

Research Article

A Conjecture on Demographic Mortality at High Ages

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Abstract

The study considers the model of an abstract organism, called Arbitrary Oscillator (ArbO), which is capable of making decisions at each timed step. These decisions are ‘critical’ since, randomly, their outcome can be ‘fatal’ for ArbO, thus bringing its life cycle to an end. If we impose limits on the total number of critical decisions using a fixed parameter TC (Total Cases), we can treat the statistical distribution of fatal events over a large number of ArbOs using statistical mechanics methods. This results in a mathematically definable asymmetric ‘bell’ distribution, which can be compared with demographic mortality curves (dx curves), with an appropriate choice of time scale (one step = five years). The possibility of modeling and therefore predicting the trend of demographic mortality is of great scientific and social interest. Our conjecture assumes that, as demographic longevity improves, i.e., with the lengthening of lifespan, the actual demographic curves will increasingly match the mathematical distribution curve of our ArbO. The statistical distribution of the ArbO was introduced by the author in a previous paper and is here recalled and formalized analytically and its characteristics are detailed. The above said conjecture is based on two case studies: mortality in the United States from 1900 to 2017 and mortality in Italy from 1974 to 2019. The conjecture, applied to both case studies, appears reasonable. Tables and comparison figures are provided to support this. Also, an attempt to predict demographic mortality behavior and limitations for the years to come is provided. Finally, the more general theme of the nature of human aging can also be related to our conjecture, since it can highlight the presence of an absolute limit on the number of ‘critical’ events (the TC parameter). As ‘critical’ events accumulate over time by aging, approaching the final limit value, the probability of death will tend toward one.

Keywords

Demographic Mortality, Cellular Automata, S-System Distribution, Demographic Life Tables, Aging

1. Introduction and Recalls

Operating on demographic Life Tables, mortality curves can be obtained that illustrate the number of deaths in a given age interval when that age interval spans a lifetime. These statistical data are normally presented from year to year in tabular form for a standard number of total cases (100,000 people) and represent the evolution of life possibility to the social conditions of the demographic community under consideration. A typical generic mortality curve takes the form

presented in [Figure 1](#). Three main highlighted areas are noted: an area A representing infant mortality, an area B representing a quasi-constant number of deaths (i.e., not very dependent on age), and finally an area C related to the more evident peak mortality at advanced ages. The sum $A+B+C$ leads to 100000 dx events.

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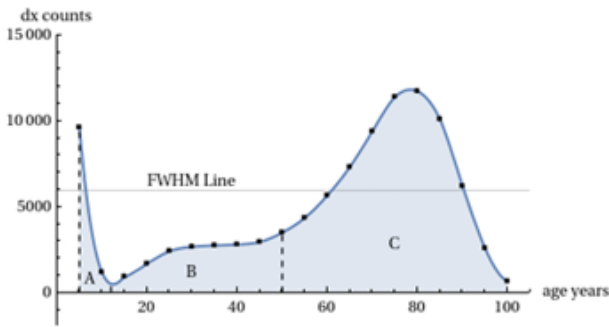


Figure 1. Mortality poll points & interpolated curve with A, B, C areas and FWHM line along age intervals.

The plotted single points correspond to demographic mortality data i.e. the deceases (called dx counts in the Life Table) for the considered age interval (in this case five years wide). The continuous curve is the interpolation of the point data. A horizontal line is also presented useful to define the FWHM (Full Width at Half Maximum) parameter associated to the curve peak. The FWHM figure measures the age width of the segment intercepted between the FWHM line and the continuous curve. In this study we present the thesis that, as lifespan increases, the mortality curve also changes, converging to a curve of a statistical type that we refer to as the S-system curve. In other words, areas A and B will tend to cancel out, while area C will follow the pattern of an S-type curve (which itself has no significant A or B component). This curve is describable analytically as a function of a time variable (age of the person) and a parameter equal to the total area subtended by the curve. This curve formula was presented in a study as per Ref. [1] (also detailed in Ref. [2]). In that Ref. [1] work we introduced the S-system object and its properties. Correlated to this we also introduced the so-called Arbitrary Oscillator (ArbO). The curve under discussion is derived by the analysis of these two objects. Hereunder we provide some recall of these concepts for the ease of the reader. In the second section we describe in more detail the characteristic of the curve while in the other following sections we deal with the mortality real demographic data and their possible convergence toward the theoretical mortality curve including a possible future mortality forecast. Finally, the conclusions test the credibility of the conjecture and outline possible areas of research development a for further confirmation of the conjecture.

S-systems mathematical definition

The S system of equations is defined as follows:

$$\sum_{i=1}^{\text{imax}} (0.5)^i m_i = 1; m_i \text{ positive or null integers}$$

$$\sum_{i=1}^{\text{imax}} m_i = \text{TC};$$

$$\text{TC} = \text{imax} + 1$$

As a consequence of above equations, the solutions $\{m_i\}$ of

the system must be:

$$0 \leq m_i \leq 2^i \text{ with } 1 \leq i \leq \text{imax}$$

Note that the first eq. can be expressed also in the equivalent form:

$$\sum_{i=1}^{\text{imax}} 2^{\text{imax}-i} m_i = 2^{\text{imax}}$$

obtained by multiplying both members by 2^{imax} .

A simple example with TC = 5 can clarify the system. The S system in this case will be:

$$8m_1 + 4m_2 + 2m_3 + m_4 = 16$$

$$m_1 + m_2 + m_3 + m_4 = 5$$

and the three possible solutions are:

$$\begin{array}{llll} m_1 \rightarrow 0 & m_2 \rightarrow 3 & m_3 \rightarrow 2 & m_4 \rightarrow 0 \\ m_1 \rightarrow 1 & m_2 \rightarrow 0 & m_3 \rightarrow 4 & m_4 \rightarrow 0 \\ m_1 \rightarrow 1 & m_2 \rightarrow 1 & m_3 \rightarrow 1 & m_4 \rightarrow 2 \end{array}$$

The arbitrary oscillator object

The ArbO object can be associated to a S^{TC} system. We imagine indeed, just like the classic harmonic oscillator well known in physics, an object that can move between two fixed positions, but on the contrary with the classic oscillator, the "decision" to move to and from is not sure but aleatory. So, the Arbitrary Oscillator, at any step of time r (or clock step), can stay still or jump to the other position. If we tag the "decisions" with a label "0" or "1" meaning e.g. stay or move, we can have a sequence of decisions or "cells" list like e.g. $\{0,1,0,0,1,\dots\}$ that define the story of the motion and relevant "decisions". We see also that at any previous decision two next future decisions, 0 or 1, can arise. So, all around the clock time, the number of possible sequences will expand in an exponential way: 2^r . But if we admit the possibility to have some "death" instance (again as random instance) at one or more of the possible choices available at the generic step r , we will have a choice count at step r not exponentially determined but only defined by the preceding evolution as follows:

(Equation group S) (EGS):

$$m_r + v_r = 2v_{r-1};$$

$$0 \leq m_r, v_r \leq 2^r;$$

$$m_r, v_r \text{ integers; } v_0 = 1; r \geq 1$$

where m_r, v_r represent the number of mortal events and safe events respectively at the end of the r th step. This process can continue indefinitely or stop when at some "rend" step we will reach $v_{\text{rend}}=0$. At this moment the ArbO device will not have any more v "fuel" to generate the next step. In this case there will be a total final count of previous m_r, v_r integer numbers

and if we fix a max. m_r sum defined as TC ("Total Counts") we will result in a S^{TC} system as shown hereunder.

The math of ArbO

The mathematical description of the ArbO object is conditioned to a criterion of max limit of evolution: the ArbO can't indefinitely evolve, so a limit is imposed with the condition:

$$\sum_{r=1}^{R_{\max}} m_i = TC$$

Coming back to the above (EGS) eq.s, we observe that this lead also to a recursive solution:

$$v_r = 2^r - \sum_{t=1}^r 2^{r-t} m_t$$

meaning that the v_r , as expected, depends from the evolution of the m_r . Imposing the existence of an $R_{\max}$ such that $v_{R_{\max}}=0$, we will result into a system of diophantine equations like:

(Equation Group EGDS) (EGDS)

$$\sum_{r=1}^{R_{\max}} m_r = TC;$$

$$\sum_{r=1}^{R_{\max}} 2^{-r} m_r = 1;$$

$$R_{\max} = TC - 1;$$

$$\sum_{r=1}^{R_{\max}} v_r = TC - 2;$$

$$Q_r = m_r + v_r;$$

$$\sum_{r=1}^{R_{\max}} Q_r = 2(TC - 1);$$

We see that the first three eq.s of (EGDS) are the usual S^{TC} equations system previously introduced. We conclude that a diophantine S^{TC} system describes the ArbO object to which we can add also the v_r variables (specific of the ArbO mechanism) that, at any rate, are fully determined by the independent m_r variables. For the already known example of $TC=5$ we have then all the following possible solutions, including the v_r variables:

$$8 m_1 + 4 m_2 + 2 m_3 + m_4 = 16$$

$$m_1 + m_2 + m_3 + m_4 = 5$$

$$\{ \{ m_1 \rightarrow 0, m_2 \rightarrow 3, m_3 \rightarrow 2, m_4 \rightarrow 0, v_0 \rightarrow 1, v_1 \rightarrow 2, v_2 \rightarrow 1, v_3 \rightarrow 0, v_4 \rightarrow 0 \} \\ , \{ m_1 \rightarrow 1, m_2 \rightarrow 0, m_3 \rightarrow 4, m_4 \rightarrow 0, v_0 \rightarrow 1, v_1 \rightarrow 1, v_2 \rightarrow 2, v_3 \rightarrow 0, v_4 \rightarrow 0 \} , \\ \{ m_1 \rightarrow 1, m_2 \rightarrow 1, m_3 \rightarrow 1, m_4 \rightarrow 2, v_0 \rightarrow 1, v_1 \rightarrow 1, v_2 \rightarrow 1, v_3 \rightarrow 1, v_4 \rightarrow 0 \} \}$$

The ArbO configurations

The (EGDS) eq.s does not fully describe the ArbO possible evolutions sequences. The (EGDS) describe the total quantities of m_r, v_r along the r steps evolution, but these do not specify on which "cell" (or decision place), from the Q_r available, the effective deadly events occur. This aleatory

condition holds for all the solutions of a S system, in the sense that given a particular solution, one can wonder about the number of the associated configurations (i.e. 0,1 sequences) to this specific solution. Now considering the exponential growth of the number of solutions in the above systems, this growth is again more enhanced for the possible associated configurations. For example (Ref. [2]) with $TC=21$, the S system will cover 30410 different $\{m_r, v_r\}$ solutions. Between these solutions there will be one (or some) with the maximum number of configurations.

For the $TC=21$ case, this max. number of configurations results in 14.112.000 configurations.

The most probable solution

Applying the methods of the Fermi statistics (by virtue of some formal analogies between the arbitrary oscillator model above described and the quantum models studied in the last century by E. Fermi, (Ref. [3]), one seeks for the most probable solution of a ArbO - S system i.e. the solution that shows the higher number of configurations compatible with some boundary limiting conditions. In Ref. [1] we found a recursive equation to compute this maximum likelihood solution. We also identified an analytic representation of this discrete solution with a continuous real r variable. This theoretical ArbO most probable mortality $m(r)$ has the following form, with " r " intended as a time continuous variable and TC a parameter equal to the area under the curve:

$$m(r, TC) = 2^{2r - \frac{(1+2g) \text{Log}[2^{rF} + 2^r g]}{g \text{Log}[2]}} c1 \quad (1)$$

The g, k terms are numbers while $c1$ and rF are constant depending only from the TC parameter, as follows, where Log is the natural logarithm function:

$$g = (1 - k); k = \text{Log}(2);$$

$$c1 = (1 + g)(2^{rF} + g)^{1 + \frac{1}{g}k}; \quad (2)$$

$$rF = \frac{\text{Log}(-2+TC)}{k};$$

In according with the S -System EGDS equations, also for the continuous form $m(r, TC)$ the following conditions will hold:

$$\int_0^\infty m(r, TC) dr = TC; \quad (3)$$

$$\int_0^\infty m(r, TC) 2^{-t} dt = 1;$$

2. Properties of the $m(r, TC)$

If we look to all the terms in eq.s (2) we see that they can be reduced to numbers or to a function of TC . Then, by substituting them into Eq. (1), we obtain the following expression of $m(r, TC)$, that we will rename as $mTC(r, TC)$:

$$mTC(r, TC) = -4^r(-1 + TC - \text{Log}[2])^{1+\frac{1}{1-\text{Log}[2]}}(-2 + \text{Log}[2])\text{Log}[2](-2 + 2^r + TC - 2^r\text{Log}[2])^{\frac{3-\text{Log}[4]}{-1+\text{Log}[2]}} \quad (4)$$

As r varies from zero to Infinity, the curve takes on a 'bell' shape with a peak at position ' r_{peak} ' on the r -axis and going to zero at Infinity. This ' r_{peak} ' depends only from the TC parameter by means of a logarithmic law:

$$r_{\text{peak}} = \frac{\text{Log}[2(-2+TC)]}{\text{Log}[2]} \quad (5)$$

The possible correlation with mortality curves

Equation (4) shows a function that depends on the variable r . As already mentioned, this continuous variable is linked to the recursive variable that identifies the time steps in the evolution of the cellular automaton ArbO. Now -in the general ArbO model scheme- it would be in principle possible to associate the mTC with biological species capable of developing decision-making capacities between basic alternatives including death issues possibilities, i.e. such that they can be modelled with our Arbitrary Oscillator discussed above. But if we wish to extend this general mechanism of evolution to such real situations, we must introduce the following relationship that links the generic time step to the organism's life-time:

$$r = a / u \quad (6)$$

where ' a ' may represent the age of the evolving organism and ' u ' a time constant characteristic of the specific organism. Both a and u will be expressed in the same unit of time. For example, we may have a and u expressed in days, weeks, months or years. An e.g. value of r equal to 20 can thus be obtained from the ratio of $a=100$ days and $u=5$ days or the ratio of $a=100$ years and $u=5$ years. This last example therefore means that -after 20 steps of time intervals ' u '- the age of 100 years will be reached. It will then be possible to associate the generic ArbO clock variable r with the age a of the individuals considered in the demographic Life Tables. The ' u ' will be linked to the specific biological species and must be

considered as a constant. These different ArbO modeled species will show a mortality trend with a peak age ' a_{peak} ' positioned on the age a -axis. This a_{peak} will then be given by the following formula coming from the eq. (5):

$$a_{\text{peak}} = u \frac{\text{Log}[2(-2+TC)]}{\text{Log}[2]} \quad (7)$$

Our mTC will then become, replacing r with (a / u) in the eq. (4), a function of a and TC :

$$mTC(a, TC) = -4^{a/u}(-1 + TC - \text{Log}[2])^{1+\frac{1}{1-\text{Log}[2]}}(-2 + \text{Log}[2])\text{Log}[2](-2 + 2^{a/u} + TC - 2^{a/u}\text{Log}[2])^{\frac{3-\text{Log}[4]}{-1+\text{Log}[2]}}$$

This $mTC(a, TC)$ will then represent the number of deaths due to the theoretical component expressed by the ArbO model, in the interval of amplitude ' u ' between ' $a-u$ ' and ' a ', with a as a continuous sliding variable of age. In our case of interest, i.e. that of demographic mortality expressed in human Life Tables, we will take a value $u = 5$ years as a constant figure for all subsequent considerations and computations. Our mTC then will become:

$$mTC(a, TC) = -4^{a/5}(-1 + TC - \text{Log}[2])^{1+\frac{1}{1-\text{Log}[2]}}(-2 + \text{Log}[2])\text{Log}[2](-2 + 2^{a/5} + TC - 2^{a/5}\text{Log}[2])^{\frac{3-\text{Log}[4]}{-1+\text{Log}[2]}} \quad (8)$$

The general shape of the curve:

To visualize the shape of $mTC(a, TC)$ on the age axis, we will need to choose an arbitrary conventional value of TC , which we will take e.g. as $TC=100000$. Figure 2 shows the plots of the function $mTC(a, TC)$ (in the following called " mTC ") for the e.g. case where $TC = 100000$. The mTC values are called ' dx counts' for similarity with the Life Tables mortality data. It is also shown the ' a ' value (a_{peak}) that leads to the curve maximum (in this case $a_{\text{peak}} \sim 88$ years). It appears that, with reference to Figure 1, for the mTC curve the areas A and B, introduced in Section 1, are almost negligible or absent. The mTC curve shows also a slight left asymmetry around the curve peak.

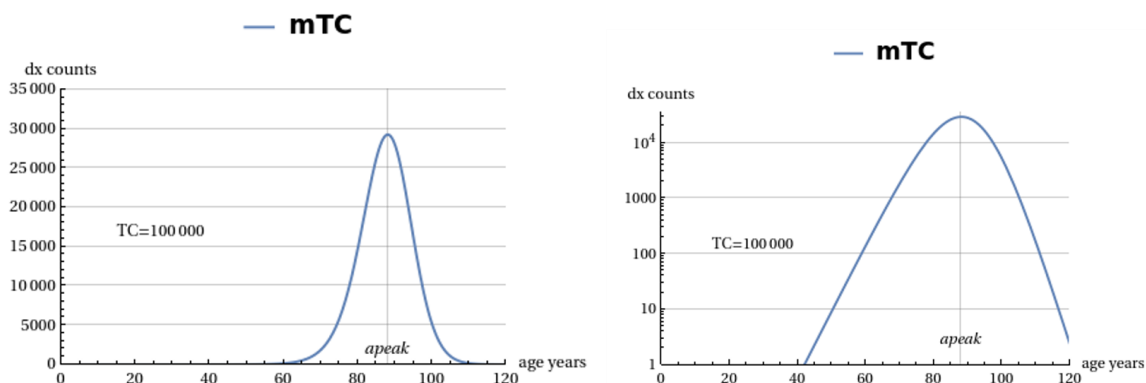


Figure 2. Linear and Log plot of the $m(a, TC)$ as function of a , with $TC=100000$.

The definite integrals

An interesting property of $mTC(a, TC)$, coming from eq.'s (3) above, is also that the area under the curve itself, is proportional to the parameter TC and the continuous equations of the system S are still valid, as per the following formulae:

$$\int_0^{\infty} mTC(a, TC) da = 5 TC;$$

$$\int_0^{\infty} mTC(a, TC) 2^{-a/5} da = 5; \quad (9)$$

The TC due to an apeak value

The apeak value depends only by TC, i.e. fixed a TC value we obtain a curve with the apeak of eq. (7):

$$apeak = 5 \frac{\text{Log}[2(-2+TC)]}{\text{Log}[2]}$$

The reverse also holds in the sense that if we deal with a mTC function and we define an apeak value this leads to a unique TC parameter value as per eq. (5):

$$TC = 2 + 2^{-1+\frac{apeak}{5}} \quad (10)$$

The mTC 'normalized' form

The mTC function area under the curve is proportional to TC according to eq. (9). This means that e.g. with a TC value growing we will have an mTC curve expanding in size and position on age axis. This size expanding effect could be avoided by dividing the mTC by TC leading to a mTCn function:

$$mTCn(a, TC) = -4^{\frac{a}{5}}(-1 + TC - \text{Log}[2])^{1+\frac{1}{1-\text{Log}[2]}}(-2 + \text{Log}[2])\text{Log}[2] \left(-2 + 2^{\frac{a}{5}} + TC - 2^{\frac{a}{5}}\text{Log}[2]\right)^{\frac{3-\text{Log}[4]}{-1+\text{Log}[2]}} / TC \quad (11)$$

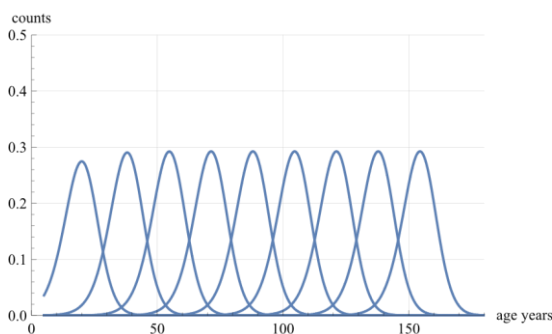


Figure 3. Plots of normalized $mTCn$ with $TC=10^n$, with $n=1,2,\dots,9$.

With the normalized form we can easily study the various curves shapes vs different TC values, as in Figure 3. Here the $mTCn$'s are plotted over nine orders of magnitude of TC, namely from 10, 100,..., 10^9 . We see that the apeak varies as expected shifting the plots to high apeaks. However, with exception of the initial plots, the other curves shapes look like very similar in shape and maximum height.

The mTCnp function

It can be useful for the further analysis to express the mTC also as function of a and apeak (=ap) by using the (10) relation. We obtain:

$$mTCnp(a, ap) = -\frac{1}{4+2^{ap/5}} 2^{2a/5} (1 + 2^{-1+\frac{ap}{5}} - \text{Log}[2])^{\frac{1}{1-\text{Log}[2]}} (-2 + \text{Log}[2]) \text{Log}[2] (2^{a/5} + 2^{-1+\frac{ap}{5}} - 2^{a/5} \text{Log}[2])^{\frac{3-\text{Log}[4]}{-1+\text{Log}[2]}} (2 + 2^{ap/5} - \text{Log}[4]) \quad (12)$$

The mTCnx function and the S-system distribution

A further step can be taken, in describing the mTC function, again by means of algebraic transformations. We formalize a mTCnx function where $x = a - ap$. In this way, we want to study the shape of the normalised mTC curve when the age variable x varies around the peak of maximum mortality. This function mTCnx becomes:

$$mTCnx(x, TC) = -\frac{1}{TC} 2^{2x/5} (-2 + TC)^2 (-1 + TC - \text{Log}[2])^{1+\frac{1}{1-\text{Log}[2]}} (-2 + \text{Log}[2]) \text{Log}[2]^{\frac{-2+\text{Log}[2]}{-1+\text{Log}[2]}} \text{Log}[4]^2 \left(- \left((-2 + TC) (-2^{x/5} \text{Log}[4] + \text{Log}[2](-1 + 2^{x/5} \text{Log}[4])) \right) \right)^{\frac{3-\text{Log}[4]}{-1+\text{Log}[2]}} \quad (13)$$

The normalized mTCnx function is useful for showing some aspects of the S-system distribution, particularly the near-invariance of shape and maximum height as a function of TC values, as seen in Figure 4. Here about nine out of 10 curves are concentrated on a small range of very similar heights. This is seen in the total graph as a seemingly single curve with a maximum height of about 0.29. This is in agreement with the patterning of the curves shown in Figure 3. Moreover, we see also a common slight asymmetry around the peaks leading to a minimal left skewness (also shown in the right graph of Figure 2). This feature is not inconsistent with the greater left lateral asymmetry of current demographic curves.

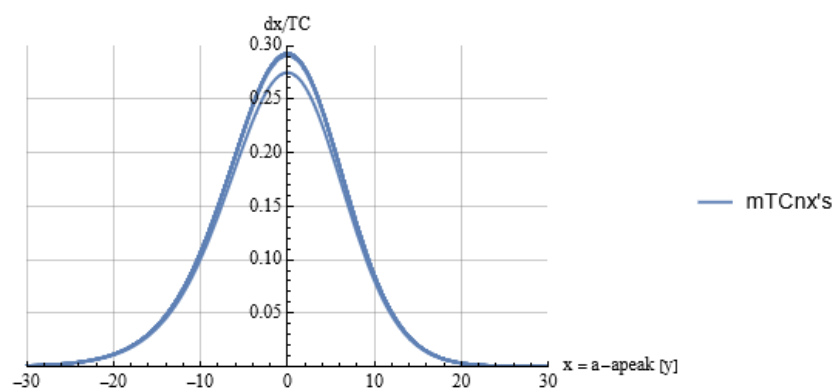


Figure 4. Plots of normalized $mTCnx$ with $TC=10^n$, with $n=1,2,\dots,9$.

The height limit of the theoretical mortality curve

Considering relation (13) above, we see that the point of maximum height of the generic curve will be given by

$$\text{Limit}(mTCnp(ap, ap), ap \rightarrow \text{Infinity}) = -4 \frac{\text{Log}[\frac{\text{Log}[4]}{\text{Log}[2]}]}{\text{Log}[2]} (-2 + \text{Log}[2]) \text{Log}[2] (3 - \text{Log}[4])^{\frac{3 - \text{Log}[4]}{-1 + \text{Log}[2]}} \quad (14)$$

where the second member of eq. (14) is an absolute number, whose value is 0.292541, which then in the conventional case of the Life Tables of 100000 deaths leads to a peak limit value of 29254 cases for our standard age interval of five years. This limit is asymptotic for $mTCnp(ap, ap)$ although for practical purposes it is actually reached -in the theoretical curve case- by the age of about 60 years. Note that this limit value is a number independent from the parameter 'u' and therefore appears as an absolute limit for our general Life Tables max. peaks.

The full width at half maximum limit of the theoretical mortality curve

If, as conjectured in the present study, mortality curves are to hold up to a theoretical mTC curve as lifespan increases, then it will also be interesting to assess the 'shape' of these curves to see whether they approximate the theoretical shape of the mTC. This evaluation will have to be done on a measurable basis and to this end we resort to the curve FWHM (full width at half maximum). To obtain a computable FWHM, the following equation must be solved in the unknown 'a':

$$mTCnp(a, ap) = mTCnp(ap, ap)/2 \quad (15)$$

In our case, the solutions can be expected to be two values, a_1 and a_2 , with $a_1 < ap < a_2$ and the sought-after value of FWHM will be equal to:

$$\text{FWHM} = a_2 - a_1$$

Unfortunately, equation (15) is transcendent in nature and therefore very difficult to solve analytically. With numerical techniques, however, it is possible to provide quite significant results as shown in the next Figure 5.

$mTCnp(ap, ap)$. It will then be possible to study its value as ap -and consequently TC - tend to infinity. It turns out from the calculations that:

Age peak year	$10^5 * mTCnp(ap, ap)$	a_1 [y]	a_2 [y]	FWHM [y]
15	26 718.1	6.85785	22.4807	15.6228
30	28 675.4	21.8579	37.4807	15.6228
45	29 175.8	36.8579	52.4807	15.6228
60	29 244.2	51.8579	67.4807	15.6228
75	29 252.9	66.8579	82.4807	15.6228
90	29 253.9	81.8579	97.4807	15.6228
105	29 254.1	96.8579	112.481	15.6228
120	29 254.1	111.858	127.481	15.6228
135	29 254.1	126.858	142.481	15.6228

Figure 5. Reference limit FWHM computation.

It can be seen from Figure 5 that the FWHM appears invariant over the entire range of 'ap' values and that therefore the reference value for the FWHM to be set for the actual curves is approx. 15.6 years. The second column shows the max. height of the $mTCnp$ and the asymptotic convergence to the max. value above defined. It should be noted, however, that while the height limit of normalized mTC is independent of the choice of species parameter u, the FWHM depends on the specific choice of u and thus can be considered constant if u is assumed to be constant (as in our case).

3. Comparison Between the Real Demographic Data and the mTC Function

The comparison method

In order to check our conjecture, depicted in the Introduction, we need to compare the real Life Tables mortality data with the possible convergence with our mTC function. To this

task we will use the following steps:

- for any real data set (country, survey year) interpolate the data and find the maximum apeak ¹(*)
- also find the TC corresponding to this peak (eq. (10))
- by scaling, plot an mTC curve with the TC and apeak found and with the same maximum as the real data curve
- Also plot a "difference curve" (D-curve) obtained by subtracting the above scaled mTC from the real curve
- measure the FWHM of the interpolated real curve and the area of the D-curve and see the trend with respect to the survey years

To clarify this method, Figs. 6 and 7 are useful. In Figure 6, the dotted curve represents actual demographic data appropriately interpolated with a continuous curve. The continuous curve below the dotted curve is our mTC function scaled to match the same peak. In Figure 7, we have the D-curve with two vertical lines showing the location of the Figure 6 peak and also the location of a secondary peak on the left.

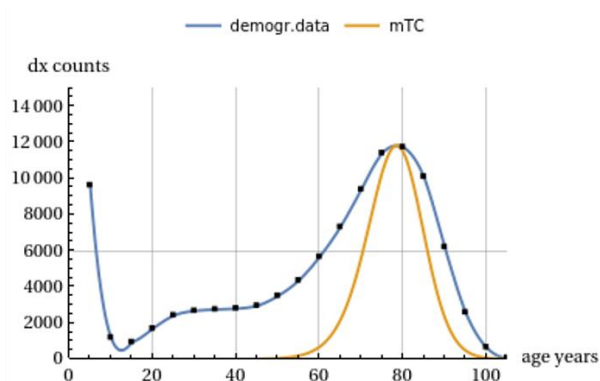


Figure 6. Plots of interpolated demographic data and a compliant mTC.

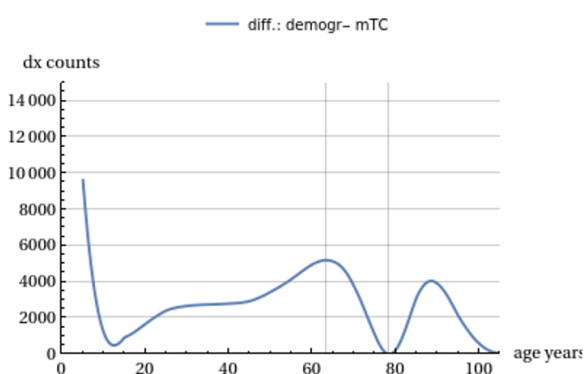


Figure 7. Plot of difference between demographic data curve and mTC curve.

The selection of demographic data

A large amount of mortality demographic data is available for the various countries and year of collection. We here chose to use both Italy and USA data. The ISTAT data for Italy are available at Ref. [4]. These data span a 45-years period from 1974 to 2019 (having excluded years after 2019 to avoid statistical peculiar effects due to Covid 19). The USA data were processed from a database of tables made available in the works in Ref. [5] and [6]. The USA data range runs from the year 1900 to the year 2017 mainly in ten years steps, while the Italy data are available at five years intervals. For this comparison of trends over time, it is also useful to consider differences between subsets of data that may affect the total sum result. In particular, significant differences are found between male and female mortality and also between regional subsets (not included at this stage of the study). All these different data sets were subjected to comparison with theoretical predictions of the mTC function using the method described above. The data sets used for this study are given in tables collected in the Appendix. In the following we provide some of the graphic evidences obtained and the relevant numerical figures for the main significant magnitudes. Even if total unisex data have been processed and available, we provide hereunder the above said comparison results limited for respectively USA male and female mortality and Italy male and female mortality. The graphs hereunder are presented with the format of Figure 6 and Figure 7. The individual discrete points correspond to the demographic data (available in the Appendix), while the curve joining them is a curve interpolated by a well-known and widely used mathematical computer application. The figures have been minified to give a quick look overview of the evolution of the shape of the curves. The main parameters (peak ages in years unit and areas in dx counts) that can be derived from the data are summarized in the data summary figures at the end of each group of figures. These data highlight interesting data for an evaluation of our conjecture. In particular, the FWHM (years) figure can serve as a comparison with the theoretical FWHM value of an mTC curve (about 15.6 years). A measure of the total areas and individual left and right lobes of the D-curve can also show whether these curves tend to decrease with improvement in lifespan and thus whether there is convergence toward our mTC. The last column of the tables identifies a total "error" value between the possible compatible mTC and the actual curve by summing the absolute values of the two lobes and dividing them by the total area of the demographic curve. In case of perfect coincidence between mTC and real curve, this error should be zero. Note also that for data where infant mortality is very high, the AT deviates slightly from the canonical value of 100000 cases. This is due to interpolation in the initial interval that considers about 50% of the actual value.

¹ (*) The constraint assumed for the continuous curve implies a possible shift (about 2.5 years) to the right of the simulated curve with respect to the real curve. This is not critical for our analysis, as we are looking for structural effects (not influenced by an offset component) and not for an absolute age effect.

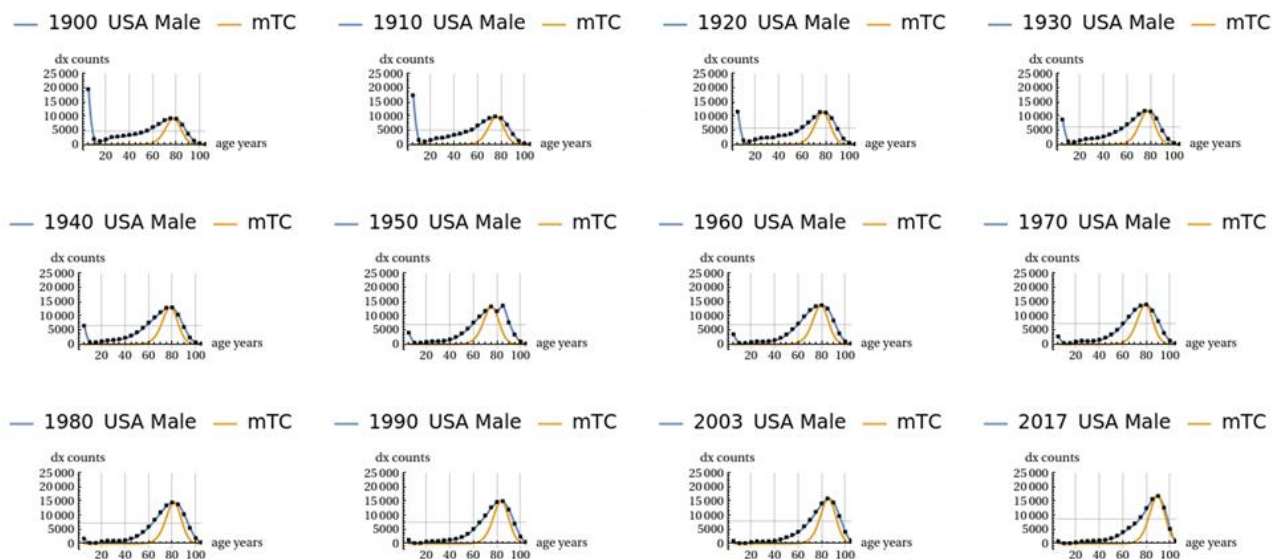


Figure 8. The USA male data comparison - The over-imposed curves graphs.

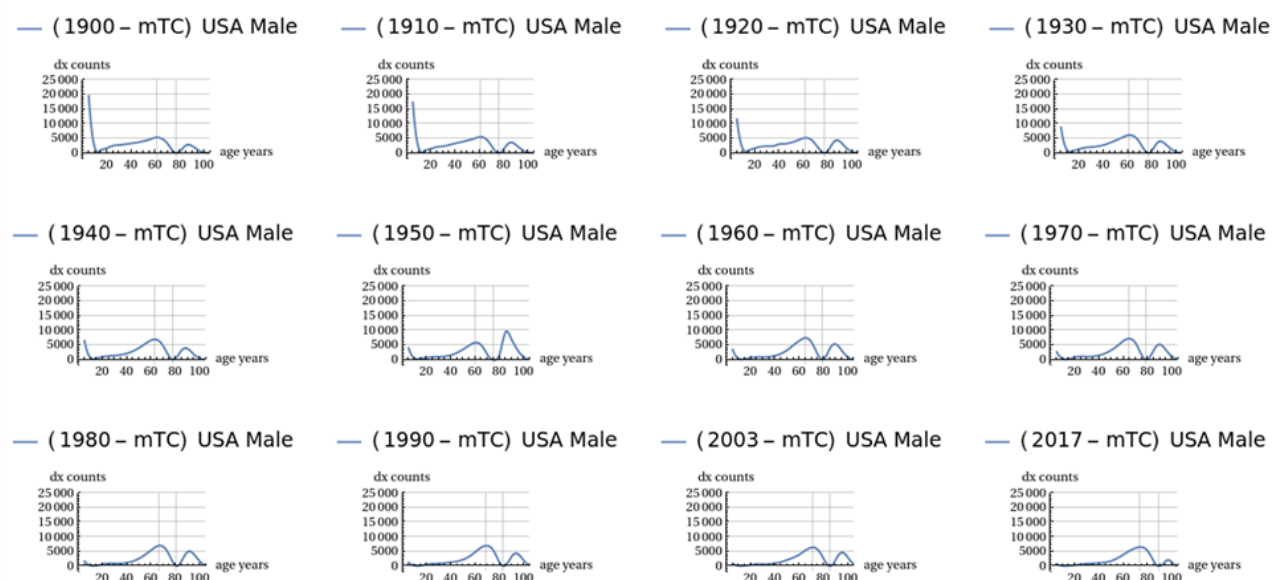


Figure 9. The USA male data comparison -The D-curve graphs.

Year	Sex	2nd Peak left	Peak	Dist. btw Peaks	FWHM	TC	Param.	Area Tot.(AT)	Area Diff.	Area Diff.left(AL)	Area Diff. Right(AR)	(AL + AR)/AT
1900	Male	61.	77.1	16.1	34.6	21 974		87 438	55 856	48 955	6901	63.88%
1910	Male	60.8	75.6	14.8	34.2	17 809		88 802	55 241	46 103	9138	62.21%
1920	Male	61.8	77.1	15.2	30.5	21 776		92 621	53 265	42 436	10 829	57.51%
1930	Male	61.6	76.9	15.3	32.2	21 277		94 386	53 667	43 668	9998	56.86%
1940	Male	62.8	78.	15.1	31.8	24 743		95 837	51 189	41 635	9555	53.41%
1950	Male	60.6	75.	14.4	33.1	16 357		97 392	52 295	30 208	22 088	53.7%
1960	Male	65.	78.9	13.9	32.2	28 129		97 729	50 953	37 962	12 991	52.14%
1970	Male	64.6	78.6	14.	31.6	27 038		98 205	50 484	37 417	13 066	51.41%
1980	Male	67.1	81.	14.	30.3	37 744		98 714	49 161	36 601	12 561	49.8%
1990	Male	68.9	83.2	14.3	29.1	51 167		98 890	47 252	37 309	9943	47.78%
2003	Male	71.1	85.3	14.2	27.2	68 110		98 928	44 689	34 403	10 286	45.17%
2017	Male	73.8	89.	15.1	24.5	113 787		98 960	41 805	38 673	3132	42.24%

Figure 10. USA male summary data.

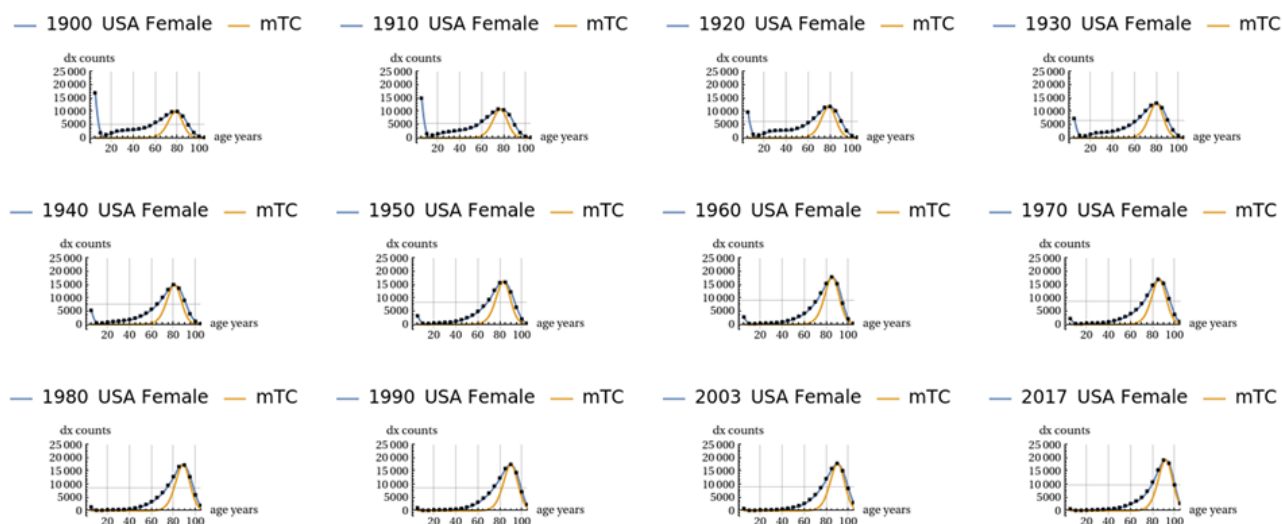


Figure 11. The USA female data comparison- The over-imposed curves graphs.

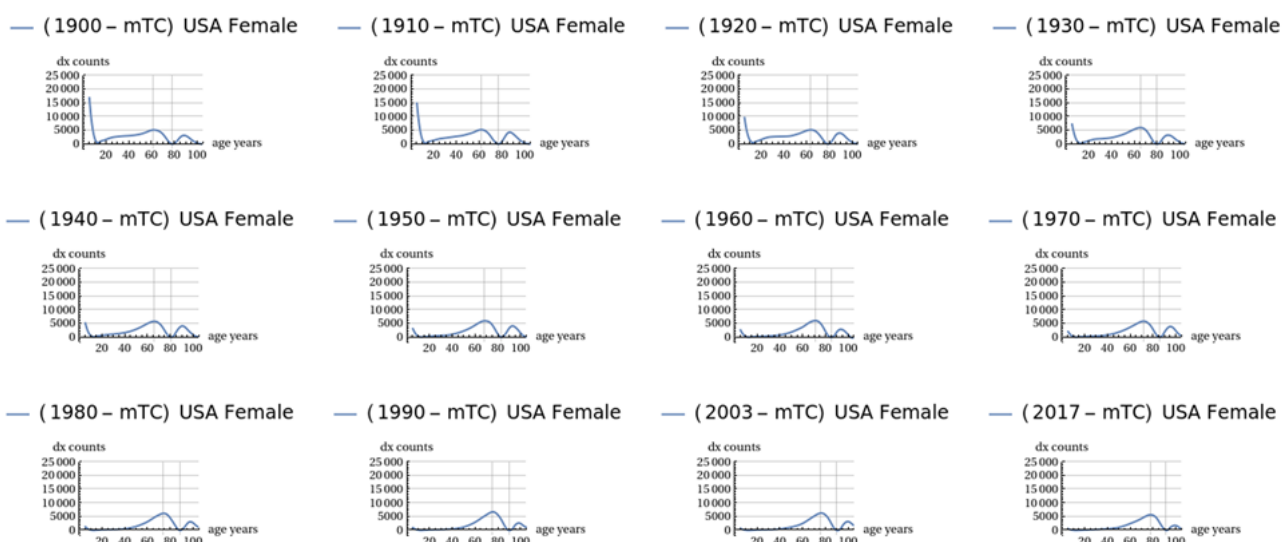


Figure 12. The USA female data comparison - The D-curve graphs.

Year	Sex	2nd Peak left	Peak	Dist. btw Peaks	FWHM	TC Param.	Area Tot.(AT)	Area Diff.	Area Diff. left(AL)	Area Diff. Right(AR)	(AL + AR)/AT
1900	Female	61.7	78.1	16.4	32.6	25052	89123	54965	47217	7748	61.67%
1910	Female	61.6	76.6	15.	31.4	20362	90365	53325	42601	10724	59.01%
1920	Female	63.3	78.4	15.1	29.5	26381	93820	53405	43345	10060	56.92%
1930	Female	65.3	79.6	14.3	28.7	30875	95325	50787	42622	8165	53.28%
1940	Female	65.7	80.4	14.7	26.6	34742	96565	45603	35943	9660	47.23%
1950	Female	68.3	82.9	14.6	25.7	48760	97798	42663	33523	9141	43.62%
1960	Female	70.9	85.	14.1	23.5	65538	98000	37277	31941	5336	38.04%
1970	Female	71.4	85.6	14.1	24.6	70986	98133	40376	31974	8402	41.14%
1980	Female	74.	88.3	14.3	24.2	103346	98181	38835	32570	6265	39.55%
1990	Female	75.2	89.6	14.4	24.8	124863	98267	39179	34225	4954	39.87%
2003	Female	76.	90.	14.	24.2	131069	98257	38090	32076	6014	38.77%
2017	Female	77.6	91.5	14.	21.5	161934	98454	33789	30723	3066	34.32%

Figure 13. USA female summary data.

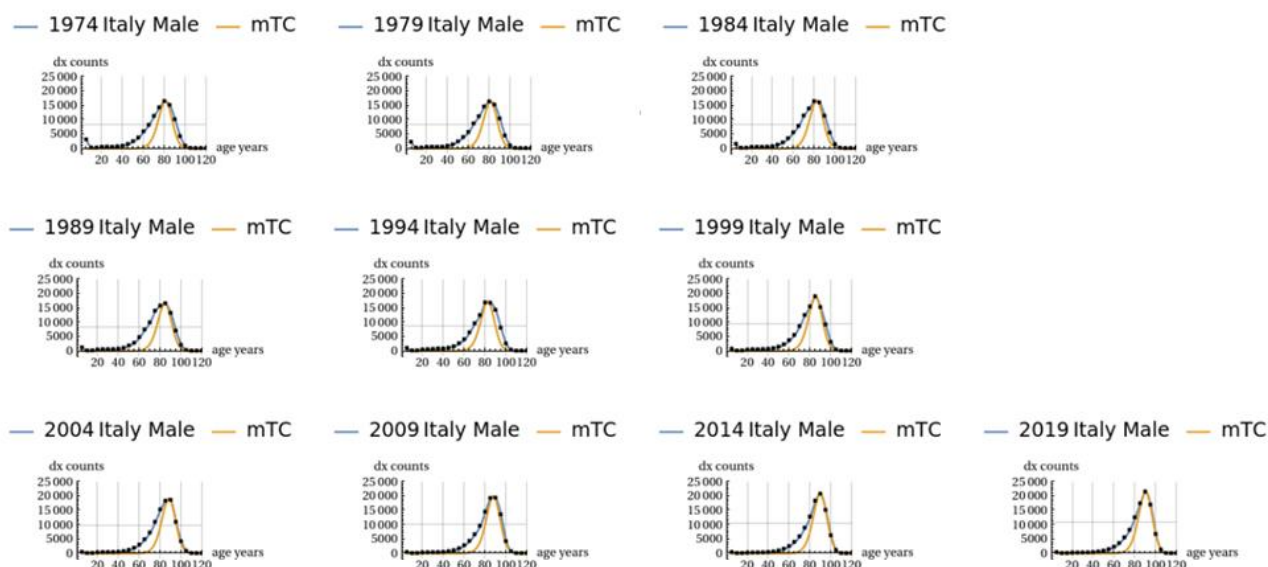


Figure 14. The Italy male data comparison - The over-imposed curves graphs.

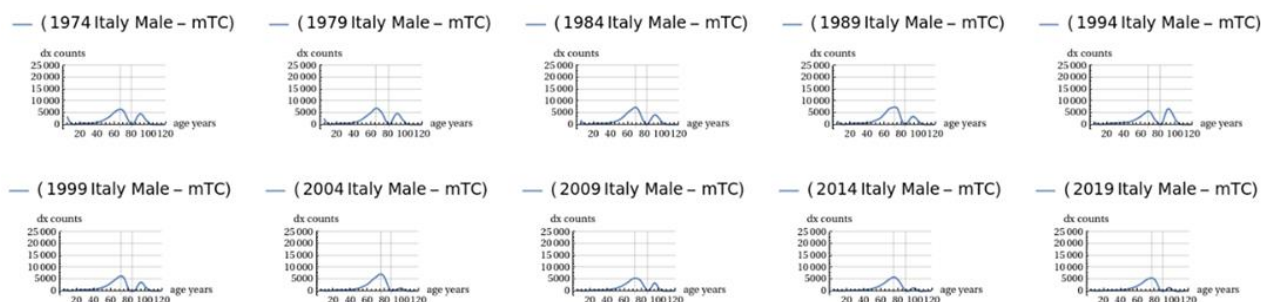


Figure 15. The Italy male data comparison- The D-curve graphs.

Year	Sex	2nd Peak left	Peak	Dist. btw Peaks	FWHM	TC Param.	Area Tot.(AT)	Area Diff.	Area Diff.left(AL)	Area Diff. Right(AR)	(AL + AR)/AT
1974	Male	66.9	80.6	13.7	26.3	35 761	98 022	41 864	31 912	9953	42.71%
1979	Male	65.9	80.8	14.9	27.5	36 676	98 559	42 768	32 554	10 214	43.39%
1984	Male	69.1	82.	12.9	26.7	43 347	99 048	42 245	33 194	9052	42.65%
1989	Male	72.2	84.1	11.9	26.9	57 540	99 265	42 636	35 618	7018	42.95%
1994	Male	68.5	82.2	13.7	26.	44 624	99 406	40 700	25 628	15 072	40.94%
1999	Male	71.8	85.	13.2	23.5	65 538	99 590	34 861	28 044	6817	35%
2004	Male	75.4	88.	12.5	22.6	98 807	99 724	34 495	32 610	1885	34.59%
2009	Male	72.7	87.6	15.	21.4	94 551	99 761	31 670	26 616	5054	31.75%
2014	Male	75.	89.5	14.5	20.4	122 737	99 788	28 797	27 580	1217	28.86%
2019	Male	76.3	90.	13.7	19.9	130 945	99 810	26 463	25 342	1120	26.51%

Figure 16. Italy male summary data.

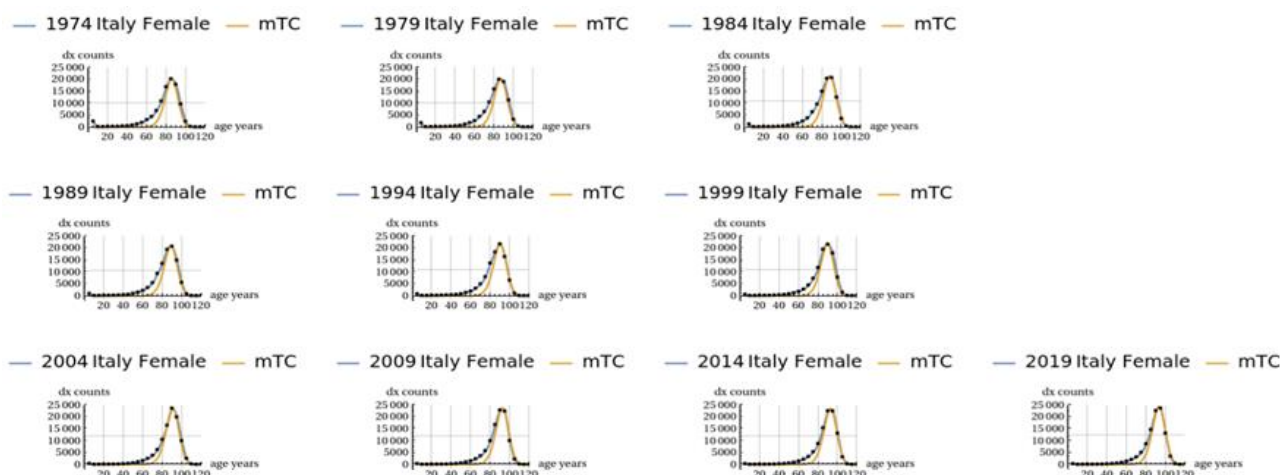


Figure 17. The Italy female data comparison - The over-imposed curves graphs.

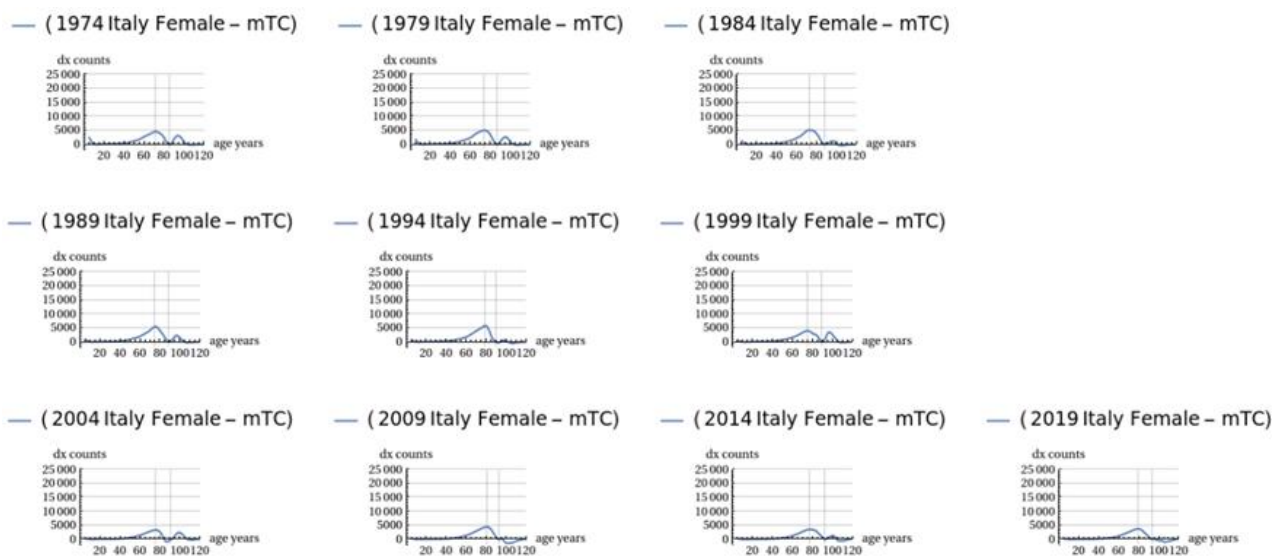


Figure 18. The D-curve graphs.

Year	Sex	2nd Peak left	Peak	Dist. btw Peaks	FWHM	TC Param.	Area Tot.(AT)	Area Diff.	Area Diff. Left(AL)	Area Diff. Right(AR)	(AL + AR)/AT
1974	Female	71.5	85.5	14.	20.5	69 960	98 428	29 490	23 848	5642	29.96%
1979	Female	73.7	86.7	13.	20.9	82 646	98 872	29 727	25 271	4457	30.07%
1984	Female	73.	87.8	14.8	19.8	96 897	99 230	26 291	25 133	1157	26.49%
1989	Female	75.	88.6	13.6	20.8	108 577	99 406	27 955	24 617	3338	28.12%
1994	Female	78.6	90.	11.4	20.1	131 073	99 523	25 487	25 664	-177	25.96%
1999	Female	74.9	89.4	14.5	19.4	119 992	99 658	25 920	20 161	5758	26.01%
2004	Female	75.6	90.5	14.9	17.8	139 670	99 811	19 369	15 020	4349	19.41%
2009	Female	80.8	92.4	11.6	17.7	182 288	99 844	18 963	21 925	-2962	24.93%
2014	Female	77.	92.5	15.5	18.1	185 706	99 888	19 919	18 865	1054	19.94%
2019	Female	78.9	93.1	14.3	17.3	201 847	99 900	17 120	18 910	-1790	20.72%

Figure 19. Italy female summary data.

4. Discussion of the Results

From the graphs and data shown above for the two case studies (U.S. and Italy), there is a general trend of shrinking for areas A and B and also evident is the shrinking FWHM of area C. This occurs in the face of an increase in life span. The shape of area C also approximates the theoretical shape of the mTC function as lifespan improves (improvement measurable by the shift to the right on the age axis of the mortality peak in the succession of different survey years). The process of convergence toward the mTC curve takes place not only with the disappearance of areas A and B (not really present in the mTC model) but also with the gradual narrowing (to the point of disappearing or becoming negative in some cases) of the right-hand lobe of the D-curve. Another remarkable aspect is the difference in parameters (peak, FWHM) between males and females in both case studies. In the case of Italian females, the tendency to converge toward a mTC-type curve is more pronounced. The FWHM of 17.3 years, for year 2019 females, is very close to the theoretical figure of 15.6 years. The area "error" in last table column marking the difference between the actual and theoretical curves areas is also reduced to about 20% in the best case. An interesting aspect is also the relative invariance of the distance in years (around 14 years) between the main peak and the secondary peak to the left of the D-curve. This is even though the area of the left lobe tends to decrease. This invariance holds for the two study cases (USA and Italy). These findings are presented in various graphs that collect the main parameters on a single time scale from the year 1900 to 2019. In Figures 20 and 21 the FWHM datum is given together with the theoretical FWHM level for a mTC function. The downward trend in FWHM compared to demographic surveys is present in both the U.S. and Italian data, although the absolute values of FWHM are generally higher for the United States. This can be explained by considering that the U.S. population is about a factor of five larger than that of Italy, which probably leads to a statistical dispersion between the mortality curves of the two case studies.

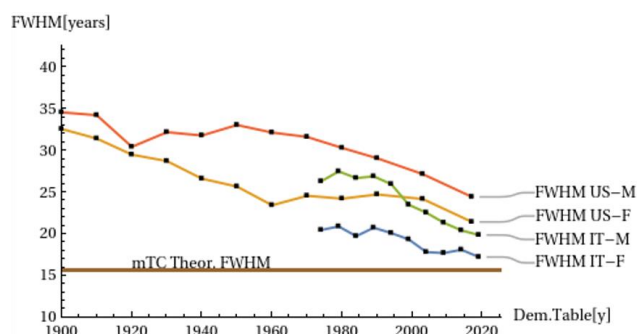


Figure 20. FWHM USA & Italy subsets vs demogr table year.

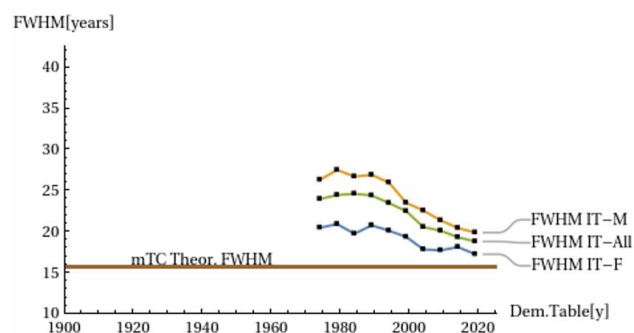


Figure 21. Italy FWHM showing the sex split plus total datum.

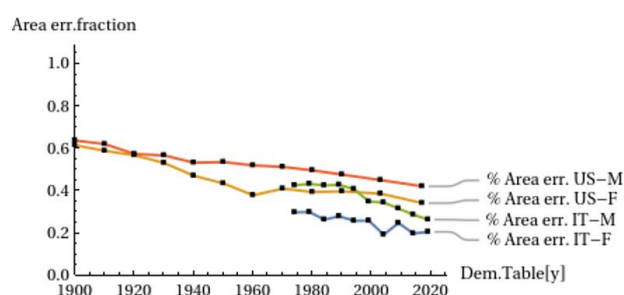


Figure 22. Area "error" for USA & Italy subsets vs demogr. table year.

In Figure 22 the area "error" amount trend is shown.

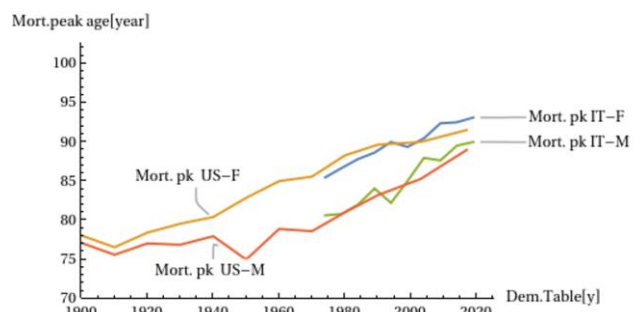


Figure 23. Apeak for USA & Italy subsets vs Dem. table year.

Figure 23 shows the improvement in the maximum mortality peak vs time. This is in particular evident for females in both study cases. The mix effect on "apeak" is also presented for Italy in Figure 24. The overlap of the US and Italy data in the common time period is significant.

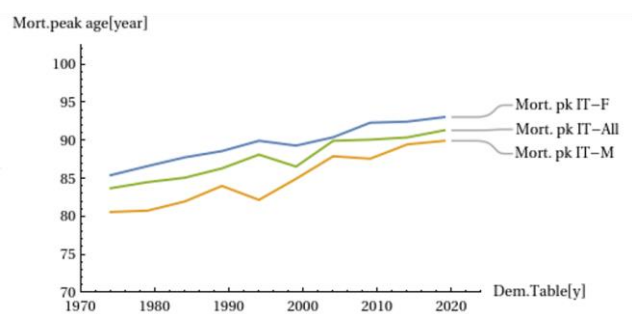


Figure 24. Italy apeak showing the sex split plus total datum.

Figure 25 shows in Log scale the evolution of the curves TC equivalent parameter, confirming the overlap of USA and Italy TC data for the common time interval.

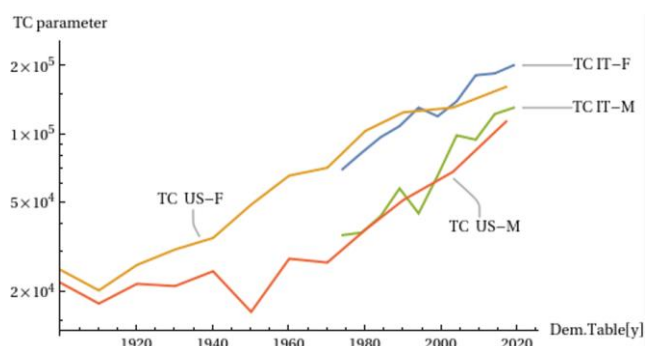


Figure 25. TC parameter Log scale for USA & Italy subsets vs demogr. table year.

5. An Attempt to Forecast Demographic Mortality for the Years to Come

Considering the above data, there is an almost linear trend in the growth of the apeak value (Figure 23). This justifies the assumption of a continuous growth in lifespan. This also allows us to try a forecast for the future evolution of demographic mortality. This can be done by using the mTCnp version of the formula (12) and assuming a future peak change in continuity with the rate of change recorded in the last years of population surveys. The result of this simulation is shown in Figure 26 for the case of Italian females. The figure shows the latest demographic curves (2009 and 2019) along with the theoretical projections of the mTCnp function -multiplied by 100000 for commonality with standard sampled data- when it assumes a constant shift rate for 'apeak' values for the years 2029, 2039, 2049. These peak values are calculated with the same peak growth rate recorded for last year's surveys. It is interesting to note that, as predicted in Section 2, the theoretical mortality curves, while shifting on the age axis, maintain the same shape and height at 29254 deaths (over 100000 total) on the peak mortality. Even this feature that defines an invariant shape and a constant upper limit number of peak

mortality may be useful for validating -or not validating- the conjecture in the future.

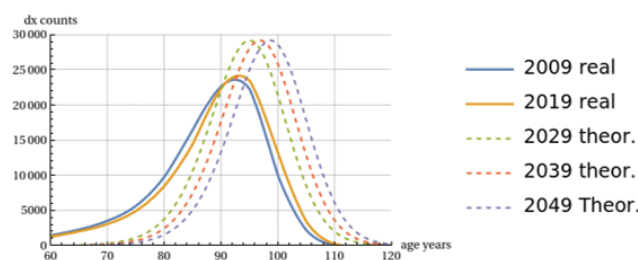


Figure 26. Possible future evolution of demographic mortality according to the conjecture (Italy female case).

Of course, in this hypothetical prediction the demographic curve must also confirm the trend of narrowing left skewness and we must hypothesize an almost disappearance of A and B areas in Life Tables. If these trends were less fast, than the above forecast might be different. In other words, the future curve for 2029 may catch up with the theoretical curve by evolving in the 2019-2029 interval or come close to it without concurring with it and leaving the final overlap for later years. This will depend on the speed of reduction of the left skewness. We can summarize here the features that the conjecture would imply about future mortality curve projections, in particular involving the theoretical limits described in Section 2:

- the peak mortality will never exceed 29254 cases in a 5-year sampling interval
- the FWHM of the curves cannot decline indefinitely but will have a lower limit of 15.6 years with a constant $u=5$ years
- the slope of the descent curve to the right of the peak will be constant regardless of lifespan improvement

A detailed study on the actual practical existence of these theoretical limits in relation to real population curves was made by the author in Ref. [7].

6. Conclusions, Validity of the Conjecture and Aging Theories

The present work is based on a model (the Arbitrary Oscillator - ArbO, Ref. [1]) that generates events that evolve over time and may also include instances of "death." To find the most probable distribution of such events, the Fermi statistic has been used, obtaining a recursive computational algorithm that provides the solution as dependent on a single parameter TC. By means of scaling, the mortality predictions generated by the algorithm can be compared with actual demographic mortality data. This comparison shows similarities of the theoretical curves generated by the algorithm with the shape of the real data. From the Sec. 3 results, the convergence of the real curves toward the theoretical mTC curve as the apeak value increases seems to be realistic. Therefore, the conjecture of the trend convergence of the real mortality data

toward a theoretical S-System type curve in the presence of increasing life span seems reasonable. However, there persists a component of the D curve, namely the left lobe area, which - while trending downward as expected - does not decrease with the same speed as the right lobe area in the time sequence. This fact may suggest a complex structure of components underlying the total real curve. In fact, consider, for example, [Figure 24](#), where a mix effect of the sum of male and female mortality on total mortality is observed, leading to a diversification of the total mortality peak with a shift to the left from the highest peak in the female group. Similarly, there could be diversified components of the theoretical mTC curves that add up generating the leftward bias of the actual curves. In this hypothesis, the trend curve of the theoretical mTC would not be unique, but given by a group or "spectrum" of components of the theoretical mTC's. These sub-components could add up to produce the actual curve. This further analysis can be a research ground for further development and verification of the conjecture. See in this connection also Ref. [\[8\]](#) where a tentative explanation of these sub-components is given. As an additional comment it should be noted that the model to which the conjecture refers is not the result of application of predictive "filters" on data sequences or of exercises in fitting statistical mortality data or an "a-priori" assumption of a mortality probability distribution, but an extension of a theoretical mathematical model (the ArbO model) when applied to demographic mortality data.

The assumed issue of lifespan extension is obviously linked to the issue of aging modelling. Some theories refer to the reliability model Ref. [\[9, 10\]](#) and failure accumulation Ref. [\[11\]](#). Other theories explain aging as a statistical effect Ref. [\[12, 13\]](#). Some other theories predict both the possibility of an indefinite extension of lifespan Ref. [\[14, 15\]](#) and -on the contrary- the implausibility of this hypothesis Ref. [\[16\]](#). Finally, there is also the hypothesis that aging is an effect inherent in evolution Ref. [\[17, 18\]](#). Our conjecture does not provide evidence to determine whether increased longevity is an effect that can continue or whether it is destined to stop. In fact, if the TC parameter is increased, the curves shift towards greater longevity. However, we do not know whether TC will

continue to grow, as appears from the data collected so far, or whether it will stop in the future. Certainly, in our model, the aging of a population is something structurally imposed by the limit on the number of possible 'critical' cases, i.e., by the TC parameter. Once TC is set for a population of organisms following the ArbO model, the accumulation of critical events will inevitably approach the accumulation limit of 'fatal' events, leading to 'critical' events always deadly ended. Aging, i.e. the approaching to the end of life with advancing age, therefore appears to be an inevitable statistical fact predicted by the 'more probable' solution of the equations set of the ArbO model.

Abbreviations

ArbO	Arbitrary Oscillator
TC	Total Cases
FWHM	Full Width at Half Maximum

Author Contributions

Giuseppe Alberti is the sole author. The author read and approved the final manuscript.

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Data Availability Statement

The data supporting the outcome of this research work has been referred in this manuscript.

Conflicts of Interest

The author declares no conflicts of interest.

Appendix

In the following pages we provide the demographic data at the origin of the study.

Age interv. [y]	1900	1910	1920	1930	1940	1950	1960	1970	1980	1990	2003	2017
0-4	19 452	17 282	11 495	8706	6376	3923	3357	2605	1667	1246	900	739
5-9	1773	1469	1321	948	570	351	268	244	173	127	80	62
10-14	1094	988	1028	785	546	360	268	247	188	163	114	92
15-19	1697	1469	1716	1341	891	671	616	778	656	610	456	358
20-24	2512	2117	2188	1861	1232	904	860	1086	955	805	689	678
25-29	2725	2297	2362	2013	1376	930	805	968	931	883	650	836
30-34	2995	2764	2376	2271	1638	1101	937	1075	929	1075	720	951
35-39	3305	3317	3082	2718	2125	1553	1317	1456	1156	1330	970	1088
40-44	3598	3779	3188	3475	2910	2388	2080	2172	1696	1622	1440	1293
45-49	4113	4400	3691	4364	4082	3661	3293	3299	2642	2274	2135	1798
50-54	4797	5148	4588	5537	5627	5377	5160	4931	4071	3373	3000	2740
55-59	6044	6627	6048	7072	7485	7535	7152	7181	5924	5114	4121	4021
60-64	7159	8079	7699	8755	9366	9680	9710	9640	8366	7407	6032	5506
65-69	8519	9241	9550	10 638	11 188	11 616	11 933	12 022	10 965	9864	8312	7053
70-74	9141	9810	11 352	11 798	12 724	13 194	13 294	13 499	13 409	12 722	11 153	9261
75-79	8992	9271	11 188	11 546	12 869	11 519	13 650	13 876	14 462	14 636	14 148	12 429
80-84	6905	6883	9208	9065	10 302	13 487	12 455	11 753	13 790	14 934	15 892	15 656
85-89	3671	3557	5393	4824	5906	7553	8236	8061	10 288	11 937	14 445	16 752
90-94	1246	1213	1971	1832	2201	3242	3639	3781	5453	6951	9633	12 617
95-99	240	256	494	411	508	834	853	1104	1856	2398	4085	5099
>100	22	33	62	40	78	121	117	222	423	529	1025	971

USA mortality 1900-2017, Male*Figure A1. Usa mortality data 1900-2017, male.*

Age interv. [y]	1900	1910	1920	1930	1940	1950	1960	1970	1980	1990	2003	2017
0-4	16 881	14 883	9620	7211	5152	3092	2629	2045	1334	994	718	607
5-9	1729	1389	1194	781	446	256	198	171	122	95	65	52
10-14	1083	915	939	644	402	221	157	148	112	97	74	61
15-19	1752	1395	1691	1248	707	365	260	305	248	217	194	146
20-24	2436	1937	2421	1788	971	483	338	365	301	272	246	251
25-29	2725	2234	2672	1930	1140	650	422	422	332	312	273	340
30-34	2931	2528	2750	2094	1372	727	587	578	411	417	358	460
35-39	3056	2825	2806	2377	1718	1105	849	869	609	563	562	590
40-44	3286	3139	2953	2886	2236	1632	1295	1304	961	811	869	796
45-49	3706	3754	3502	3585	3028	2394	1938	1941	1510	1290	1267	1154
50-54	4507	4609	4353	4624	4120	3381	2876	2786	2300	2051	1808	1775
55-59	5753	6166	5661	6037	5615	4804	4021	3927	3346	3139	2694	2606
60-64	6909	7788	7312	7871	7570	6771	5968	5441	4894	4667	4159	3566
65-69	8525	9522	9385	10 150	10 074	9246	8362	7743	6800	6553	6001	4959
70-74	9727	10 761	11 397	12 174	13 024	12 762	11 706	10 848	9534	9235	8633	7293
75-79	9865	10 473	11 731	13 022	14 901	15 625	15 331	14 662	12 814	12 301	12 018	10 753
80-84	8066	8631	10 098	11 256	13 552	15 818	17 794	16 907	16 600	15 871	15 870	15 327
85-89	4757	4782	6201	6666	8928	12 120	15 213	15 378	17 194	17 449	17 803	19 042
90-94	1854	1828	2586	2849	3849	6341	7863	9595	12 716	14 320	15 027	17 839
95-99	409	392	656	725	1016	1909	1929	3611	5935	7095	8408	9686
>100	43	49	72	82	179	298	264	954	1927	2251	2952	2697

USA mortality 1900-2017, Female*Figure A2. Usa mortality data 1900-2017, female*

Age interv. [y]	1974	1979	1984	1989	1994	1999	2004	2009	2014	2019
0-4	3042	2219	1487	1149	949	666	473	410	389	363
5-9	214	172	138	103	101	72	58	46	42	39
10-14	213	194	158	131	129	106	74	70	50	49
15-19	478	429	419	389	416	323	260	218	148	138
20-24	538	503	477	523	518	499	367	305	224	206
25-29	479	483	447	531	606	475	383	329	248	229
30-34	634	522	518	548	758	556	380	360	290	265
35-39	862	833	690	682	756	653	502	444	398	354
40-44	1441	1320	1237	1006	1016	884	724	676	580	572
45-49	2424	2372	2004	1809	1509	1393	1142	1030	947	883
50-54	3686	3869	3451	2751	2553	2189	1865	1678	1526	1393
55-59	5839	5623	5488	4694	3938	3633	2961	2729	2433	2213
60-64	8109	8608	7770	7339	6366	5481	4844	4267	3906	3503
65-69	11 222	11 117	11 339	9835	9519	8540	7165	6565	5849	5498
70-74	14 196	14 495	13 833	13 909	12 360	12 402	10 896	9534	8868	8146
75-79	16 400	16 282	16 350	15 679	16 788	15 376	15 223	14 444	12 711	12 473
80-84	15 055	15 177	15 953	16 500	16 686	18 936	18 243	19 207	18 257	17 349
85-89	10 049	10 340	11 280	13 157	14 205	15 171	18 540	19 308	20 733	21 459
90-94	4166	4400	5427	6975	7965	9123	10 890	13 512	15 069	16 910
95-99	882	961	1393	2035	2516	3057	4144	4167	6208	6665
100-104	70	79	140	245	335	447	817	671	1073	1229
105-109	1	2	4	8	13	20	47	31	52	65
110-114	0	0	0	0	0	0	0	0	0	1
115-119	0	0	0	0	0	0	0	0	0	0

Italy mortality 1974-2019, Male*Figure A3. Italy mortality data 1974-2019, male.*

Age interv. [y]	1974	1979	1984	1989	1994	1999	2004	2009	2014	2019
0-4	2412	1742	1206	951	791	590	408	350	323	305
5-9	144	113	98	77	81	59	43	42	34	33
10-14	125	114	90	81	84	67	48	44	40	38
15-19	183	154	139	125	136	123	96	86	65	58
20-24	224	176	153	158	150	147	104	98	80	75
25-29	251	215	179	182	220	161	122	106	97	92
30-34	369	284	258	242	277	226	160	144	133	128
35-39	499	462	380	379	361	316	256	222	224	208
40-44	798	684	662	570	530	488	402	376	352	349
45-49	1271	1131	1011	981	829	795	668	620	581	550
50-54	1865	1778	1576	1429	1316	1178	1065	1018	906	828
55-59	3033	2583	2437	2172	1928	1783	1600	1513	1395	1322
60-64	4331	4345	3770	3408	3085	2697	2453	2327	2160	2063
65-69	6860	6461	6351	5375	4913	4439	3745	3580	3299	3124
70-74	10 825	10 375	9546	9249	7885	7280	6167	5722	5270	5000
75-79	16 790	15 818	14 897	13 451	13 604	11 735	10 410	9881	8690	8573
80-84	20 142	19 922	20 321	19 358	18 257	19 401	16 351	16 591	15 252	14 569
85-89	17 798	18 907	20 624	20 657	21 659	21 525	23 489	22 727	22 398	22 507
90-94	9557	11 251	12 428	14 844	16 353	17 830	19 820	22 284	22 334	23 485
95-99	2332	3168	3522	5492	6470	7696	9924	9947	13 000	13 014
100-104	187	310	345	785	1021	1380	2480	2182	3150	3404
105-109	4	8	9	33	49	79	187	139	215	271
110-114	0	0	0	0	1	1	3	2	3	4
115-119	0	0	0	0	0	0	0	0	0	0

Italy mortality 1974-2019, Female*Figure A4. Italy mortality data 1974-2019, female.*

References

- [1] G. Alberti "Fermi statistics method applied to model macroscopic demographic data." arXiv preprint arXiv:2205.12989 (2022).
- [2] S-Q-U Systems Web Site, Available from: <https://squ-systems.eu/> [Accessed 13 November 2025]
- [3] E. Fermi, "Molecules, Crystals and Quantum Statistics", W. A. Benjamin, 1966, pag. 264 and subseq.
- [4] Istituto Italiano di Statistica, "ISTAT Data", Available from: <https://esploradati.istat.it/databrowser/#/en> [Accessed 13 November 2025]
- [5] L. A. Gavrilov and N. S. Gavrilova, "Mortality Measurement at Advanced Ages: a Study of the Social Security Administration Death Master File", North American Actuarial Journal. 15(3): 432-447. <https://doi.org/10.1080/10920277.2011.10597629>
- [6] Elizabeth Arias and Jiaquan Xu, "United States Life Tables, 2017", NVSS, Volume 68, Number 7, June 24, 2019.
- [7] G. Alberti "On two asymptotic limits for demographic mortality Life Tables data" <https://doi.org/10.13140/rg.2.2.27428.86405>
- [8] G. Alberti "More on the mortality conjecture: the components of demographic mortality" <https://doi.org/10.13140/rg.2.2.14304.46086>
- [9] P. Y. Nielsen, M. K Jensen, N. Mitarai, S. Bhatt "The Gompertz Law emerges naturally from the inter-dependencies between sub-components in complex organisms" <https://doi.org/10.1038/s41598-024-51669-5>
- [10] L. A. Gavrilov and N. S. Gavrilova, "The Reliability Theory of Aging and Longevity" J. theor. Biol. (2001) 213, 527-545.
- [11] V. Flietner, B. Heidergott, F. den Hollander, I. Lindner, A. Parvaneh, H. Strulik, "A Unifying Theory of Aging and Mortality", <https://doi.org/10.48550/arXiv.2412.12815>
- [12] G. A. Shilovsky, A. V. Seliverstov1, O. A. Zverkov, "Demographic indicators, models, and testing", <https://doi.org/10.22363/2658-4670-2023-31-4-359-374>
- [13] S. Azaele, A. Maritan and S. S. Suweis, "Recent developments and future perspectives in statistical mechanics of ecological systems", <https://doi.org/10.1209/0295-5075/ade9ec>
- [14] D. McCarthy, P.L. Wang, "Mortality postponement and compression at older ages in human cohorts", <https://doi.org/10.1371/journal.pone.0281752>
- [15] A. Kondyurin, "Chemical kinetic theory of aging". <https://doi.org/10.48550/arXiv.2303.05585>
- [16] S. J. Olshansky, B. J. Willcox, L. Demetrius & H. Beltrán-Sánchez, "Implausibility of radical life extension in humans in the twenty-first century", <https://doi.org/10.1038/s43587-024-00702-3>
- [17] Roget T., MacMurray C., Jolivet P., M é árd S. and Rera M, "A scenario for an evolutionary selection of ageing", <https://doi.org/10.7554/eLife.92914.2>
- [18] Mark T. Mc Auley, "The evolution of ageing: classic theories and emerging ideas", <https://doi.org/10.1007/s10522-024-10143-5>