

POPULATION & SOCIÉTÉS

No. 365
FEBRUARY 2001

Living beyond the age of 100

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Humanity has always been fascinated by extreme longevity. According to the Bible, the first man, Adam, lived 930 years, and some of his descendents lived even longer: Enoch died at 965, and Methuselah, the champion of them all, lived to 969! Of course, these are all legends. The Bible is full of epic stories and the image of these age-old patriarchs who lived before the flood is meant to stir imagination, not to reflect reality. After the flood, the patriarchs began to die at more reasonable ages: Abraham lived to the age of 275, Isaac died at 180, Jacob at 147, Joseph at 110, etc.

In more recent times, many stories went around about men and women who were said to have lived well over a hundred years, in the Caucasus or in some remote valleys of the Andes, or even in the American state of Georgia. Although for a long time, these cases were considered possibly true, we now know that they were in fact imaginary. These stories reflect a classical phenomenon: in many societies, very old people inspire a great deal of awe and respect, and if their actual birth date has not been precisely consigned anywhere, their ages are often overestimated. If this information is supported by some kind of "logical" reasoning (for instance, the benefits of living in altitude, a yogurt-based diet, or even the hypothesis of a genetically-based longevity, particular to an isolated population group), legends are quick to arise and spread. Stalin did everything he could to spread the myth of the longevity of the Georgians from the Caucasus, because it flattered him. The ages of the Indians from Vilcabamba, in the Andes, were also found to have been overestimated. As to the American Georgians who had supposedly reached the ages of 120, 130 even 140, the truth is that a century ago, age

was not very accurately stated by the census, especially as concerns the black population, for which births were seldom registered.

In fact, until recent years, it was quite unlikely for anyone to ever live to much more than a hundred. Today, however, there are several thousand centenarians, and we know with near certainty that at least one woman, the Frenchwoman Jeanne Calment (1), lived to the age of 122 [1]. Does this mean that human longevity is on the increase?

◆ Indications of increasing longevity

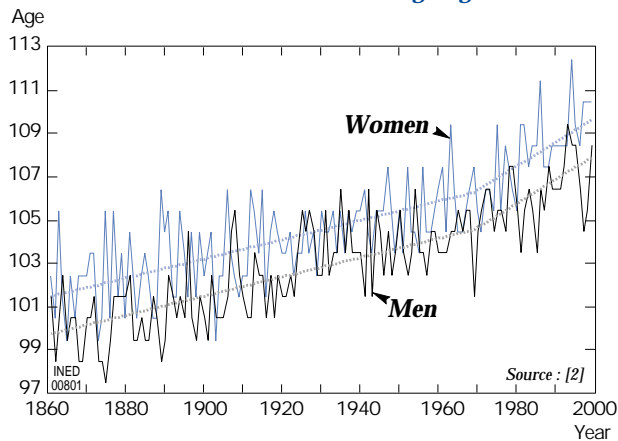
The study of the oldest ages at death over a period of several centuries in a country like Sweden which has long had an excellent record of births might suggest at first glance that human life-span is on the increase (see figure 1).

The oldest age at death observed during the course of one year is necessarily a very fluctuating figure. Indeed, we are dealing with extreme, record performances, which are never the same from one year to the next. Nevertheless, despite the very high fluctuations observed for both men and women in figure 1, the trend clearly shows an increase: towards the middle of the 19th century, the oldest age at death hovered between 100 and 105 for women and 97 and 102 for men, whereas in the last twenty years, it has reached 107 to 112 for women and 103 to 109 for men. In addition, the oldest age at death has been rising at a faster

(1) Jeanne Calment was born on February 21, 1875 and died on August 4, 1997. The oldest person alive now is Marie Brémont, a French citizen born on April 25, 1886, now 114 years old. The oldest man to have ever lived was the Californian Kristian Mortensen, born on August 16, 1882 in Denmark, who died on April 25, 1998 at the age of 115.

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Figure 1: Maximum ages at death observed within a year, since 1861, in Sweden, according to gender



pace: indeed, the slope of the regression line for the years 1970 to 1997 is much steeper than that of the years 1851 to 1969 [2].

However, this does not necessarily mean that human longevity is increasing. Indeed, this phenomenon can also be explained by higher statistical probability, since, thanks to improved health care, the elderly population is growing. The greater the number of persons alive at the age of 90, the greater the probability that at least one of them will reach 95, 100, 105, etc., all chances of survival being equal. For quite a long time, human populations grew very slowly, since fertility rates only slightly exceeded very high mortality rates. The age pyramid was extremely tapered at the apex, since persons over 60 made up only 5% of the total population. Very old persons were very rare and the likelihood of reaching the age of 100 quite poor.

From the end the 18th century on, the European population began to grow at an exceptionally rapid pace, a fact which in itself would have been enough to cause an increase in the number of very elderly persons. Population growth, together with the overall aging of the population increased the likelihood of reaching a very old age. At first, the decrease of infant mortality led to a notable increase, sixty years later, in the number of senior citizens. Next (beginning in the 1960s), the rate of survival beyond the age of 60 also considerably increased, leading to a rise in the number of persons aged 70, 80 and 90 years, and thus to the added likelihood of reaching an unprecedented age. In Sweden, since 1969, the decline in mortality rates after the age of 70 has in fact been responsible for 95% of the increase in the maximum age at death [2].

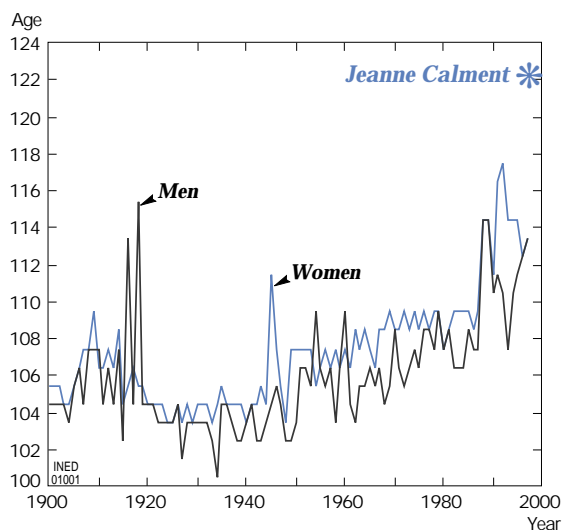
However, beyond the simple impact of numbers, the fact that mortality rates among the very elderly are decreasing at a faster pace raises all the more acutely the question of whether the maximum duration of human life may not be lengthening thanks to a new phase in the progress of health care.

Indeed, since the 1950s, life expectancy at the ages 70, 80 and 90, relatively stable so far, has increased at

Maximum ages at death in France

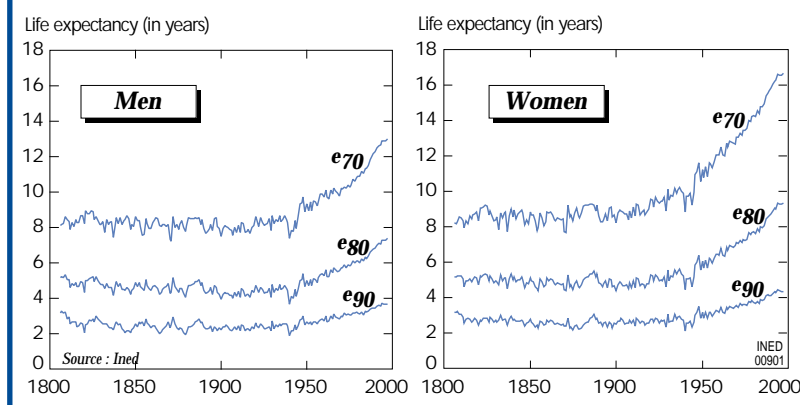
In the case of France, figure 2 shows that the changes in the oldest age at death observed in the course of one year are much less clear than in Sweden, as shown in figure 1. This is explained by the uneven quality of statistical records. At the turn of the 20th century, the age of very elderly people could not be precisely determined because before 1850, births were not always officially registered. Many of the ages indicated at the left in figure 2 are thus overestimated. This problem gradually disappeared, giving the false impression that the maximum age at death had dropped. On the contrary, from the 1930s to the 1960s, the maximum age at death significantly increased, just like in Sweden. However, at this point, a new problem arose: between 1960 and 1980, the maximum age at death of women seems to reach a plateau at 109. This is simply due to the fact that INSEE, judging that all declarations above 109 were suspicious, attributed a different age, at random, to all declarations exceeding that age. This age limit was raised to 119 only at the end of the 1980s. Due to this constraint, death statistics attributed another, younger, age to Jeanne Calment, who died at 122. Thus, in 1997, according to statistics of births and deaths, the maximum age at death was reportedly 113. Nonetheless, Jeanne Calment is now registered in the official records of physical persons as having died at the age of 122 years, and this fact is marked by an asterisk in figure 2. Conversely, some ages at death may still be overestimated today, in particular as concerns men. Thus, the deaths of men aged 114 recorded in 1988 and 1989 have not yet been validated. However, these suspicious cases do not call into question the trend observed in recent years, since, during these same years, several men are registered as having died at the proven ages of 108 and 109. Therefore, one can safely assert that if France had kept its records as accurately as Sweden, it would have been able to observe the same trend: a steady increase in the maximum age at death during the last century and a recent acceleration.

Figure 2 – Maximum ages at death observed within a year, since 1900, in France, according to gender



Source: data provided by INSEE in the framework of the INSEE-INED agreement.

Figure 3: Life expectancy at 70, 80 and 90 years in France since 1806



a spectacular pace, especially among men (see figure 3). Thus, in France, in 1997, the life expectancy of men at the age of 70, which from the end of the 19th century until World War II had been consistently hovering between 7 and 9 years, exceeded 13 years. Among women, the increase began a little earlier, between the two world wars, rising from a previously constant 8 to 10 years up to 17 years today. A similar increase can be observed for life expectancy at the ages of 80 and 90, and if the pace of the increase in recent years seems less rapid at those extreme ages than at the age of 70, this is simply due to the scale of the arithmetic graph. Indeed, the relative gains are just as high: over 60% for men and almost twofold for women.

Even the life expectancy at the age of 100 has notably increased over the past decades. A man aged 100 in the early 1950s could expect to live 1.3 years; now, a man that age can expect to live 1.9 years. The life expectancy of 100-year-old women has risen from 1.6 to 2.1 years. This sudden increase in the survival rates of the oldest old remains a mystery. Does it mean that improved health care is leading to the extension not only of the average duration (life expectancy at birth) but also of the maximum duration (longevity) of human life?

◆ A question as yet unresolved

Up until the 1970s, it was commonly thought that the progress made since the 18th century had brought the average life-span closer to its longest possible duration, itself an immutable fact of the species. For many, this remains the only true theory. However, more and more scientists are coming to believe that human longevity may be on the increase.

For the advocates of the first theory, such as the biologist James Fries [3] or the demographer Jay Olshansky [4], the annual reduction of mortality at extreme ages is only the final phase in a long process of "rectangularization of the survival curve", which gradually leads to a situation where the vast majority of the members of a generation survive until a very

old age but die almost all at once, soon after reaching the latter age (2). For these scientists, this process will soon end and it is quite unlikely that human life expectancy will ever exceed 85 years.

For other scientists, on the contrary, human longevity, far from being limited once and for all, is flexible; the present leaps in the life expectancy of advanced ages are, in part, a consequence of this flexibility. In a recent special issue of *Population* devoted to "Biodemographic Perspectives on Human Longevity", James Carey writes that human longevity has always varied throughout history. In his view, the life-span of *Homo*

habilis exceeded the age of menopause by only 7 to 11 years, whereas that of *Homo erectus* by 15 to 18 years. The longevity of the latter thus reached 60 to 63 years, and grew to over 70 years among the first *Homo sapiens*. This could mean that longevity can increase within the species as well, since the maximum life-span now reaches beyond 120 years, as shown by the case of Jeanne Calment who died at the age of 122. If this were true, one could expect a possible increase in the future life expectancy of human beings. Why not imagine, for instance, a human life expectancy of 150 years? (see the articles by Caselli and Vallin in the above-mentioned issue of *Population*). Better even, some biologists believe that several living beings (the queen bee, some flies, not to mention sequoias) escape the general rule whereby death risks increase exponentially with age, and that they would be practically immortal were it not for the risk of violent death [5]. This idea has led the demographer James Vaupel to wonder whether human mortality, like that of flies, may not decline at very old ages [6]. A happy (?) few might then dream of becoming immortal.

In any case, the hypothesis defended by Fries and Olshansky seems too pessimistic. Indeed, French data shows that, even with a fixed life expectancy at age 105 (a simple way of applying the "rectangularization" theory), if the trends observed today for younger ages remained constant, by 2100 the life expectancy of Frenchmen would reach 91 and that of Frenchwomen 95, a great deal older than the suggested limit of 85.

◆ A centenarian boom

The unprecedented decrease in the mortality of very elderly people in recent decades has led to their considerable increase in number. Reaching the age of 100 was a rare feat fifty years ago, but today it has become almost banal. The number of centenarians in 1950 in France, for example, was assessed at 200; by January 1,

(2) The proportion of survivors within a cohort remains close to 100% until a very advanced age and then falls very rapidly to 0; the survival curve looks like a right angle, whence the term "rectangularization".

1998, according to the French national institute of statistics (INSEE), there were 6,840 (3). This increase corresponds to an average yearly growth of nearly 8%, 8 times faster than that of persons over 60. It goes without saying that even if the overall health status of a same age group improves with time, the health of an individual inevitably deteriorates with age and the number of elderly dependent persons will probably be growing very fast.

Indeed, the growth process is far from ended. INSEE projections based on the 1990 census foresee 150,000 centenarians by the year 2050, a 750-fold increase in the space of a century, despite an expected decline in the population growth rate (4).

As can be seen, women are way ahead of men in this race. Due to the cumulated effects of the higher mortality of males at all ages, the difference is quite marked: beyond the age of 100, there is only one man for seven women. Indeed, the proportions change quite swiftly at these extreme ages: at the age of 95, the proportion is of one man for four women, but by the age of 104, it is down to one man for ten women.

Last, this spectacular increase in the number of centenarians has led to the creation of a new statistical age group: that of the “super-centenarians”, those who have reached their 110th birthday. Although several — often suspicious — cases have been reported throughout history, this age group really began to emerge after the 1980s in the most advanced industrialized countries. This was shown in the most detailed survey carried out so far on the subject, thanks to which a list was drawn up of all proven “super-centenarians” for England and Wales (see the article by Roger Thatcher in the above-mentioned issue of *Population*). French data remains for the time being incomplete [7]. INED, in collaboration with INSERM, plans to fill the gap in two complementary ways: first, by drawing up a list of names, by calling for information on persons, living or dead, having reached the age of 110 (5), and secondly, by verifying the exact age of all the persons officially deceased at 110 or more. If similar studies are conducted in Germany, Belgium, the Netherlands, Italy, Scandinavia, Canada and the

(3) The 1999 census came up with the figure of 11,593, but this is probably overestimated. The 1990 census, which laid special emphasis on verification of the ages of very elderly persons, had yielded the figure of 3,800. The increase from 3,800 in 1990 to 6,840 in 1998 represents an 8% annual increase, already a very high rate.

(4) The impressive figure of 150,000 persons aged at least 100 in 2050 does not mean that the majority of persons born in 1950 will reach that age; on the contrary, only 1.5% of the men and 6% of the women of that cohort will do so. This is quite a long way away from the 50% announced by some. However, these proportions will be rapidly rising. If the decrease in mortality rates per age continues at its current pace, 5% of the men and 16% of the women born in 2001 will reach the age of 100.

(5) The French list is being drawn up in collaboration with INSERM (Demography and Health, Montpellier), INED (Mortality, Health and Epidemiology Unit, Paris) and the Ipsen Foundation (Paris). Contact: Jean-Marie Robine, Inserm Démographie et Santé
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Definitions

Longevity: Taken in its usual, common sense, longevity means the duration of life. In a more technical context, this term is used to mean the maximum duration of life of a given species; in that case the terms “maximum longevity” or “maximum duration of life” can be used. This theoretical duration is unknown. What we know is the “maximum age at death”.

Maximum age at death: The oldest age at death observed in a given population during a given time period.

Life expectancy at birth: Average number of years a cohort may be expected to live, if it were subjected, age after age, to the death risks in a particular life table. This life table may correspond to the health conditions prevalent in a given period (for example, a calendar year life table based on the death risks observed during a specific year), or to the living conditions of an actual cohort (cohort life table constructed on the basis of the risks met at each age by a cohort of individuals, from birth to the death of all its members).

Life expectancy at a given age: Average number of years left to be lived for a group of individuals having reached a given age. Again, life expectancy can be measured either at a given point in time or for a given cohort. Of course, the total average duration of life for this group of individuals corresponds to the current age plus the number of years of life expectancy at that age.

United States, it will be possible to follow the evolution of mortality at very advanced ages with greater precision and possibly shed some light on the enigma of human longevity. ◆◆◆

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The recent volume of *Population* referred to here, a special issue entitled “Biological Perspectives on Human Longevity”, has been published in both French and English: respectively, *Population*, 56(1), 2001, and *Population: An English Selection*, 13(1), 2001.