cohorts 1871–1908. They are followed to death, censoring (out-migration) or 31 December 2013, whichever comes first, see Figure 1.

A comparison is made with the Italian study by Barbi et al. (2018), who kindly sold their data to us: Birth cohorts 1896–1910.

4 Models and Methods

The survival distribution of subsets of the data is estimated by both a non-parametric and a parametric model, specifically the *Gompertz* distribution with hazard function h given by

$$h(t) = \alpha e^{-\beta t}, \quad t > 0; \quad \alpha > 0, \, \beta \geq 0.$$

The hypothesis of constant hazard is tested both graphically and formally. In the informal graphical test we compare the estimated cumulative hazards for an exponential distribution with the *Nelson-Aalen* estimator, and the formal test is performed by testing the hypothesis $\beta = 0$ in the Gompertz model.

5 Results

5.1 Graphical comparison of cumulative hazard functions

From Figure 2 it is evident that the constant hazard function model (exponential survival distribution) gives an excellent fit! The slope is estimated to 0.7, which corresponds to a one-year survival probability of 0.497.

The cumulative hazards in subgroups are shown in Figure 3: Same conclusion.

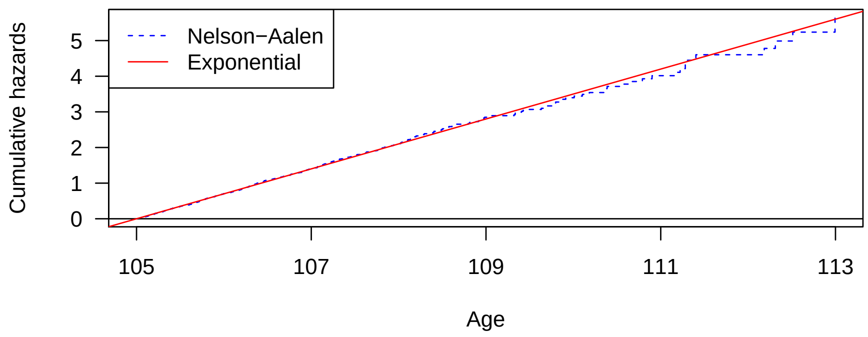

Figure 2: Nonparametric and exponential cumulative hazards estimates for the Swedish cohort consisting of those who reached age 105 between 1976 and 2004.

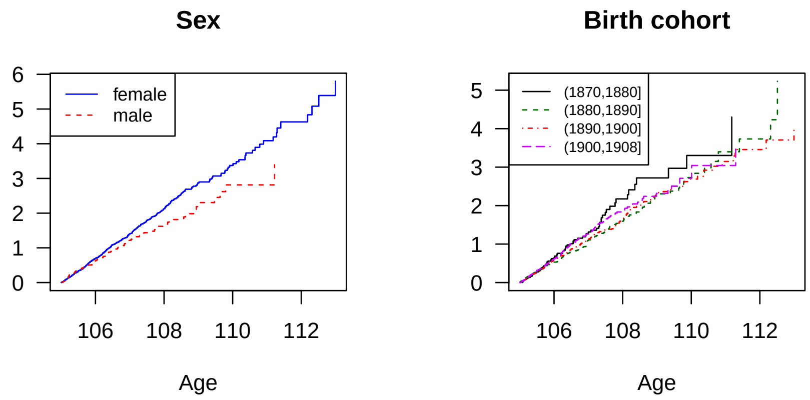

Figure 3: Cumulative hazards by sex (left panel) and birth cohort (right panel).

5.2 Formal test of constant hazard function

The formal test of constant hazard is performed by a parametric survival analysis assuming a proportional hazards model. See Table 1.

[Table 1 about here.]

The estimate of the *rate* parameter is essentially zero (-0.0055), implying an *exponential* baseline distribution. Notice also that there are no statistically significant differences in mortality in the given subgroups of *sex* and *cohort*.

6 Conclusions

The answers to the above given research questions are four *No* and one *Yes*, respectively, for *semi-supercentenarians* (age above 105). In the final paper, the results for social groups will also be added, as will the comparison with the Italian case, which shows a striking similarity with the Swedish case.

A general conclusion is that semi-supercentenarian mortality is constant, and equally distributed over subgroups. The latter statement seems to indicate that this phenomenon is *not* the result of selection effects due to heterogeneity. It must be added, though, that all these conclusions are based on *negative inference*, that is, null hypotheses that could not be rejected. When more data will be available, the conclusions may well be different.

References

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Dong, X., Milholland, B., and Vijg, J. (2016). Evidence for a limit to human lifespan. *Nature*, 538:257–259.

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Malmberg, G., Nilsson, L.-G., and Weinehall, L. (2010). Longitudinal data for interdisciplinary ageing research. Design of the Linnaeus Database. *Scandinavian Journal of Public Health*, page 1403494810382812.

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Covariate	Mean	Coef	Risk Ratio	S.E.	L-R p
sex					0.0850
female	0.8523	0	1	(reference)	
male	0.1477	-0.1774	0.8375	0.1052	
cohort					0.2541
(1870,1880]	0.0875	0	1	(reference)	
(1880,1890]	0.2222	-0.2081	0.8122	0.1340	
(1890,1900]	0.3519	-0.2134	0.8079	0.1259	
(1900,1908]	0.3384	-0.1016	0.9034	0.1245	
Baseline parameters					
rate		-0.0055	0.9945	0.0268	0.8364
log(level)		-0.3498	0.7048	0.1158	0.0025
Events	819	TTR	1398		
Max. Log Likelihood	-1254				

Table 1: Gompertz fit.