Living and dying beyond age 100 in Japan

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Abstract: It is acknowledged today that the number of oldest old persons, nonagenarians and centenarians, is increasing rapidly. Analysis of data from Japan, where female life expectancy at birth approaches the assumed limit of 85 years, can provide priceless information on a possible acceleration of the demographic changes concerning the oldest old population. Adjusted for a constant size of the birth cohorts, the Centenarian Doubling Time (CDT i.e. the number of years needed to double the number of centenarians), has been halved in nearly 25 years. During this period, data show a strong increase in the maximum reported age at death. Death rates at 100 years and above clearly decrease if we exclude males at age 105 and over. In addition, previous studies of excess mortality in the Winter months suggest environment interventions that could further decrease the death rates.

In 1980, James Fries published "*Aging, natural death, and the compression of morbidity*", a paper which became a seminal work for those studying health trends (Fries, 1980). In his paper, Fries asserted that the number of very old persons will not increase in the future, emphasizing that, for example, in England and Wales there has been no detectable change in the number of people living longer than 100 years despite a great change in life expectancy. In addition, he stated that mortality rates increase exponentially with age ensuring a fixed limit to the length of the human life, pointing out that, in Sweden where careful investigations are

carried out, no one has yet exceeded 110 years of age. Finally, he suggested that consequently life expectancy is limited to 85 year, which he expected to be reached in 2045.

Twenty years later at the beginning of the 21st century, it is well acknowledged that the oldest old persons are a growing segment of most populations and that the number of centenarians has doubled every decade since 1960 in low mortality countries including England and Wales (Vaupel and Jeune 1995; Vaupel et al., 1998; Thatcher, 1999; 2001). It is also acknowledged that the maximum reported age at death is now well above 110 years (Robine and Vaupel, 2001; Wilmoth and Robine, 200X) and increases year after year, even in Sweden (Wilmoth and Lundstöm, 1996; Wilmoth et al, 2000). By contrast, nothing is clear about the limit of 85 years for life expectancy (Bonneux et al., 1998; Olshansky et al., 2001). In most countries, life expectancy has not approached 85 closely enough to challenge Fries' third prediction. In Japan, however, female life expectancy at birth has reached 84.6 years in the year 2000 without any observed change in its rate of increase over the past 15 years. Altogether these demographic trends raise important questions about the future number of oldest-old, nonagenarians or centenarians, their health status, and their quality of life. It is therefore of the utmost importance to monitor the demographic changes currently at work beyond the age of 100 years. But only a few countries can provide useful data on demographic changes in the last few decades for the oldest old population and, consequently, to help in predicting the future of human longevity. In fact, obtaining reliable data on the age at death above age 100 or beyond depends upon a long standing, reliable birth registration system, in existence for more than 100 years.

Belgium, England and Wales, Denmark, France, Sweden, and Switzerland, along with some other countries, have already provided useful data for studying these demographic changes for those above the age of 100 (Jeune and Schytthe 2001; Kjaergaard 1995; Meslé, Vallin and Robine, 2000; Poulain, Chambre and Foulon 2001; Schytthe and Jeune 1995; Thatcher 1992, 1997, 1999, and 2001; Vallin and Meslé 2001; Wilmoth and Lundstöm, 1996; Wilmoth et al., 2000) allowing some global studies (Robine and Vaupel, 2001; Wilmoth and Robine, 200X). Unfortunately, most of the few countries providing these data are relatively low-population nations. Under these circumstances, Japanese data provide a unique opportunity to examine the possible acceleration of demographic trends concerning the extremely old population[1].

A national registration law (Koseki-Ho in Japanese) was enacted in Japan at the beginning of the Meiji Era and a national registration system (Jin-Shin Koseki), based on the place of residence at birth, was implemented in 1872. It was the first national system to cover the entire population. Previously a caste-like system prevented the counting of those who were classified as humble people and often small children were not enumerated. In the new system, a chief of households was appointed to be in charge of enumerating a specific number of households and reporting the results to the regional government office (Taeuber 1958). The age of those born before 1872 was self reported at the time of the implementation of the national registration system.[2] Therefore, the reported age of those born before 1872 may be mis-reported unwittingly . The institution of the penalty for failing to timely report births or deaths in 1886 suggests that it took some time for the system to be complete and precise. The reported age of those born in the first years following 1872 should, therefore, be used with caution. The registration system is supplemented by periodic censuses of population starting in 1920.[3] In addition, detailed statistics on mortality have been published since 1899 by the Ministry of Health and Welfare (Vital Statistics of Japan) and a list of centenarians as of

September 30th has been compiled by municipalities from the national registration system, each September 1st since 1963. (*Zenkoku koureisha meibo*, A list of centenarians in Japan).[4] These data are largely sufficient to understand the increase in the number of centenarians during the last forty years, the increase in the maximum reported age at death, the change in the death rates at the extreme ages in a country whose population is 14 times larger than in Sweden and, where current life expectancy is the highest in the world (Robine and Saito, 200X).

In this study we describe the increase in life expectancy at birth in Japan, the emergence of centenarians (and subsequently those aged 105+ and 110+), the trends in the number of deaths of centenarians (and subsequently of those aged 105+ and 110+) and, the increase in maximum reported age at death. Then we take great care to compute and analyse death rates above the age of 100 in Japan since 1963. This study completes and updates results presented in a previous study (Robine and Saito, 200X).

1. The increase of life expectancy in Japan

Today, life expectancy at birth is as high as 77.6 years for males in Japan and 84.6 years for females according to the latest life table (Abridged Life Tables for Japan 2000) and comes close to the limit of 85 years for life expectancy at birth as hypothesized by James Fries twenty years ago (Fries 1980). Figure 1 shows that since 1960, life expectancy at birth continuously increases in Japan, reaching the highest values ever observed in the world. In

1999, female life expectancy at birth (83.99 years) was lower than in 1998 (84.01 years) while male life expectancy (77.10 years) was, for the second consecutive year, lower than in previous years (77.16 years in 1998 and 77.16 in 1997). This was enough to speculate on the end of the growth of the life expectancy in Japan. In 2000, life expectancy at birth reached 84.62 years for females and 77.64 years for males. The relatively low values in 1999 were due to an epidemic of influenza. It was not the first time that life expectancy at birth had decreased in Japan in comparison to previous years. This decrease had already occurred for females in 1970, 1980, 1988, and 1995, and for males in 1980, 1983, 1988, 1992, and 1995.
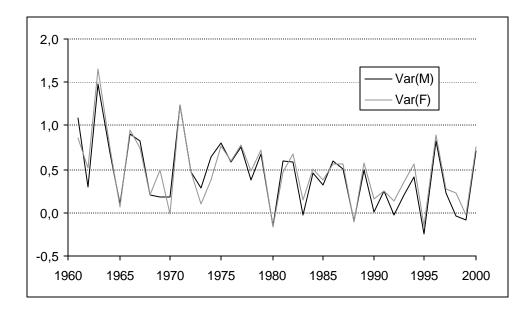
Figure 1: Life expectancy at birth by sex in Japan since 1960

Source: Ministry of Health and Welfare (1960-2000) *Abridged Life Tables for Japan*

Figure 2 shows that the rate of increase of life expectancy at birth has obviously decreased since 1960, but it is not clear that it is still decreasing. In fact since 1980, the figure shows no trend suggesting a constant rate of increase behind the yearly fluctuations.

Figure 2: Rate of increase in the life expectancy at birth by sex in Japan since 1960

Fluctuations of the rates of increase look identical for both sexes leading to a smoother increase in the sex gap since 1980, with the gap increasing from 5.4 years in 1980 to 7 years in 2000 (see Figure 3), and the pace of increase accelerating (see Figure 4). The Japanese data do not support narrowing of the sex gap in terms of life expectancy at birth, often made in population forecasts.

Contrary to all expectations, as female life expectancy approaches the assumed limit of 85 years, there appears to be no slowing down in the decrease of mortality at the oldest ages but on the contrary, an acceleration of the phenomena observed. For instance, between 1995 and 2000 the probability of surviving from birth to age 80 increased from 48.4% in 1995 to 52.2% in 2000 for males and from 70.5% to 74.4% for females. Moreover the probability of surviving from age 80 to age 100 increase from 1.0% to 1.7% for males and from 4.0% to 7.0% for females. [5] The first consequence of this increase in the probability of surviving to extreme old age is to increase significantly the number of centenarians.

Figure 3: Gap in life expectancy at birth between males and females in Japan since 1960
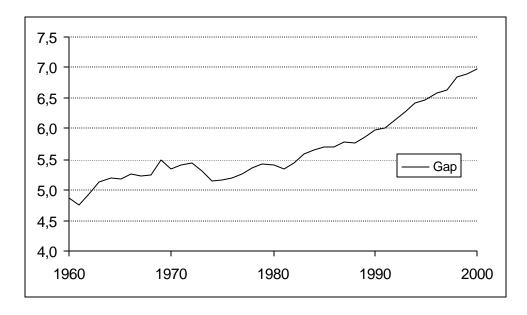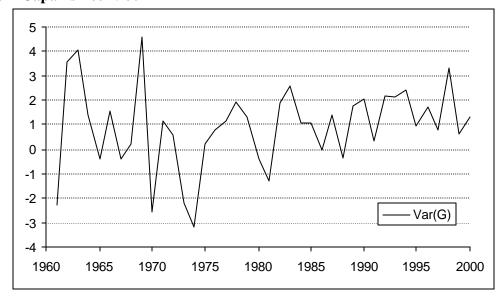

Figure 4: Rate of increase of the gap in life expectancy at birth between males and females in Japan since 1960

2. The emergence of the centenarians in Japan

The number of centenarians, persons aged 100 years and over, increased in Japan from 153 in September 1963 (20 men and 133 women) to 15,475 in September 2001 (2,541 men and 12,934 women). This increase appears to be exponential (see Figure 5), with the number of centenarians being multiplied by a factor of 100 in 38 years. In fact, behind quite large yearly

fluctuations, the rate of increase itself tends to increase. The Centenarian Doubling Time (CDT) decreases from nearly 6 years in 1960s to around 4.8 years in the last years of the 1990s.
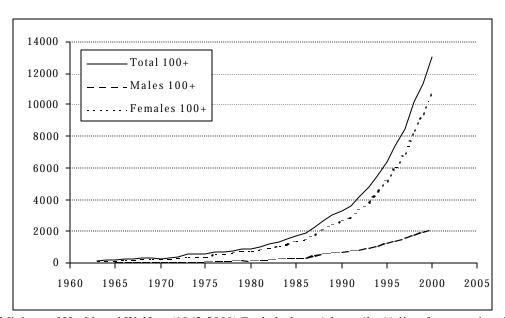
Figure 5: Number of persons 100 years old and over, Japan since 1963, by sex

Source: Ministry of Health and Welfare (1963-2000) *Zenkoku koureisha meibo* (A list of centenarians in Japan)

One reason for the increase in the number of centenarians is the dramatic increase in the number of births during the last years of the 19th century in Japan, from 569,034 births in 1872 to 1,420,534 births in 1900, a factor of 2.5 (National Institute of Population and Social Security Research, 2000). Figure 6 shows that ratio of centenarians per 10,000 births increased from 3.5 for the 1873 cohort (1.4 for men and 5.6 for women) to 38.7 for the 1900 cohort (13.0 for men and 65.6 for women).[6] This increase, independent of the size of the successive cohorts, appears as linear on a log scale. However, behind large yearly fluctuations (see Figure 7), the rate of increase is not constant and the fitted trend shows that it goes from 7.1% in 1975 to 13.4% in 2000.

Figure 6: Number of persons aged of 100 years exactly per 10,000 births 100 years before, Japan, 1973-2000
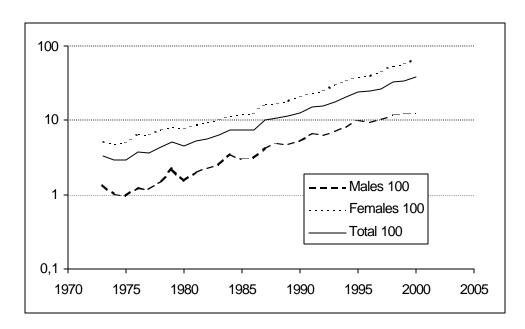

Figure 7 : Rate of increase in the number of persons aged of 100 years exactly, data adjusted on the birth level of 1873, Japan, 1973-2000
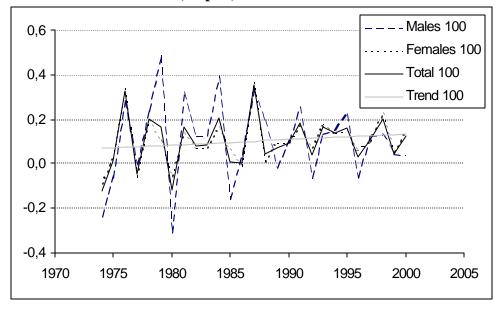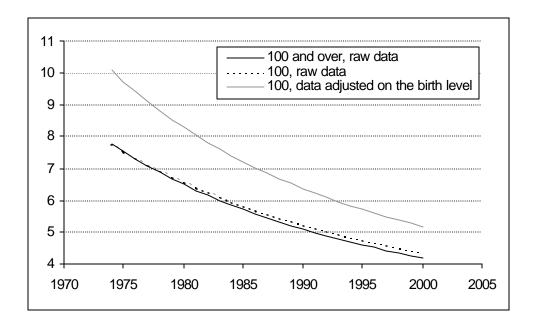

Figure 8 shows that the CDT, corresponding to fitted trend in the rate of increase, decreased from around 10 years in 1973 to about 5 years in the year 2000. Comparable to those of the other low mortality countries in the 1970s, the CDT in Japan was halved in nearly 25 years when the number of births is kept constant at the level of 1873, suggesting a significant

acceleration in the emergence of the centenarian population in Japan due to increased survival.
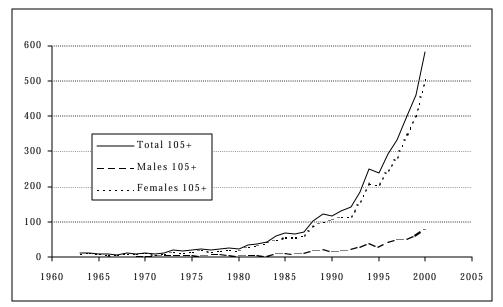
Figure 8: Centenarian Doubling Time (CDT) in year for the whole population 100 years and over (raw data) and for the number of persons aged of 100 years exactly (data adjusted on the birth level of 1873), Japan, 1973-2000

Population 105 years old and over and supercentenarians

Figure 9 shows the more astonishing rise in the number of persons aged 105 years and over which accompanied the emergence of centenarians in Japan. This number increased from 11 in September 1963 (1 man and 10 women) to 582 in September 2001 (80 men and 502 women); the number being multiplied by a factor of 53 in 37 years. The ratio of persons 105 years old per 10,000 births increased from 0.14 for the 1873 cohort (0.05 for men and 0.23 for women) to 2.58 for the 1895 cohort (0.77 for men and 4.47 for women).[7]

Figure 9: Number of persons 105 years old and over, Japan, 1963-2000, by sex
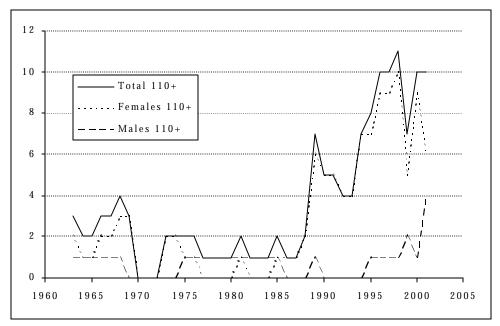

Source: Ministry of Health and Welfare (1963-2000) *Zenkoku koureisha meibo* (A list of centenarians in Japan)

In spite of large fluctuations, the rate of increase of the number of persons aged 105 years has been nearly constant during the last 22 years, meaning an exact exponential increase in the numbers, with an annual increase of nearly 20% with the raw data corresponding to a CDT of 3.5 years, and of about 17% with the data adjusted for the size of the birth cohorts corresponding to a CDT of 4 years (data not shown). This means that the number of persons 105 years old doubled every 3.5 years in Japan for the last two decades and would have doubled every 4 years if the size of the birth cohorts had remained constant since 1873.

Figure 10 shows the appearance and the sudden rise from 1989 in the number of supercentenarians, defined as persons having reached their 110th birthday. Since 1983 the persons celebrating their 110th birthday were supposed to have been registered at birth. Earlier cases must be considered with the greatest caution. In September 2001, 10 supercentenarians were living in Japan, 6 females and 4 males.
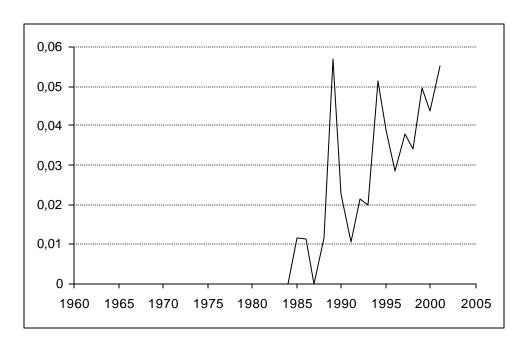
Figure 10: Number of persons 110 years old and over, Japan, 1963-2000, by sex

Source: Ministry of Health and Welfare (1963-2000) *Zenkoku koureisha meibo* (A list of centenarians in Japan)

The number of persons 110 years old per 10,000 births one century before, increased from none for the 1883 cohort, (0.012 for the 1885 cohort) to 0.055 for the 1890 cohort (see Figure 11).[8] But the series is too short to allow us to assess the shape of this increase.

Figure 11: Number of persons aged of 110 years exactly per 10,000 births 110 years before, Japan, 1983-2000

3. The deaths of centenarians in Japan

Figure 12 shows the emergence of centenarians in Japan through the evolution of the number of deaths of persons 100 years old and over since 1947. Although indirect, the number of deaths gives a robust estimation of the number of centenarians. The main interest of this series is to go back to the very beginning of the 20th century, while the published list of centenarians only begun in 1963. The series not only indicates the expected increase in the number of centenarians after World War II, but also an unexpected rise in the number of centenarians roughly between 1905 and 1925 with a maximum of 193 centenarian women in 1913, corresponding to persons aged between 51 and 67 years in 1872 when the national registration system was implemented. This series allowed us to analyse the quality of the data according to both the age reported at death and the time lag since the establishment of the national registration system (Robine and Saito, 200X).
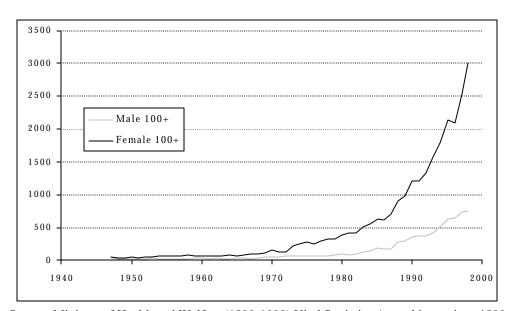
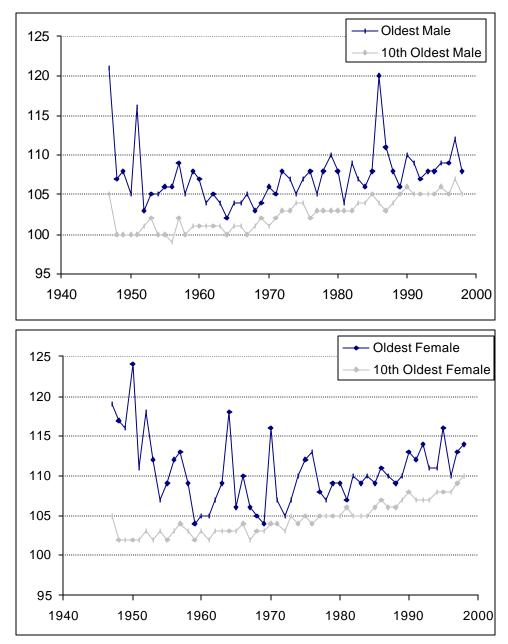**Figure 12: Number of deaths of persons 100 years old and over, Japan, Since 1947, by sex**

Source: Ministry of Health and Welfare (1899-1998) Vital Statistics Annual issue since 1899

Maximum age at death

This series, on the other hand, suggested that despite fluctuations due to previous possible age mis-reporting, there was a regular and important increase not only in the number of centenarians since the 1960s, but also in the maximum reported age at death.

When the maximum ages at death are plotted together with the 10th maximum ages at death since 1947 to eliminate the late outliers, they show a real trend in maximum age at death during the second part of the 20th century (Figure 13). A regular increase in the 10th maximum age at death for males shows an increase from approximately 100 years in 1950, to 103 years in 1980 and 105 years at the end of the century. The maximum was 107 years in 1997. Going back to the 1940s, this suggests some kind of acceleration for the increase in the 10th maximum age at death. The highest maximum age at death is, on average, five years higher. For females, an acceleration of the increase in the 10th maximum age at death, is clearly shown, ranging from 102 years in 1950, to 105 years in 1980, and 110 years in 1998. The highest maximum age at death is on average six years higher for females.

Figure 13: Maximum reported age at death, highest and 10th highest, Japan, 1899-2000, by sex

Source: Ministry of Health and Welfare (1899-1998) Vital Statistics Annual issue since 1899

4. The mortality above the age of 100 years in Japan

In order to properly celebrate the birthday of the centenarians, since 1963 the Japanese government each year has published a list of Japanese aged 99 years or older on the first of September. The persons are ordered according to the age they will be on the 30th of September. Statistical counts by age and sex are available for each year. From these counts, one can first estimate the counts of living centenarians on the 30th of September ordered by age. Compared to the target counts, the September counts include an excess consisting of those who will die in September having already reached the age of 100 years or more and those who will die in September in the last month of their 100th year before reaching their 100th birthday. Consequently, one must subtract from the September counts the number of deaths of centenarians (defined as aged 100 and more) occurring during September as well as the number of deaths of people still 99 years on the first of September who died during September before reaching their 100th birthday. The number of deaths of centenarians by age, sex, and month is available for each year but the number of deaths of people still 99 years on the first of September who died during September before reaching their 100th birthday must be estimated. Assuming that birthdays are uniformly distributed across the year, we can assume that one twelfth (1/12) of the 99 years old persons who died in September were in the twelfth month of their 100th year. With the further assumption that half of this group will die before reaching their 100th anniversary, one can consider that one twenty-fourth (1/24) of the deaths of 99 years old persons in September corresponds to people counted also by excess in the September counts. Consequently, one can subtract from the September population counts the number of deaths of centenarians occurring in September and one twenty-fourth of the deaths of 99 years old persons occurring in September, in order to estimate the target counts. The linearity hypotheses assumed in this estimation are ones often used in demographic research. Taking a little more or less than one twenty-fourth of the deaths of 99 years old persons would have little impact on the result.

Figure 14 shows the changes in actual and fitted Japanese death rates at age 100-104 years, by sex, since 1973, when the fluctuations of the death rates have mostly disappeared. For females, the fitted death rate at age 100-104 clearly decreased from around 45% in 1973 to about 30% in 1998. For males, the fitted death rate at age 100-104 decreased from around 50% in 1973 to about 35% in 1998.
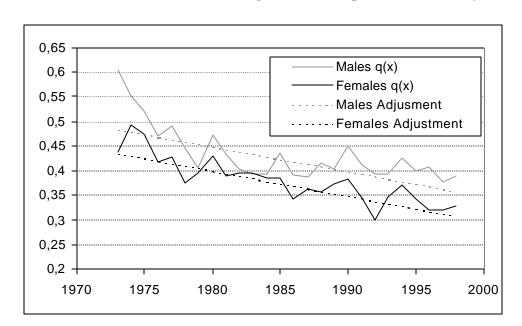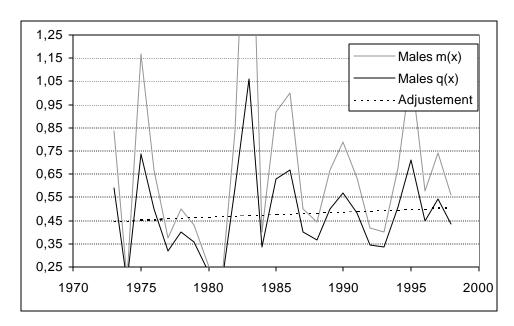
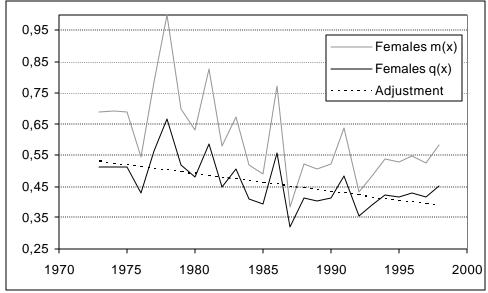**Figure 14: Actual and fitted death rate at age 100-104, Japan, since 1973, by sex**

Despite larger fluctuation, figure 15 also suggests a decrease for female death rates at age 105 and over from about 55% in 1973 to around 40% at the end of the 20th century. On the other hand, death rates for males at age 105 and over shows no clear trend.

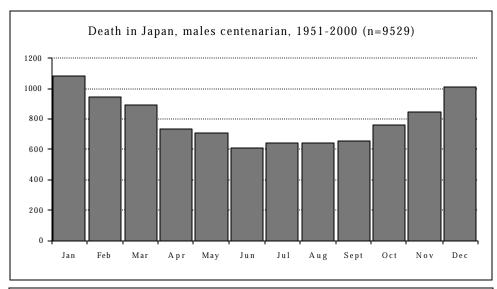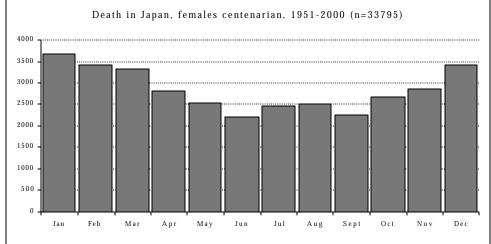**Figure 15: Death rate at 105 and over, Japan, 1975-2000, by sex**

5. The seasons of death in Japan

Figure 16 presents and updates a previous analysis of the seasonality of deaths of centenarians in Japan. The figure shows a clear difference in the number of deaths between June, which appears to be the most favourable month, and the three winter months, December, January and February. Only, twenty percent of the deaths of centenarian men occurred in summer, compared to nearly 32% in winter; these figures are respectively 21% and 31% for centenarian women. On the one hand, this considerable variation in the level of mortality with the passing of seasons suggest that centenarians are frail persons, at risk for harmful events during the winter months. On the other hand, this variability suggests that the mortality level of centenarians could still decrease significantly if Japan was able to lessen the impact of the detrimental environment changes responsible for this seasonal excess in mortality. If Japan could keep the level of mortality at its summer level throughout the year, it could potentially decrease the death rate of Japanese centenarians by 20% for males and by 16% for females (Robine and Saito, 200X).

Figure 16: Distribution of deaths of persons 100 years old and over according to month, Japan 1951-2000, by sex

Death in Japan, males centenarian, 1951-2000 (n=9529)

Death in Japan, females centenarian, 1951-2000 (n=33795)

Source: Ministry of Health and Welfare (1951-2000) Vital Statistics Annual issue since 1899

Discussion

The fall, and the acceleration of the fall, of mortality at the highest ages in the low mortality countries (Vaupel and Lundström, 1996; Vaupel et al., 1998) still provoke controversies (Olshansky, Carnes and Désesquelles 2001; Bonneux, Barendregt and Van der Maas 1998). Our analysis uses unique data coming from the country where life expectancy at birth is the

highest in the world, establishing it as an 'avant-garde' country (Wilmoth, 1998), where female life expectancy is quite close to the ultimate limit of 85 years suggested by Fries in 1980. The data allow careful monitoring of the demographic changes among the oldest old population for at least the last quarter of the 20th century when almost all the living Japanese have been registered at birth through the national registration system implemented in 1872.

Our study shows a sustainable growth of life expectancy at birth in Japan without any sign of slowing down when approaching 85 years for females. It also suggests a strong continuing acceleration in the emergence of the centenarian population with the Centenarian Doubling Time (CDT) being halved in just 25 years, after taking out the effect of the birth cohorts size. The data show a regular increase in the maximum reported age at death during the same period, with an acceleration of this phenomenon for females. Death rates at age 100-104 significantly decreased for males and females from 1973 to 1998, and also at age 105 and over for females. In addition seasonal fluctuations in mortality suggest that the mortality level of the centenarians could still decrease significantly. Whatever indicators are used, life expectancy, number of centenarians, maximum reported age at death, or death rate after age 100, Japanese data do not support the hypothesis of a slowing down in the decrease of mortality of the oldest old or in the lengthening of life.

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Notes

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[1] Some Japanese data have already been used by Wilmoth and Lundstöm (Wilmoth and Lundstöm, 1996).

[2] During the 19th century, Japan knew a long series of eras: Bunka Era (1804-1818), Bunsei Era (1818-1830), Tenpou Era (1830-1844), Kouka Era (1844-1847), Kaei Era (1848-1853), Ansei Era (1854-1859), Manen Era (1860), Bunkyuu Era (1861-1863), Ganji Era (1864), Keiou Era (1865-1867), and Meiji Era (1868-1911). Thus those born in the 5th year of Bunda Era, that is 1809, had in theory to remember all the names of the eras and the number of years in each era to count their age in 1872 when the new registration system started. However, the knowledge of his/her animal year, one of the twelve animal signs of the Japanese zodiac, may have helped to count their age, leading to an eventual mis-reporting by 12 years (or a multiple of 12).

[3] Since 1920, censuses took place every five years on October 1 except in 1945

[4] If we except 1968. From 1963 to 1967 the information is listed as of September 30th each year. In 1968, the information is listed as of October 31st. From 1969 to 1973 the information is listed as of September 30th each year. From 1974 to 2001, the list was compiled on September 1st but information is listed as of September 30th each year.

[5] We use for this comparison a special life table for 1995 where the influence of the Great Hanshin-Awaji Earthquake is excluded (The 18th life tables of Japan, Additional tables). Doing that we minimize the gaps between 1995 and 2000.

[6] The number of persons 100 years old for 10,000 births is computed by dividing the number of persons aged 100 years exactly, alive at each successive September 30th, by the number of births which occurred between January first and December 31st, one century before. For instance, the number of persons aged 100 years exactly on September 30th, 2000, is divided by the number of births which occurred in 1900 between January first and December 31st. Thus the ratio computed is not exactly a ratio by cohort of persons reaching his/her 100th anniversary for 10,000 births, but a quite fair estimation of this ratio. The number of births by sex is estimated using a ratio of 105 males for 100 females at birth, ratio which is verified for the years when the detail by sex is available.

[7] The number of persons 105 years old for 10,000 births is computed by dividing the number of persons aged of 105 years exactly, alive at each successive September 30th, by the number of births occurred between January first and December 31st, 105 years before. See note 2.