error that could arise from the indexing process is incorrect citation of origin for the authors. By using the author addresses listed in the bylines of research articles, one can only identify countries and organizations where the authors were employed when the research was done or where the article was written, or both. Whereas our bibliometric analysis results may biased toward underestimation, it is good to know that the true reality may be even more encouraging. Despite this limitation, we strongly believe that our conclusions remain valid and informed by our results. The overall positive trend of manuscripts published over time speaks to the fact that epidemiological and public health publications are on the rise in the WHO/AFRO. However, more capacity building and training initiatives in epidemiology are required to promote research and address the public health challenges facing the African continent.

Funding

This work was supported by the International Epidemiological Association (IEA) as well as the U.S. President's Emergency Plan for AIDS Relief (PEPFAR), through The Health Resources and Services Administration (HRSA) and via the Stellenbosch University Rural Medical Education Partnership Initiative (SURMEPI). Dr Jean Nachega was supported by the United States National Institutes for Allergy and Infectious Disease (NIAID-NIH), Division of AIDS (DAIDS): K23 AI 068582-01; the US PEPFAR Grant Award, T84HA21652-01-00 for Medical Education Partnership Initiative (MEPI); the European Developing Countries Clinical Trial Partnership (EDCTP) Senior Fellowship Award: TA-08-40200-021 and the Wellcome Trust Southern Africa Consortium for Research Excellence (SACORE), WT087537MA.

Reference

1 Nachega JB, Uthman OA, Ho YS *et al*. Current status and future prospects of epidemiology and public health training and research in the WHO African region. *Int J Epidemiol* 2012;**41:**1829–46.

doi:10.1093/ije/dyt051

International Journal of Epidemiology 2013;**42**:914–916

Limitless longevity: Comment on the Contribution of rectangularization to the secular increase of life expectancy

From KARIN MODIG,[1]* SVEN DREFAHL[1,2] and ANDERS AHLBOM[1]

[1]Institute of Environmental Medicine, Division of Epidemiology, Karolinska Institutet, Stockholm, Sweden and [2]Department of Sociology, Demography Unit, Stockholm University, Stockholm, Sweden

*Corresponding author. Institute of Environmental Medicine, Karolinska Institutet, Box 210, 171 77 Stockholm, Sweden. E-mail: karin.modig@ki.se

Rossi *et al.* looked at the increase in life expectancy in nine European countries, including Sweden, from 1922–2006.[1] To do this, they used a method that allowed them to separate the two respective contributions to increased life expectancy of: (i) postponement of death, through rectangularization of the survival curve; and (ii) an upward shift in the maximum age at death, as a measure of longevity. They found that both factors have contributed to the increase in life expectancy in the nine countries in their study, but that increased longevity played a relatively greater role than postponement of death. They propose that changes in life-style factors, and particularly cigarette smoking, have been essential for rectangularizing the survival curve, but they have less specific suggestions for explaining the upward shift in the age at death in the countries included in their study.

We previously analyzed mortality among Swedish centenarians in a cohort study based on individual data for all persons in Sweden who reached the age of 100 years from 1969–2009 ($n = 15\,231$).[2] In the analyses for this study we divided the data into a sequence of one-year cohorts. We used these data in an attempt to add some further insights to the findings by Rossi *et al.*

We could indeed confirm that longevity, measured as the maximum age at death, has increased steadily during the period that we studied (Figure 1), and this was also shown by others for an earlier period.[3] This corroborates Rossi and colleagues' results, although

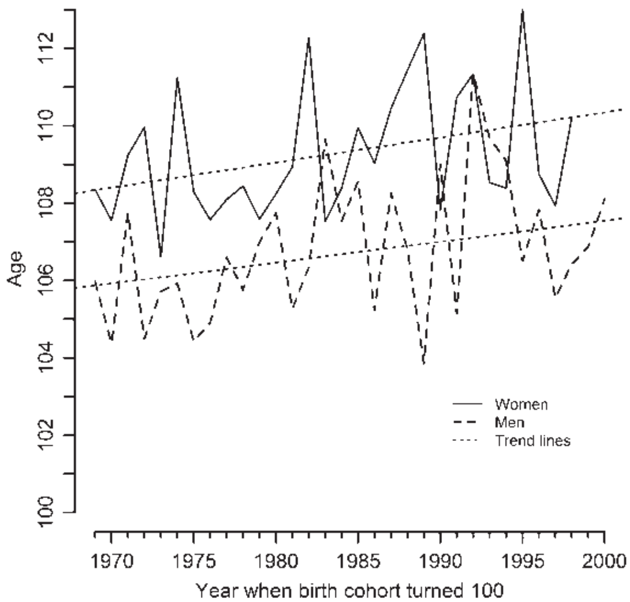

Figure 1 Highest age reached by cohort of centenarians (1969–2000)

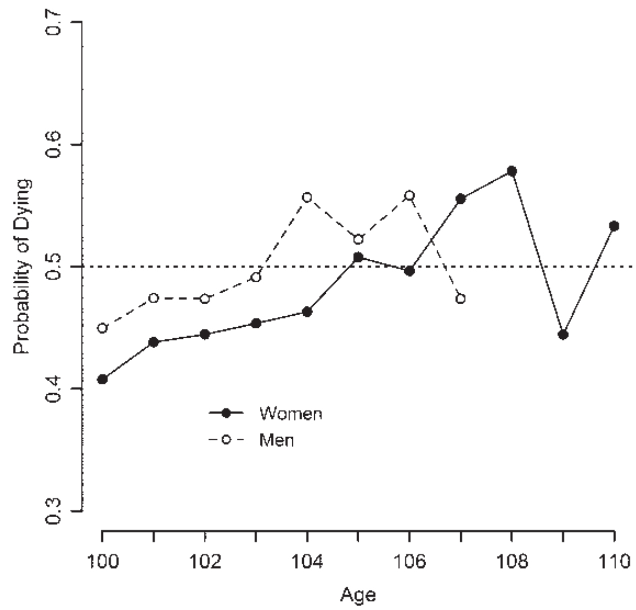

Figure 2 Probability of dying for Swedish men and women over 100 years of age (1969–2009)

their method of discrimination of the components of life expectancy leads to a slightly different definition of longevity than maximum age at death. Interestingly, however, there was no secular trend in the average age at death in our one-year cohorts of centenarians, either for males or for females.[2] The mean age at death of females was ~102 years throughout the 40-year period of the study, and about half a year less in males. This shows that the increase in maximum age at death was not caused by a decrease in mortality among the very oldest subjects in the study. Instead, the increase in maximum age at death was fueled by an increase in the number of people surviving to the age of 100 years; with a larger number of centenarians the probability that at least one dies at very old age also gets larger. A similar argument can be brought forward for the observations of Rossi *et al*.[1] Declining mortality at younger ages eventually leads to rectangularization of the survival curve and thus to a greater number of individuals reaching higher ages. However, it will also lead to an increase in Rossi and colleagues' chosen longevity measure, even in the case in which mortality rates at the higher ages have remained stable.

Furthermore, our data suggest that the age-specific probabilities of dying may level off at some point closely above 100 years, rather than continuing to increase continuously with age. At the very end of life too few people remain in the population for proper estimations, but the observed figures would be consistent with one-year probabilities of dying stabilized at a level of about 0.5 (Figure 2). Such a level would be in agreement with previous reports, and the concept of probabilities of dying leveling off at old age would be consistent with the theory of heterogeneity of mortality introduced by Vaupel.[4] At present there are no data available that allow an examination of mortality at much older ages, but such data will come. However, Gampe *et al.* have shown the leveling off of mortality after age 110 years through the use of combined data for many countries.[5] It is perhaps natural to think of mortality as something that increases continuously with age and that the probability of dying eventually reaches 100% at a certain age, i.e., at the maximum life span. If, instead, probabilities of dying level off at old age, the maximum age at death will still increase steadily as long as the population that survives to old age increases as the result of decreased mortality at younger ages. One can only speculate about the age at which the probability of dying is no longer below 100 percent (we don't even know if a limit exists) or about the period for which the maximum age of dying may increase. The negative binomial distribution applied to persons who reach 100 years of age, with the annual probability of dying as a parameter, may provide a model for consideration.

Our data are based on the Swedish experience of mortality, for which we know from official statistics that there are downward secular trends in mortality for age groups below 100 years, but as we have shown, not for age groups above this. At present we have less information about secular trends in centenarian mortality in countries other than Sweden. However, our key point, that longevity, defined as the maximum age of death, will continue to increase, is essentially independent of actual mortality trends among centenarians.

Funding

This study was funded by the Swedish Council for Working Life and Social Research (Swedish acronym: FAS). The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Conflict of interest: None declared.

References

1 Rossi IA, Rousson V, Paccaud F. The contribution of rectangularization to the secular increase of life expectancy: an empirical study. *Int J Epidemiol* 2013;**42:**250–58.

2 Drefahl S, Lundstrom H, Modig K, Ahlbom A. The era of centenarians: mortality of the oldest old in Sweden. *J Intern Med* 2012;**272:**100–02.

3 Wilmoth JR, Deegan LJ, Lundstrom H, Horiuchi S. Increase of maximum life-span in Sweden, 1861–1999. *Science* 2000;**289:**2366–68.

4 Vaupel JW, Carey JR, Christensen K *et al*. Biodemographic trajectories of longevity. *Science* 1998; **280:**855–60.

5 Gampe J. Human mortality beyond age 110. In Maier H, Gampe J, Jeune B, Robine J-M, Vaupel JW (eds). *Supercentenarians*. Heidelberg, Dordrecht, London, New York: Springer, 2010.

doi:10.1093/ije/dyt035

Published by Oxford University Press on behalf of the International Epidemiological Association *International Journal of Epidemiology* 2013;**42**:916–917

Authors' response to 'Limitless longevity': The contribution of rectangularization to the secular increase in life expectancy: an empirical study

From ISABELLE ROSSI, VALENTIN ROUSSON and FRED PACCAUD*

Institute for Social and Preventive Medicine, Lausanne University Hospital, Lausanne, Switzerland

*Corresponding author. Institut Universitaire de Médecine Sociale et Préventive, Corniche 10, 1010 Lausanne, Switzerland. E-mail: fred.paccaud@chuv.ch

We thank our colleagues Modig *et al.*[1] for their interest in our paper 'The contribution of rectangularization to the secular increase of life expectancy: an empirical study',[2] and for raising substantial issues related to mortality among the oldest old persons.

The authors are correct in pointing out that the maximum age at death depends partly on the size of the population at risk of dying, in that a larger number of people reaching old age will increase the probability of there being one single person with a very high age at death. It was for this very reason of buffering the effect of population size on extreme values that our paper used the 90th quantile as an indicator of longevity, rather than using the maximum age at death. One should note that from a theoretical point of view, the maximum age at death is an ambiguous dimension. According to the Gompertz model or the logistic one, the maximal age at death is in fact infinite, and one may ask whether it is relevant to use it at all.[3]

Further to this point is that empirical evidence in our study shows that rectangularization of a survival curve does not automatically increase our indicator of longevity. From a theoretical perspective, we illustrated, in an earlier paper (top panel of Figure 2),[4] a situation combining a rectangularization of the survival curve with the lack of an increase in longevity (which incidentally corresponds to the paradigm developed by Fries on the future of longevity).[5] In our study we also noted that the pace of increase in longevity was not strictly related to the pace of rectangularization. There were in fact substantial differences between the two processes, as summarized in Figure 4 (panels a and b).[2]

Even when an increase is observed in both rectangularity and longevity as indicators of mortality, the effect of each process on the number of years gained in life expectancy does vary. Whereas we found that the extension of longevity was responsible for more gained years than was rectangularization in most of the countries in our study from 1922 to 2006, the opposite is true during some periods and/or in some countries. Consider, for example, the analysis by Gavrilov *et al.* of Swedish male mortality.[6] There, a Gompertz–Makeham model was fitted, in which the mortality rate at age x is given by the equation $a*exp(b*x)+g$. In the period from 1901–1910, the parameters of the model were estimated to be $a=0.0000356$, $b=0.1005$, and $g=0.00557$, whereas in the period from 1966–1970 these parameters were estimated to be $a=0.0000244$, $b=0.1048$, and $g=0.00068$, as seen in Table 1 in Gavrilov *et al.*'s paper.[6] Between the two periods, the gain in (trimmed) life expectancy at 50 years was 2.5 years. Applying our indicators to this example, we found that rectangularization was responsible for a gain of 1.8 years, whereas the longevity extension contributed only 0.7 years, showing that rectangularization of the