Maximum human lifespan may increase to 125 years

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Dong et al. [1] have argued that there is a limit to human lifespan of around 115 years. Their main rationale is that the maximum reported age at death in Japan, France, UK and US has not increased since 1995. However, this does not necessarily imply that no one will survive beyond 115 in the future. We show that even if the death probabilities do not change in the future, Japanese women will reach an age of 118 before 2070, simply because of the rise in the number of supercentenarians. If we take into account the evidence that mortality has been delayed to older ages in the past, we can even project that an age of 125 years will be reached by 2070. This projected increase in the maximum age at death implies that a limit to human lifespan is not yet in sight.

The maximum reported age at death can be considered the limit to human lifespan only if the probability of death equals one at that age. Since Jeanne Calment survived to age 122 in 1997[2], we know that the death probabilities below age 122 are smaller than one, and that the limit to human lifespan is at least 122. The finding that in recent years no person has survived to such a high age does not imply that a natural limit to human lifespan has been reached, but rather that the probability of reaching that age is small. Given the recent and expected strong increase in the number of centenarians[3], the probability that in the future one person will survive to such an old age will, however, increase substantially. The highest age that can be reached in the foreseeable future depends on the death probabilities at older ages and on the size of the older population rather than on past trends in the maximum reported age at death (see the Supplementary Information).

Given the scarcity of data on the death probabilities in very old age, we estimate the death probabilities for ages 110 and above by applying a logistic-type model to mortality data of Japanese women up to 109[4]. We study Japanese women since a large number of very old

women live in Japan. The logistic model is considered superior to the widely known Gompertz model[5,6,7,8,9,10]. Whereas the Gompertz model overestimates the acceleration of the increase in the death probabilities at the oldest ages, our logistic-type model describes this increase very accurately: $R^2 = 99.97\%$ (see Figure 1). Using our logistic-type model we estimate that the maximum death probability equals 0.6. Our estimate is slightly more conservative than Gampe[11] who concluded, based on the analysis of 637 supercentenarians, that death probabilities after age 110 are flat at a constant level of around 0.5.

We define the maximum reported age at death by the highest age at which at least one woman is alive and at which the probability that at least one woman will survive to the next age is smaller than 50 per cent. If the death probabilities estimated by our logistic-type model do not change in the future, the probability that a Japanese woman aged 85 on January 1, 2015, will reach age 118 is one in 450 thousand. The number of Japanese women who were aged 85 on January 1, 2015, was 482 thousand[4]. Thus, we expect that one of these Japanese women will reach age 118 by January,1 2048 (see Figure 2).

Given the declines in the death probabilities and the delay of mortality to older ages that occurred in the past[10], it is, however, unlikely that the death probabilities will remain constant in the future. If we assume that survival to age 100 continues to improve at the same pace over the next 55 years as it did over the last 55 years, the number of centenarians will increase from 56 thousand in 2015 to 750 thousand in 2050. This increases the likelihood that some of these women will survive to 120, even if we assume that the survival rate among centenarians does not improve (see Figure 2). Assuming a continuation of the observed decline in the death probabilities at ages 100 or over, we anticipate that one in 840 thousand women who were aged 70 on January 1 2015, will survive to age 125 in the year 2070 (see Figure 2).

According to all three projections no Japanese woman is expected to survive to an age beyond 116 before 2025. This stagnation in the maximum reported age at death over the next 10 years, however, does not imply that the limit to human lifespan is reached as was suggested by Dong et al.[1] By contrast, the projected increase in the maximum reported age at death in the long run implies that a limit to human lifespan is not yet in sight.

There are three reasons why we expect that the maximum reported age at death will increase in the long run. First, the increase in the number of centenarians makes it likely that some of these women will survive beyond age 116, even if death probabilities would not decline. Second, the projected improvement in survival up to age 100, which is in line with past trends, will lead to a further increase in the number of female Japanese centenarians which in turn increases the likelihood that some women will survive to very old ages. Third, continued improvements in survival among centenarians may be expected to result in a further increase in the age at death beyond the 122 years reached by Jeanne Calment.

METHODS

We used population data and unsmoothed mortality data from the Human Mortality Database (HMD) obtained on October 11, 2016 [4]. To estimate death probabilities for ages beyond 109 and for projecting future age-specific death probabilities, we used the CoDe 2.0 model. The CoDe 2.0 model is a continuous version of the recently published and validated CoDe model[10], that describes the full age pattern of mortality and assesses mortality delay and compression. The model includes a logistic-type term that describes the age pattern of the death probabilities at older ages. To project the values of the parameters of the CoDe 2.0 model we used a multivariate stochastic time series model. For more information about the model and the projections see the Supplementary Information at www.futuremortality.com.

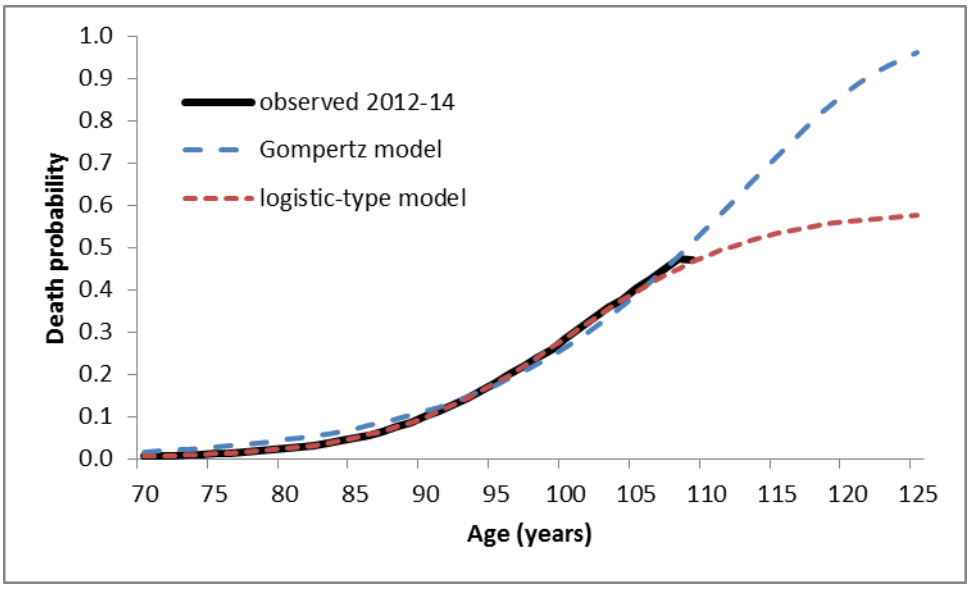

Figure 1. Death probabilities, Japanese women. The death probability is the probability that an individual will die within one year. The solid black line shows the average observed values for the years 2012-2014 for ages 70-109. The dashed blue line shows the fit of the Gompertz model for ages 70-109 and the projection for ages 110 and over. The Gompertz model overestimates the acceleration of the increase in death probabilities in old age: the Gompertz model underestimates the death probabilities around age 100 and overestimates the death probabilities around age 110. Note that the oldest recorded age at death is 122 years[2]. This implies that the death probabilities up to age 122 are smaller than one. The dashed red line shows the fit of our logistic-type model which is more accurate than that of the Gompertz model (see the Supplementary Information for additional evidence). The logistic-type model projects that the death probability increases from 0.5 at age 110 to 0.6 at age 125.

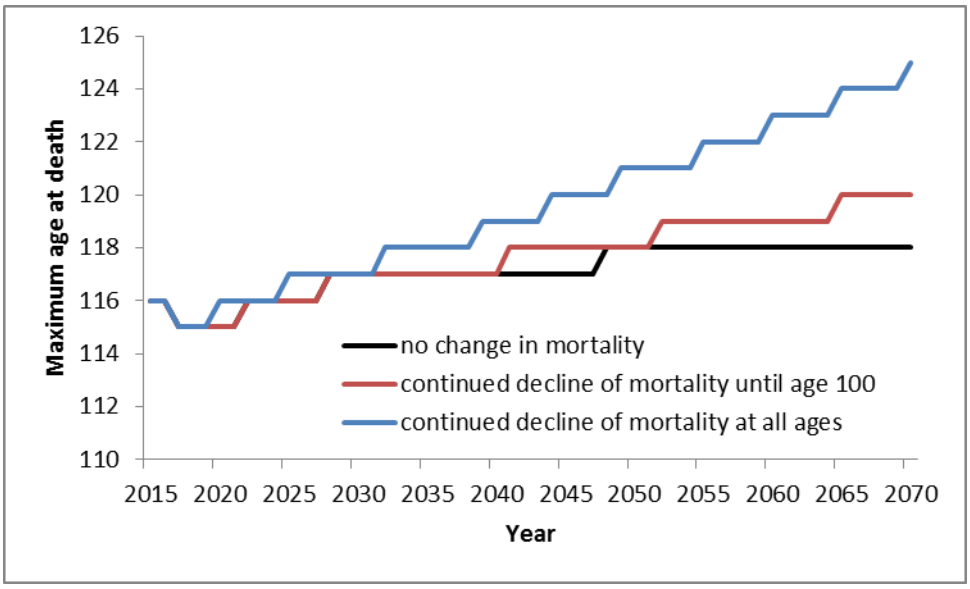

Figure 2. Maximum age at death, Japanese women, 2015-2070 on January 1. On January 1, 2015 the oldest living Japanese woman was aged 116. She died in 2015 after her 117th birthday[12]. On January 1, 2016, the oldest Japanese woman was aged 115. She celebrated her 116th birthday in August 2016. Note that no Japanese woman is expected to survive beyond age 116 before 2025. This does not, however, imply that the limit to lifespan is reached, as the maximum reported age at death is expected to rise in the long run. The black line shows the development of the maximum age at death based on the assumption that the death probabilities do not change between 2015 and 2070. The increase in the maximum age is due to the increase in the number of centenarians to 150 thousand in 2050. This substantial increase makes it likely that some of these women will survive to age 118. The red line is based on the assumption that the decline in the death probabilities up to age 100 observed in the 1960-2014 period will continue in the years 2015-2070. The projected delay of mortality will lead to a further increase in the number of female Japanese centenarians to 750 thousand in 2050. This in turn increases the likelihood that some of these women will survive to 120 and beyond. The blue line is based on the assumption that the death probabilities at the oldest ages will decline as well. The resulting improved survival of centenarians is expected to result in an increase in the maximum age to 125 years in 2070.

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