IS LIFE EXPECTANCY AT BIRTH REALLY THE BEST MEASURE OF MORTALITY IN A POPULATION?

EVGENY ANDREEV

It is generally considered that the most adequate indicator of mortality in any population in a certain calendar period is life expectancy at birth (LE). Yet this indicator has serious drawbacks, and its use leads to a number of unjustified difficulties. The main limitation is that the method for calculating life expectancy is still not unified and most likely never can be. As a result, LE for different countries and periods may not be comparable. The data of the international Human Life-Table Database makes it possible to demonstrate that in LE comparisons it is often impossible to use the first decimal digit.

Computation of LE requires the calculation of life tables for a hypothetical cohort corresponding to the calendar period under consideration. When mortality declines rapidly, as has been the case in most countries since the mid-20th century, life tables for a hypothetical cohort say little about the age patterns of cohort mortality, and instead form false impressions. Counting how many people in a hypothetical cohort survived or did not survive to a certain age has no relation to any real population.

The transition from age-specific mortality rates to life expectancy is described not by a formula but by a computational procedure. This creates serious difficulties when trying to assess the impact of mortality at certain ages from certain causes of death in certain regions and population groups.

All these drawbacks are not shared by the standardized death rate (SDR), the calculation of which becomes the only option as soon as the standard population is specified. Data from the Human Life-Table Database allowed us to show that mortality level estimations based on SDR almost coincide with those based on LE.

SDR is a linear function of age-specific mortality rates; therefore, it is not difficult to calculate the effect of mortality in certain ages, regions or population groups and from different causes of death on SDR.

Non-professionals perceive LE on an intuitive level as the duration of a human life, which is rather a drawback of the indicator. The use of SDR requires more explanation. But in practical research and in professional publications, focusing on SDR will facilitate the work and protect against unwarranted emotions.

Key words: *mortality, life expectancy, standardized mortality rate, mortality rate*.

INTRODUCTION

It is generally accepted that the most adequate characterization of the level of mortality in the population at a certain period of time is the indicator "life expectancy at birth" (LE).

The indicator is perceived as the life expectancy of a certain person, and due to this it is easily understood on an intuitive level. As evidenced by materials from the national projects "Demography" and "Healthcare", this indicator requires no comment, while the simpler indicator "total fertility rate" (TFR) does. However, in our opinion, a good understanding of the meaning of the indicator at an intuitive, everyday level often interferes with a correct interpretation. Of a person who lived 75 years it can be said that he lived a long life, but for a modern European country, LE of 75 years is considered to be low.

EVGENY ANDREEV (e.andreev@hse.ru), NATIONAL RESEARCH UNIVERSITY HIGHER SCHOOL OF ECONOMICS, RUSSIA.

To determine LE in a certain time period, it is necessary to calculate a life table (survival table) for the population under study. With the use of modern computer technology, this is not at all difficult, but the difficulty is that the method for calculating such tables has not yet been unified, and there is no single correct method for calculating the life table. The list of calculation methods used since the Second World War would take up more than one page. In Russia, the method of calculating official life tables has changed at least 5 times over this period. The UN Population Division, WHO, and Eurostat use different tabulation methods, and these are for countries providing the complete demographic data required for the calculation.

In countries where mortality is analyzed by different research centers or groups of demographers, discrepancies in the results of LE calculations are common. And although the differences are small, they are sufficient to treat with caution not only the second decimal place in the LE value, but often the first one as well.

The calculation of LE sometimes gives results that contradict logic. In the late 1980s, when life tables for the republics of the USSR began to be published, it turned out that if the life tables for the entire, both urban and rural, population of a republic are calculated according to standard rules as for independent populations, then LE for the entire population can turn out to be more or less than for the urban and the rural populations, i.e. not a kind of average for the two subpopulations, which is contrary to logic.

It happens that a generally reliable method for calculating life tables has its own “skeleton in the closet”, which no one likes to talk about, but tries to get around. Thus, at present the most popular formula for converting from the age-specific mortality rate to the probability of death is the Chang formula (Chiang 1984). However, in the case of one-year age groups, this formula assumes that the death rate is no more than 1, and for a five-year interval no more than 0.2. In real statistics, the one-year rate may well be greater than 1. Usually such rates decrease in one way or another.

Even if the authors of the tables report which method they used to calculate the life table, this does not guarantee complete comparability of the results obtained by the "named" method. Even the use of the same software with the same data format, which also affects the result of the calculation, is not a guarantee of comparability. Data for one-year and five-year age groups may be used, and the series may extend beyond 100 years of age, but they may end in an open age group A years and older. It's good if A = 100, but in the history of Russia there have also been cases where A = 70. At that point, determining the life expectancy at age A becomes a rather difficult task, allowing many solutions.

When calculating the life table using the MortPak software package developed at the UN, at different beginnings of the open age interval (the package provides such an opportunity), you can get a different result.

The algorithm for calculating the life table may contain logical branches; the program itself decides what to do if the age-specific mortality rate is greater than the maximum that allows the use of the Chang formula, how to continue calculations if the denominator for calculating the mortality rate is zero, how if both the denominator and the numerator are equal to zero, and so on.

In this article we will try to:

1. convince the reader not to overestimate the accuracy of LE as a measure of mortality;
2. show that LE cannot serve as an exhaustive characteristic of the level of mortality in the period for which it is calculated;
3. demonstrate alternative, no less informative, but easier to calculate measures of mortality.

DATA

This article is based on two databases.

The first is the Human Life-Table Database (HLD) (Max Planck Institute… 2021), collected mainly by The Max Planck Institute for Demographic Research in Rostock (Germany). At the time of this writing, there were 10,903 pairs of male and female life tables that began at birth.

The collection includes both published, including official, life tables, and tables sent by their authors, as a rule, university research centers or well-known research groups. Many publications contain only part of the indicators of life tables. Only publications are used that make it possible to unambiguously restore the table, for example, those containing a number of age probabilities or mortality rates or survival numbers. A range of life expectancy for all ages is required.

The HLD uses the following procedure. Each life table is fully recalculated based on the selected, most informative series. The standard life table is supplemented by an original series of life expectancies for all ages. Such a table is entered in the database as a text file. In addition, a copy of the original life table is entered in the database, usually in PDF format.

The second database is The Human Mortality Database (HMD) (University of California … 2021), which is the result of a collaboration between the staff of the University of California, Berkeley and the Max Planck Institute for Demographic Research. The database contains information on the mortality of countries for the years when these data are recognized as reliable. At the beginning of 2021, it contained mortality data for the population of 50 countries, their parts or population groups since 1750. The total number of {population, year} pairs was 4,769. For brevity, we will also refer to the {population, year} pair as an observation. For each observation, the database contains the average annual population by sex and age, the number of deaths by sex, age, and Lexis triangles, age-specific mortality rates, and life tables built on the basis of these indicators.

Calculation algorithms used in HLD and HMD are detailed on the database sites.

ON THE ACCURACY OF LE

To assess the accuracy of an LE value, we compared for the same tables the author's values for LE with the values calculated by us using a standardized algorithm.

Only in 3,374 (30.95%) men's tables and 3,079 (28.24%) women's tables does the author's LE coincide with the calculated one with an accuracy of two decimal places. In our opinion, this is a very good result.

On the other hand, it turns out that for 1,643 (15.07%) men's tables and 2,886 (26.47%) women's tables, the absolute difference between the two LE exceeds 0.2 years. Many problems are associated with estimating LE at the last, oldest age presented in the table. That is why the differences in women are more significant than in men.

Either way, the risk of error when comparing LEs seems to be very high.

WHAT THE CALENDAR PERIOD LIFE TABLES SAY

To determine LE for a certain calendar period, it is necessary to calculate the life table in some way. The table is a model of the change with age in the number of a certain generation of people who were born and lived their lives under the influence of mortality in the period under study. This generation is called hypothetical or conditional. Probably, if the model were to appear today, it would be called a virtual generation. The life table contains data on the decrease with age in the size of the conditional generation and on how many years the members of the generation still have to live at each age.

In the middle of the last century, the official name of life tables in Russia was "tables of mortality and average life span" (TsSU USSR 1962). The word "expected" replaced the word "average" only in the late 1980s.

The expanded name indicates that the determination of life expectancy was considered the main purpose of calculating the life tables of the calendar period. To what extent is this assumption correct?

For practical purposes, such as demographic projections or population estimates, one needs mortality rates and, based on them, easily calculated probabilities of death or survival and probabilities of surviving a calendar year. In Russia, this last indicator is called the survival rate and is described as the ratio of neighboring numbers of people living in a conditional generation at the age of *x*+1 and *x*. It allegedly follows from this that the scope of application of the numbers of the living is not only the calculation of LE. But there is a simple formula which for some reason is not found in Russian textbooks. The survival rate at age x is equal to $P_x = \frac{2 - M_{x+1}}{2 + M_x}$, where M_x is the death rate at this age.

The indicators of life tables are involved in the calculation of integral characteristics of reproduction, such as the net reproduction rate of the population, which have been rarely used lately.

Table indicators can be useful when comparing mortality in two calendar periods. In particular, a number of indicators are used to assess the contribution of age intervals to a change in LE (Andreev 1982). Demographers know how to use these indicators for various useful calculations. But the problem is that all indicators covering any long age interval have nothing to do with reality. Their usefulness is that they help to describe changes in mortality in a "broad stroke", so to speak. However, since all age-specific mortality rates are intergenerational, the results may well be unstable over time. Analyzing data on mortality in Russia in recent years, we have repeatedly found that the contribution of individual age intervals to the change in life expectancy varies markedly from year to year. In addition, such a calculation can be made without life tables only on the basis of age-specific coefficients.

The idea of a conditional generation arose in the 19th century, when mortality changed slowly, and it seemed that there was no difference between conditional and real generations. When carefully reading the book by S.A. Novoselsky (1916), you suddenly realize that the author is comparing countries outside of time; the period for which the life table is calculated seems to him insignificant. At that time, no one sought to distinguish between age-related changes in mortality in conditional and real generations.

In the second half of the 20th century, when the mortality rate in most developed countries was declining extremely rapidly, the series of age-related mortality intensities of conditional and real cohorts did not lose their similarities, but the differences between them became obvious. In Figure 1, we compared the curve of age-specific mortality rates for the generation born in 1946 in England and Wales with similar curves for three conditional generations of 1951, 1981 and 2011. The cohort curve reflects 2 processes: the change in mortality with age and the decrease with time. It seems to pierce the curves for calendar years.

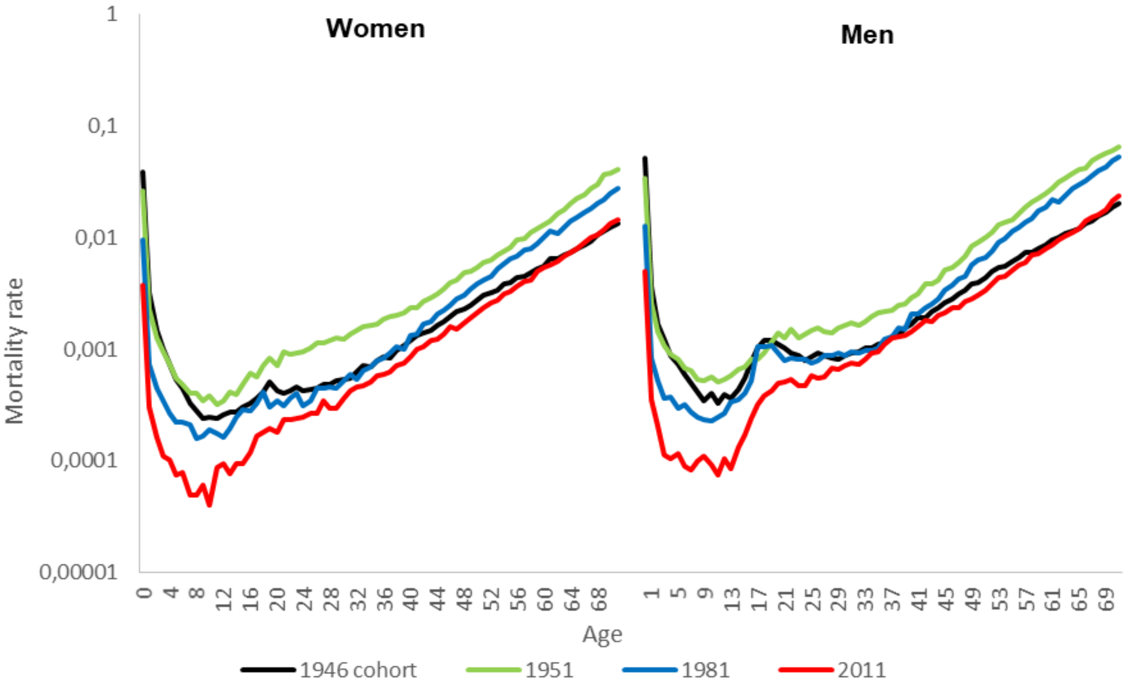

Figure 1. Comparison of age-specific mortality curves of the 1946 cohort and conditional generations of 1951, 1981 and 2011, England and Wales, general population. Semi-log scale.

Source: (University of California… 2021).

In Russia, sufficiently reliable data exist only after 1959, so the curves in Figure 2 are approximate estimates of the author. Since the decrease in mortality at older ages in Russia began much later than in Western Europe, the lines for real and conditional generations after 50 years lie closer to each other. However, Figures 1 and 2 show that in both cases there is hardly any possibility you can use tables for conditional generations to estimate the chances of the average person surviving to retirement age.

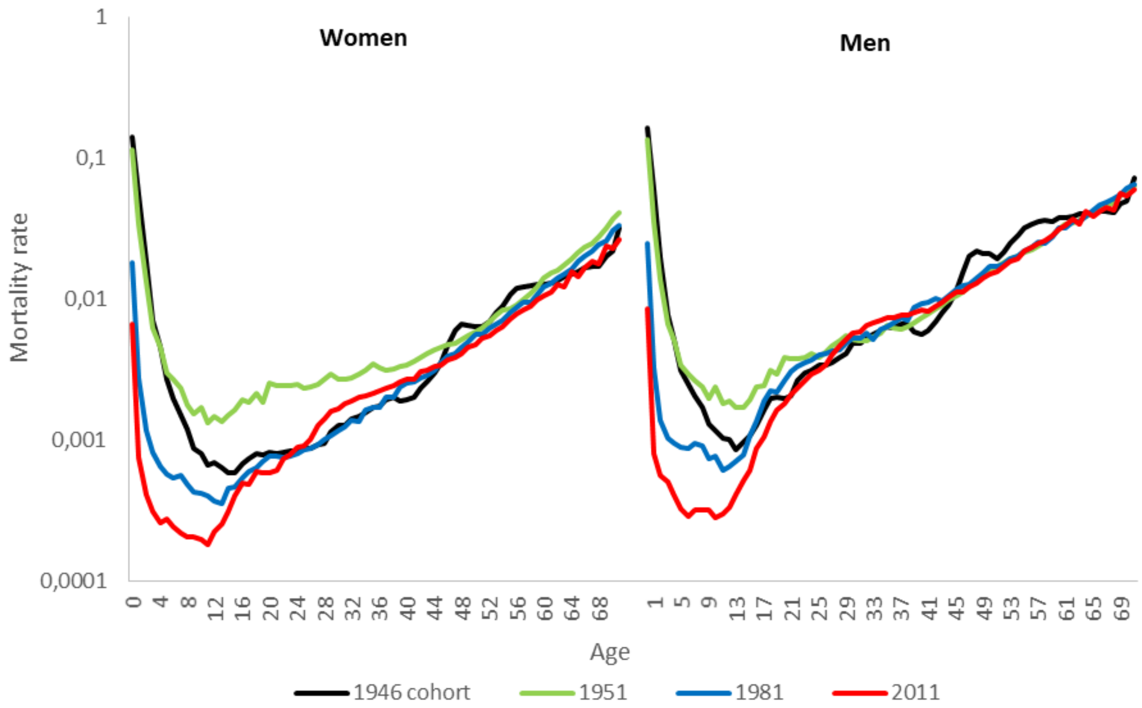

Figure 2. Comparison of age curves of mortality of the 1946 cohort and conditional generations of 1951, 1981 and 2011. Russian Federation. Semi-log scale.

Source: Calculated based on (Andreev, Darsky, Kharkova 1997) and data (Russian School of Economics 2021).

Another justification for the usefulness of calculating life tables is based on the fact that they allow one to judge the patterns of mortality in real generations. Undoubtedly, the performance curves for the conditional generation are similar to those for the real generation. But this is a very superficial similarity.

It is known that the dependence of the intensity of mortality on age is well described by the Gompertz curve. About forty years ago, Russian demography survived attempts to explain this with the help of aging models (Gavrilov, Gavrilova 1979; Shukailo 1979) (see also (Streler 1964)). Everywhere in the explanations it was about the accumulation of various kinds of malfunctions in the human body with age and how this affects the mortality of a generation. But the curve could be selected only for indicators of conditional generations. It does not work in real cohorts. The habit of calculating tables for conditional generations made them more real than real ones.

Typical life tables (Coale and Demeny 1966; United Nations 1982) suggest that LE can be used to predict the age-related mortality curve. If this is indeed true, it is only for conditional generations, for which typical tables are calculated.

Figure 3 shows the age-specific mortality rates of the real cohort born in 1920 and conditional generations with the same LE. For women, this is the conditional generation born in 1939. LE in the female cohort was 66.91, and in the conditional - 66.24. For men, the conditional generation of 1932 was taken; LE in both cases was 59.01.

Figure 3. Comparison of age-specific mortality curves for the 1920 cohort and conditional generations with the same LE. England and Wales, the entire population. Semi-log scale.

Source: (University of California… 2021).

We will not argue if the reader considers this example "not entirely fair", since the generation of 1920 survived the war. Unfortunately, however, it is impossible to calculate LE for generations born after the war. Of course, the consequences of the war cannot be compared with the consequences of a flu epidemic, summer heat or COVID-19. But using the example of pre-war cohorts, it is easier to see the main differences between the tables for real and conditional generations. In conditional generations, mortality changes simultaneously at all ages, in real generations, in a small range of ages.

Our analysis suggests that the main reason for the systematic calculation of life tables, which is carried out by the statistical offices of all developed countries, international organizations and individual researchers, is precisely the need to determine LE as an integral characteristic of the population.

AN ALTERNATIVE TO LE

J. Graunt's life table published on 27 February 1661 did not include an LE indicator or an equivalent. An indicator of this type appeared only several decades later, in the works of H. Huygens, who used the Graunt table in studies on probability theory and introduced the concept of mathematical expectation (LE as the mathematical expectation of a death event).

We were unable to find out who introduced the concept of the mortality rate as the ratio of the number of deaths in a period to the number of person-years lived in that period. This indicator is fundamentally different from the probability of death, which is the ratio of the number of deaths to the number at the beginning of the time interval. Note that Graunt did not correlate the number of dead and living, but considered the distribution of the dead by age.

It seems that by the end of the 18th century no one was comparing the number of deaths regardless of the population. But, obviously, the crude mortality rate equally depends on the level of age-specific mortality and on the age composition of the population. If the researcher is interested in mortality, then this indicator does not suit him. In the middle of the 19th century, W. Farr developed a method for standardizing general mortality rates. Now this method in textbooks is called the direct method of standardization.

So, in the middle of the 19th century there appeared a second integral indicator of the level of mortality - the standardized death rate (SDR). This took about 150 years from the moment the mathematical understanding of the phenomenon began.

By itself, the crude mortality rate cannot be considered as an integral characteristic of the mortality rate, since it equally depends on the age-specific mortality rates and the age composition of the population. It measures the average risk of death in a particular population. In our opinion, this indicator is not as useless as it seems. It follows that in order to reduce the risk of death in the "old" population, it is necessary to take care of the mortality of the elderly, and in the "young" population - of infant mortality.

SDR, like LE, can be associated with the demographic model, but with the model not of the generation, but of the population, in which the age structure is constant and corresponds to the standard, and the age-related mortality is the same as in the studied population. The SDR is the crude mortality rate in this model population.

Indirect and inverse methods of standardization of mortality rates are used mainly in the absence of complete information about the population: indirect if the age distribution of deaths is unknown, inverse in the absence of information about the age composition of the population. The indirect method appeared simultaneously with the direct method, while the inverse method appeared much later, in the middle of the 20th century. For both methods, it is required to determine the standard function of age-specific mortality.

With the indirect method, the total number of deaths is calculated with a known age composition of the living and some theoretical age-specific mortality. The ratio of the known total number of deaths to the result of the calculation is called the standardized mortality index.

In the inverse method, by dividing the age-specific number of deaths by the age-specific mortality rate we obtain the population that could give a given series of age-distributed deaths with standard age-specific mortality. The ratio of the actual total number to the calculated one also gives the mortality index.

Before determining LE, it is necessary to choose an algorithm for calculating the life table based on this or that transformation of age-specific mortality rates. The crude death rate standardization algorithm is determined by the standard population. You can choose one of the well-known standards, or you can use your own. In order for the publication not to displease the reader, it is enough to publish this standard.

Currently, the 1976 WHO European Standard and the 2013 Eurostat standard are the most commonly used (Eurostat 2013). The 1976 standard is certainly outdated, as it provides for an open age interval of 85 years and older, while the reduction in mortality after 85 years of age is becoming an increasingly important factor in reducing mortality.

Unlike LE, SDR is additive in terms of causes of death, so it is easy to assess the contribution of individual causes of death to its change. It is somewhat more difficult to estimate the contribution of individual age groups, since it is necessary to take into account their shares in the standard population. But nothing similar to the method of decomposition of differences in LE (Andreev 1982) will be required.

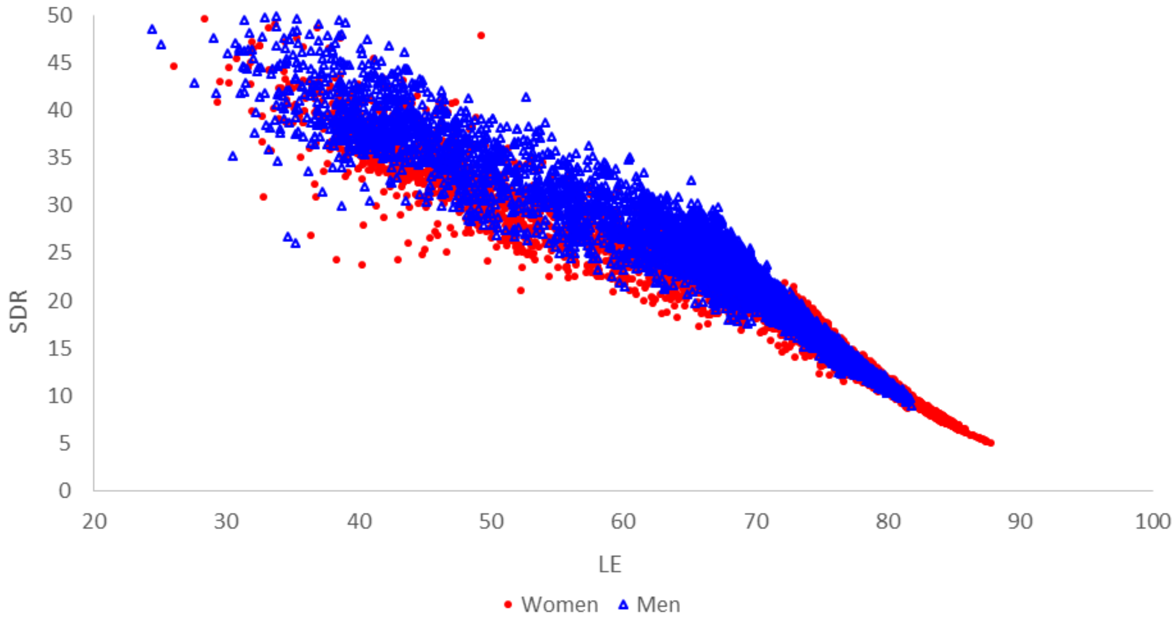

Figure 4. The ratio of the standardized death rate based on the 2013 European standard and LE for men and women according to HMD (University of California 2021) (4,769 observations)

Source: Author's calculations.

Unfortunately, mortality indices calculated both indirectly and inversely do not possess these properties. It is impossible, knowing the indices of mortality from individual causes, to evaluate their contribution to the overall index.

We used the HMD data to try and compare the 2 cumulative scores. We are interested in the question of the extent to which the estimates of the mortality rate obtained with their help are consistent.

Figure 4 shows the ratio of SDR and LE in all pairs {population, year} for men and women. The 2013 European Standard Population was used.

The figure shows that the connection, apparently, does not depend on gender and is clearly visible in the vast majority of cases. This relationship is obviously non-linear, which is especially clearly manifested at high LE and low SDR, since an infinite life expectancy would correspond to zero SDR.

The relationship between SDR and LE is still clear enough that for each value of one indicator it is possible to calculate the average value of the other. According to our calculations, a LE of 78 years, which Russia, according to the national doctrine, aims to achieve by 2030, corresponds to an average SDR of 12.4 per 1000 (if we take the European standard population of 2013), with a range of values from 11.4 to 13.3.

To assess the consistency of various mortality characteristics, it is useful to use Kendell's non-parametric rank correlation coefficient tau_b, based on the rank coincidence count (Table 1).

In our case, it would be ideal if the ranks were in reverse order. The calculation, including data for men and women, showed that the coefficient is -0.89, which is a very high absolute value for the Kendell coefficient. A similar calculation on the indicators for the two sexes together gave almost the same result - 0.90 (Table 2).

Table 1. Kendell's rank correlation coefficient tau_b for an array of 9,538 observations, men or women

		1	2	3	4	5	6
1	LE	1	-0.941	-0.887	-0.837	-0.876	-0.622
2	SDR, HMD-21 standard	-0.941	1	0.944	0.826	0.840	0.633
3	SDR, 2013 European standard	-0.887	0.944	1	0.798	0.799	0.625
4	Mortality index by indirect method	-0.837	0.826	0.798	1	0.893	0.673
5	Mortality index by inverse method	-0.876	0.840	0.799	0.893	1	0.641
6	Crude mortality rate	-0.622	0.633	0.625	0.673	0.641	1

Note. The correlation is significant below 0.01.

Table 2. Kendell's rank correlation coefficient tau_b for the two sexes together for 4,769 observations

		1	2	3	4	5	6
1	LE	1	-0.949	-0.900	-0.913	-0.905	-0.625
2	SDR, HMD-21 standard	-0.949	1	0.950	0.929	0.881	0.634
3	SDR, 2013 European standard	-0.900	0.950	1	0.908	0.843	0.628
4	Mortality index by indirect method	-0.913	0.929	0.908	1	0.897	0.696
5	Mortality index by inverse method	-0.905	0.881	0.843	0.897	1	0.661
6	Crude mortality rate	-0.625	0.634	0.628	0.696	0.661	1

Note. The correlation is significant below 0.01.

Although the distributions of observations based on SDR and LE give very close representations of what demographers perceive as "mortality rates", there is a fundamental difference between the two ways of classifying observations. LE, like any indicator of life expectancy, is sensitive to the age of the deceased. The younger the deceased, the more his death reduces life expectancy. We are not sure that this property is useful for an indicator that characterizes the mortality rate of a population in a certain year. The response to age of SDR depends on the selected standard population. The 2013 European standard makes little distinction between ages under 65.

It is known that at the end of the 19th century European Russia was distinguished by a terrifyingly high infant mortality rate. According to the tables of mortality of the population of European Russia within the borders of the RSFSR in the late 1920s, in 1896-97 303 out of 1000 newborns did not live up to 1 year. To a large extent, this is why LE was 30.5 years (mortality and life expectancy ... 1930). According to our calculations based on these life tables, the SDR was 36.0 per 1000. We found 272 cases in HMD with SDRs from 35 to 37 per 1000. The average SDR in this population is equal to the Russian one, while life expectancy is 43.3 years. This value of the SDR was recorded in France in 1944 (the entire national population). At the same time, LE in France for the same year was 55.8 years. This ratio of LE and SDR results from the fact that the SDR better captured the high mortality of the adult population. Thus, LE as a measure of the level of mortality of the population, as it were, overestimates the role of child mortality and underestimates the role of adult mortality. However, this problem deserves special consideration.

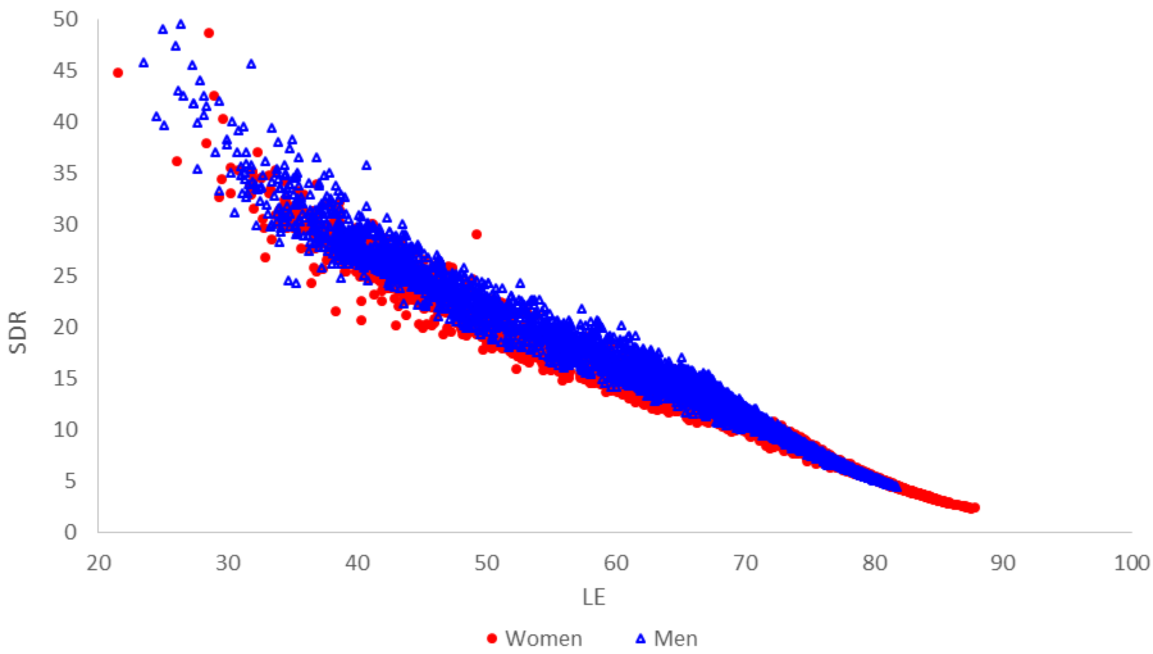

Figure 5. Ratio of the standardized death rate using the HMD average age structure at the beginning of 2021 (HMD-21) and LE for men and women according to HMD data (4769 observations)

Source: Author's calculations.

We must not forget that Eurostat, when developing the standard population, was guided by the population structures of the developed countries of Europe. The nonmonotonicity of the age structure suggests that it was supposed to be revised in 5-10 years. In any case, the standard was not intended to apply to such a wide range of countries. We decided to take as a standard the average age structure for the two sexes together over the entire list of 4769 persons and years. To somehow distinguish this standard, we called it HMD-21. The HMD-21 standard is presented in Appendix Table A1.

When using the HMD-21 standard, the Kendell rank correlation coefficient of the two indicators - LE and SDR - is -0.94 when combining indicators determined independently for men and women into one data array (Table 1) and -0.95 when calculating indicators for the two sexes combined (Table 2).

Figure 5 shows that when using the average age structure of HMD-21 as a standard, the relationship between LE and SDR looks clearer than when using the 2013 European population standard (cf. Figs. 4 and 5).

To calculate mortality indices by indirect and inverse methods, we calculated a standard series of age-specific mortality rates for the two sexes together as an average over all population-years. A short series of HMD age indicators was used with an open interval of 95 years or more (Table A2 of the Appendix). The Kendell coefficient for the indices shows their very high consistency with LE, although it is lower than that of both SDRs.

ROUGH ESTIMATES

The low, compared with others, indicators in the last row and column of tables 1 and 2 make it clear once again that the crude death rate cannot replace LE as an integral characteristic of the mortality rate. Still, Kendell's tau_b correlation scores are quite high. Hence the idea arose to use the crude rates for rough estimates.

The age structure of the population at five-year age groups, as a rule, changes rather slowly. Therefore, it can be assumed that, over a short time interval, changes in the SDR are proportional to changes in the crude death rate. We attempted to verify this.

In this case, we took the HMD-21 standard as the standard for calculating the SDR. From the HMD data we selected all such cases where data on some population are available for two consecutive years. There were 4,718 such cases. We calculated the SDR for the second of the two years, assuming that changes in the SDR are proportional to changes in the crude rate, and then compared the estimate with the “correct” indicator and calculated the relative error of the estimate. The result is encouraging: in 90% of all cases, the error lies in the range of ±3%. This is true for both men and women separately, as well as for the two sexes together.

You might expect that the probability of not making a mistake is high, but this is not always the case. Errors above 10% or below -10% occur for the period before 1920 and also for Iceland or New Zealand (Maori only).

On the contrary, our attempts to evaluate a change in LE based only on a change in the crude death rate or the total number of deaths were unsuccessful. The rank correlation coefficient between changes in LE and the crude rate for the same number of observations was -0.77 (significance level 0.01). Pearson's correlation coefficient (-0.91) also turned out to be very high in absolute value. Further analysis showed that only a linear model is possible. But the accuracy of the model is completely unsatisfactory. The average absolute deviation of the predicted LE from the actual one is 0.34 years; in a third of all observations the deviation is more than a quarter of a year.

SOME RESULTS

To determine LE in the population in a certain period, it is necessary to calculate the life table for the conditional generation of this period. The result of the calculation depends on the format of the available data on the population by age and on the age-specific numbers of the deceased, as well as on the chosen calculation algorithm. The data format is determined by the state of population statistics and the position of the national statistical office. The more detailed the data, the more noticeable their defects. To avoid possible criticism, statistical offices often publish only aggregated data.

The calculation method depends both on the available data and on the subjective preferences and knowledge of the authors of the calculation. In Russia, for example, the method of the American statistician Greville (Greville 1943) is still popular, but few people are familiar with the methods used by the Centers for Disease Control and Prevention in the USA in modern tables (Anderson 1999).

Using the HLD, we have demonstrated that the decimal places in LE depend significantly on the method of calculation. Thus, LE is not the most accurate measure of mortality.

We have shown that conditional generations of the 20th and 21st centuries bear little resemblance to real generations. Therefore, it is impossible to draw any conclusions about real generations based on the life tables of the calendar period. It seems that it is much easier to predict the life expectancy of young cohorts (Shkolnikov et al. 2014) than the remaining life expectancy of cohorts whose childhood and youth took place in the 1940s-1950s. It is known that mortality from many diseases in the elderly depends on the conditions of life in childhood and adolescence. It is impossible to predict the overall effect of this relationship, but references to data from conditional generations are hardly justified.

Our conclusion: obtaining the life expectancy value is the main, and possibly the only purpose of calculating the life tables of a conditional generation.

The relationship between LE and age-specific mortality rates is described by very complex relationships, so it is rather difficult to say how certain changes in age-specific mortality in general and from individual causes of death affect life expectancy.

In the minds of non-professionals, the LE indicator is perceived as the expected life span of specific people. They refer to it when they propose to increase the retirement age or, on the contrary, prove the illegality of such a step. The calculation of the number of people in a conditional generation who live or do not live to a certain age has nothing to do with any real population.

In the early 1970s, the leadership of the USSR came to the conclusion that life expectancy in the country should not fall below 70 years (Andreev 2011), and this indicator was repeated in international statistical publications. Starting in 1973, the United Nations Demographic Yearbooks published life expectancies in 1971-1972 in the USSR of 64 years for men and 74 for women, in Ukraine, 68 and 76, respectively, and in Belarus, 67 and 74. Only for Belarus was life expectancy over 70 for both sexes (71 years for both men and women). It was only in 1989 that the USSR

State Statistics Committee published actual life tables for the period from 1970 to 1987. In the early 2010s, LE in Russia exceeded 70 years, and this again seemed like a great achievement.

If a standard population is chosen and the structure is made public, and age-specific mortality rates are calculated, then no forces can affect the value of the SDR. The calculation of age-specific mortality rates contains some uncertainty. There are different possibilities for distributing by age the dead of unknown age, and several ways to calculate the population at risk, but all these uncertainties also arise when calculating LE.

SDR is a linear function of age-specific mortality rates. Therefore, it is extremely easy to assess the impact on the change in SDR of individual causes of death. The formula for estimating the contribution of individual age groups to the change in the SDR looks a little more complicated. A more complex expression describes the contribution of individual parts or social groups to a change in the SDR for the country as a whole. For example, it is possible to make a routine procedure of analysis of the contribution of regions to the mortality dynamics in Russia using the SDR, similar to that presented in our joint work (Timonin et al. 2017).

It is possible to calculate the SDR not for the entire scale of ages, but for individual intervals, for example, for adults, working, and retirement ages.

As for the possibility of comparing with other populations, other periods, and so on, international databases make it possible to calculate perfectly comparable SDRs. In addition to HMD, we might mention the Human Cause-of-Death Database (Institute for Demographic … 2021) and the WHO Mortality Database (World Health Organization 2021).

We will not be able to calculate the SDR for countries where adequate demographic statistics are lacking and the published LE indicators are the result of various kinds of indirect estimates, but in our opinion this is for the best.

Using the SDR frees us from the mystical “lifelong” contained in the definition of the conditional generation. To explain what SDR is, we can say that this is the number of deaths per 1000 (or 100 thousand) people of the population under study if it had the same age structure as in the standard population or, conversely, the number of deaths in the standard population if it had the same mortality rate as the population under study.

Of course, it will not be possible to abandon the use of life expectancy for a calendar period overnight. But it is quite realistic to use only SDR when analyzing the dynamics of mortality or preparing articles designed for a demographic reader.

When the article was ready, the latest statistical publications forced another short addition. Preliminary results for 2020 in Europe and Russia show that life expectancy is a very mild indicator. Thus, in Russia, the number of deaths and the crude death rate in 2020 in the context of the COVID-19 pandemic increased by more than 18% compared to 2019, while LE decreased, according to preliminary estimates, by 1.8 years or only by 2.5% (Rosstat 2021a, b, c).

REFERENCES

Anderson R.N. (1999). Method for constructing complete annual U.S. life tables. In *Vital and health statistics*, Series 2, Data evaluation and methods research, no. 129.

Andreev E.M., Darskiy L.E., Kharkova T.L. (1997). *Demograficheskaya istoriya Rossii: 1927-1959* [Demographic History of Russia: 1927-1959]. Moscow: Informatika.

Andreyev E.M. (1982). Metod komponent v analize prodolzhitel'nosti zhizni [Component method in life expectancy analysis]. *Vestnik statistiki*, (9), 42–47.

Andreyev E.M. (2011). Ozhidayemaya prodolzhitel'nost' zhizni 70 let, ili déjà vu otechestvennoy demografii [Life expectancy of 70 years, or déjà vu of domestic demography]. *Demoskope Weekly*, 487- 488.

Chiang C.L. (1984). *The Life Table and its Applications*. Malabar: Florida.

Coale A., Demeny P. (1966). *Regional Model Life Tables and Stable Populations*. Princeton: Princeton University Press.

Eurostat (2013). *Revision of the European Standard Population - Report of Eurostat's task force edition*.

Gavrilov L.A., Gavrilova N.S. (1979). Issledovaniye kineticheskikh zakonomernostey smertnosti lyudey v istoricheskom aspekte [Life expectancy of 70 years, or déjà vu of domestic demography]. *DAN SSSR*, 245(4), 1017-1020.

Greville T. (1943). Some methods of constructing abridged life tables, Records of the. *American Institute of Actuaries*, 32, 29–43.

Institute for Demographic Studies (INED), Max Planck Institute for Demographic Research (2021). *The Human Cause-of-Death Database (HCD)*. URL: https://www.causesofdeath.org/cgi-bin/main.php

Max Planck Institute for Demographic Research (2021). *Human Life Table Database*. Retrieved from https://www.lifetable.de/cgi-bin/data.php (data downloaded on 05.02.2021).

New Economic School (2021). *The Russian Fertility and Mortality database.* Retrieved from http://www.demogr.nes.ru/index.php/en/demogr_indicat/data (data downloaded on 05.02.2021).

Novosel'skiy S.A. (1916). *Smertnost' i prodolzhitel'nost' zhizni v Rossii* [Mortality and Life Expectancy in Russia]. Petrograd: Tipografiya Ministerstva Vnutrennikh Del.

Rosstat (2021a). *Yestestvennoye dvizheniye naseleniya v razreze sub"yektov Rossiyskoy Federatsii po mesyatsam. 2020 god*. [Vital statistics data on regiohs of the Russian Federation by months. 2020 year]. URL: https://rosstat.gov.ru/folder/12781 (data downloaded on 08.02.02.2021).

Rosstat (2021b). *Otsenka chislennosti postoyannogo naseleniya na 1 yanvarya 2021 g. i v srednem za 2020 g.* [Estimated resident population as of January 1, 2021 and on average for 2020]. URL: https://rosstat.gov.ru/folder/12781 (data downloaded on 19.03.2021).

Rosstat (2021c). *Predvaritel'naya otsenka ozhidayemoy prodolzhitel'nosti zhizni pri rozhdenii po sub"yektam Rossiyskoy Federatsii za 2020 god* [Preliminary estimate of life expectancy at birth for the subjects of the Russian Federation for 2020]. URL: https://rosstat.gov.ru/folder/12781 (data downloaded on 19.03.2021).

Shkolnikov V.M., Jdanov D.A., Andreev E. M., Vaupel J.W. (2014). Rapid increase in maximal country specific life expectancy across cohorts. *Advances in Gerontology*, 27(2), 229-235.

Shukaylo V.F. (1979). O printsipakh matem. otobrazheniya sushchnosti protsessov smertnosti [On the principles of mat. displaying the essence of mortality processes]. In *Prodolzhitel'nost' zhizni: analiz i modelirovaniye* (pp. 104-123). Moscow.

Smertnost' i prodolzhitel'nost' zhizni naseleniia SSSR 1926-1927 gg. [Mortality and life expectancy of the USSR 1926-1927] (1930). Tablitsy smertnosti. Moscow – Leningrad.

Strehler B. (1964). *Vremya, kletki i stareniye* [Time, cells, and aging]. Moscow.

Timonin S., Danilova I., Andreev E. M., Shkolnikov V. (2017). Recent mortality improvement in Russia: are regions following the same tempo? *European Journal of Population,* 33(5), 733-763.

TSSU SSSR (1962). *Tablitsy smertnosti i sredney prodolzhitel'nosti zhizni naseleniya SSSR. 1958-59* [Life tables and life expectancy of the population of the USSR. 1958-59]. Moscow: Gosstatizdat.

United Nations (1982). *Model Life Tables for Developing Countries* (United Nations publication, Sales No. E.81.XIII.7).

University of California, Berkeley, and Max Planck Institute for Demographic Research (2021). *The Human Mortality Database. U.K., United Kingdom Total Population*. Retrieved from https://www.mortality.org/cgi-bin/hmd/country.php?cntr=GBR_NP&level=1 (data downloaded on 05.02.2021).

World Health Organization (2021). *WHO Mortality Database.* URL: https://www.who.int/data/data-collection-tools/who-mortality-database

APPENDIX

Table A1. Average age structure for both sexes together of the population at risk for all of the Human Mortality Database at the beginning of 2021, 4769 observations

Age	0	1-4	5-9	10-14	15-19	20-24	25-29
Share	181757	687900	834378	819342	799294	771576	744360
Age	30-34	35-39	40-44	45-49	50-54	55-59	60-64
Share	714884	681483	643165	600511	552383	495744	433179
Age	65-69	70-74	75-79	80-84	85-89	90-94	95-99
Share	362419	283185	198846	119115	54967	17649	3465
Age	100-104	105-109	110+	Total			
Share	373	23	2	10000000			

Note: Download date: 05.02.2021.

Table A2. Average age-specific mortality rates per 1 million for both sexes together for all of the Human Mortality Database at the beginning of 2021, 4769 observations

Age	0	1-4	5-9	10-14	15-19	20-24	25-29
Rate	59441	8126	2225	1417	2171	3064	3209
Age	30-34	35-39	40-44	45-49	50-54	55-59	60-64
Rate	3528	4191	5275	6935	9773	13935	21115
Age	65-69	70-74	75-79	80-84	85-89	90-94	95+
Rate	31939	50400	79487	124212	190442	276548	405034

Note: Download date: 05.02.2021.