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# Maximum Normal Longevity in Low Mortality Countries

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## EXTENDED ABSTRACT

The aim of this paper is to examine whether the value of about 120 years found in Hong Kong for M + 4SD(M+), our indicator of maximum normal longevity, is confirmed in other low mortality countries. Kannisto (2001) proposed to look at the late mode (M) and standard deviation above it (SD(M+)) for examining normal human longevity. With data from 15 low mortality countries, he showed that the later the mode occurs, the smaller SD(M+) is. This observation leads him to wonder if increase in longevity is meeting an invisible wall. A recent study using Hong Kong mortality data (Cheung, 2003) confirms this negative relationship between M and SD(M+) for the last 25 years. Moreover, using four standard deviation above the mode (M + 4SD(M+)) as indicator of maximum normal longevity, the study shows that M + 4SD(M+) is constant or slowly mounting in Hong Kong from 1976 to 2001, the decrease in 4SD(M+) exactly compensating the increase in M.

Endeavour in human longevity is still preoccupied within human history (Manton and Singer, 1994) and measurement in human longevity is regarded as one of the most important topics in demography (Bongaarts and Feeney, 2002). Generally, longevity is measured by life expectancy at the population level and the maximum life span at the individual level (Manton *et al.*, 1999; Wilmoth, 2000, 2001; Hayflick, 2002) but not satisfactorily. This is because infant and premature deaths are included in life expectancy and the maximum life span is dependent on the sample size. The measurement in human longevity is still a major concern in the field of biology, demography and even fields like gerontology, public health and actuarial science.

When Fries (1980) firstly introduces the question, in the public health with his paper published by the *New England Journal of Medicine*, about the rectangularization of the survival curve and the limits to life expectancy, he was challenged by demographers such as Myers and Manton (1984a and 1984b). Later Olshansky and his colleagues (1990) attempted to find a consensus between bio-medical field and demography proposing the practical limits to human longevity.

In fact, at the beginning of demography, demographers were much open to biology than today. They were strongly interested by the distribution of life durations and not only by the life expectancy, but also by the late mode of life durations indicating the most common longevity (e.g. Lexis, 1878). However, the distribution of individual life durations and the theoretical shapes of the survival curves were mostly discussed by biologists not by demographers in the early period. Since the 1920s Pearl and his colleagues first introduced the idea of survival curves approaching the theoretically possible '*right-angled form*' (Pearl and Doering, 1923) and proposed to classify the observed survival curves in three groups, the rectangular, intermediate, and diagonal types (Pearl and Miner, 1935). They noted that this theoretical type of survival curve is approached, though not precisely realized by starved *Drosophila*. The rectangular type describes the situation where all the individuals in a cohort live for the same length of time, and all die at the same instant of time. This work was followed by other biologist (Deevey, 1947) and later the term of rectangularization of the survival curve was developed by Comfort (1956 and 1964).

Comfort proposed (1964) three possibilities to discuss the limits of human longevity. He points out that the rectangularization of the survival curve seems biologically the least likely pattern for us to achieve (Comfort, 1964, pp.275). He proposed that the human survival curve, in societies possessing developed medical services and a high standard of living, should be intermediate between the rectangular and log-linear contour. He underlines that in neither case the biological program is "*really detachable from the social program which coexists with it, and which plays equally important part in the determination of selection or survival*." Therefore, he proposes "*the more probable possibility – a scalar expansion of survival curve – means of prolonging the period of adult vigour, either alone, or with proportional prolongation of the pre-adult and the senile stage*"[1] (Comfort, 1964, pp. 275).

Later, Strehler (1975) proposes that the human survival could be improved with a combination of pharmaceutical, dietary and immunological manipulations and means for reinstating repressed gene functions and/or reinsertion of deleted portions of the genome. Fries (1980) discards the most probable possibility as proposed by Comfort (1964) about a scalar expansion of survival curve instead of developing his proposition and popularizing the research question based on the least likely pattern for human beings to achieve in a biological sense – Huxley's Brave New World[2] (Comfort, 1964, pp.275).

The current empirical values of life expectancy at birth in the low mortality countries are calling into question not only "the proposed *value* for the limit" but also even "the *concept* of limit" (Wilmoth, 1998; Vaupel *et al.*, 1998; Gavrilov and Gavrilova, 1998;

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[1] Comfort (1964) proposed the third possibility, but the least profitable one. What he says is that it might be possible to prolong the total duration of life only by prolonging the stages prior to maturity. This seems to be the nature of the McCay effect observed in rats. What he saying is interpolating 5 or 10 years at a physical and mental age of 12 and stopping the clock at a later age before human complete a normal life-cycle (pp.275-6).

[2] A situation of Huxley's Brave New World is in Alex Comfort's book referring to where people remained apparently young until high ages and then died suddenly at approximately the usual time. This would produce a nearly square survival curve with its limit short of the century. It might prove possible, first of all, to lengthen the period of adult vigor without increasing the final life-span (1964, pp.275).

Oeppen and Vaupel, 2002; Robine, 2003). Kannisto *et al.,* (1994) highlighted that life spans will rapidly increase in the near future partly as a result of the acceleration in the rates of mortality decline among the elderly in developed countries during the past few decades. Future of life expectancy is still strongly debated (Olshansky *et al.*, 2001).

But is life expectancy the right indicator to measure human longevity? Many authors (Wilmoth, 1998, 2000 and 2001; Chen, Liu and Tu, 1999; Tuljapurkar *et al.*, 2000; Horiuchi, 2000; Wilmoth *et al.*, 2000; Robine, 2001; Oeppen and Vaupel, 2002) showed that the increase in the life expectancy at birth is mainly attributed to the reduction in infant, child and young adult mortality before the first half of the twentieth century. Wilmoth and Horiuchi (1999) propose that limits to life expectancy and the rectangularization of the survival curve are independent phenomena and need to be studied separately.

The importance of the normal distribution of ages at death and normality has been underlined by many scholars (Fries, 1984; Rothenberg *et al.*, 1991; Manton, Stallard and Corder, 1999, Olshansky *et al,* 2002) and used recently by Horiuchi (2003) applying into the other species. The emergence of the concept of normal life durations thanks to the last work of Kannisto (2001). He demonstrated that the late mode is the natural indicator for measuring the common longevity. Kannisto (1988) already emphasizes the importance of determining *the mode of the natural life span* rather than extreme deviations[3] (Kannisto, 1988, pp.403). Later, he (Kannisto, 2001) reiterates the importance of normal life durations, in which life is non-pathological and follows a simple biological law, when one examines survival to old age and human longevity. He proposes to consider only the deaths occurring above the late mode as making up the second half of a normal distribution of life durations. The majority of deaths now occur under this normal distribution.

This paper adopts the improved approach which is proposed by Cheung (2003) to use four standard deviations above the late mode as an indicator of maximum life span ($\omega$) within the normal distribution. This new indicator is similar to life endurancy but free from any percentiles. It indicates the maximum life span within normal life durations. Four standard deviations above the late mode puts aside the outliers to focus only on the highest value within normal life durations. Then looking at the mirror of the estimation of $\omega$, less four standard deviations from the late mode, provides an estimation of $\gamma$, the minimum life span within normal life durations considered as the lower bound for ageing process related mortality. The estimation of $\gamma$, built from the late mode such as the estimation of $\omega$, is free from any age scale and percentile. This solves the problem of the choice of the starting age to measure the deaths related to the ageing process (Myers and Manton, 1984; Manton and Tolley, 1991; Rothenberg *et al.*, 1991) and allows monitoring any increase in the minimum life span related to this process.

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[3] Extreme cases of the oldest persons