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High Life Expectancy of Muscovites Over Age 80: Reality or a Statistical Artifact?

E. K. Papanova[a, *], V. M. Shkolnikov[a, b], E. M. Andreev[a], and S. A. Timonin[a]

[a]*International Laboratory for Population and Health, National Research University Higher School of Economics, Moscow, 123022 Russia*

[b]*Max Planck Institute for Demographic Research, Rostock, 18057 Germany*

**e-mail: epapanova@hse.ru*

Abstract—The mortality of advanced-age residents of Russia has remained stable and high for several decades. However, the steady increase in life expectancy that started in the mid-2000s is largely due to decreased mortality among the elderly. The decrease in mortality among Moscow residents over age 80 was especially large during this period. We found evidence of a systematic deviation of these dynamics from the patterns observed in countries with reliable mortality statistics. Assuming that the patterns observed in these countries are applicable to Russia, we took the possible underestimation of mortality into account and corrected the life expectancy estimates for the residents of Moscow, Russia, and the Central Federal District at age 80, at retirement age, and at birth.

Keywords: mortality, life expectancy, old age, quality of statistical data

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INTRODUCTION

The stagnation and decrease in life expectancy (LE) in Russia and the post-Communist states of Europe in the four decades between the mid-1960s and the mid-2000s contrasted sharply with the steady increase in LE in other developed countries [19]. A slow increase in mortality was occurring in these countries in the 1970s and was followed by a period of large fluctuations starting in the mid-1980s. Extremely low LE values in Russia—less than 60 years in men and slightly more than 70 years in women—were observed by the early 2000s as a result of all these preceding changes [14]. Analysis of the LE changes has shown that mortality in working-age adults made the largest contribution to LE dynamics, both during the earlier period of gradual mortality increase in the 1960s and 1970s, and during the period of mortality fluctuations in the late 1980s and 1990s. Alcohol-related and unnatural causes of death, including various accidents (murders and suicides) and early cardiovascular pathology contributed substantially to this pattern of LE dynamics [17]. Mortality in the advanced-age population changed only slightly during that time[1] and remained at the high levels reported in the 1970s.

[1] The mid-1990s constituted an exception, as a conspicuous increase followed by a decrease in mortality was also observed in the elderly population during that time.

The situation changed in the mid-2000s, when the longest and steadiest LE increase in 50 years started in Russia [10, 18]. In contrast to the earlier changes, the LE increase observed in 2004–2015 was due to decreasing mortality in both working-age and older-age populations [9, 18]. During that period, LE at birth increased 7.4 years in men and 4.9 years in women, and the decrease in mortality among people over age 60 accounted for 25% of the increase in men and 51% of the increase in women.

The overall increase in LE in Russia was accompanied by non-uniform changes in mortality dynamics in different regions of the country [23]. Mortality changes in the working-age population contributed to the attenuation of differences between regions, whereas changes in the advanced-age population caused these differences to widen. Analysis of mortality in the advanced-age population has indicated that this divergence was associated with a more pronounced mortality decrease in certain regions. Relative to other regions, Moscow played an outsized role, because the city experienced an extraordinarily rapid decrease of mortality among its advanced-age residents and because the weight of its population was large at the level of the whole country (approximately 8%). In the 2003–2015 period, LE increased 12% (eight years) among male residents of Moscow and 7% (5.4 years) among female residents of Moscow. The mortality decrease in the age group 60+ accounted for 46% of the increase in men and 62% of the increase in

Table 1. HMD life tables included in the regression model

Country	Period, years
Australia	1921–2011
Austria	1947–2014
England and Wales	1900–2013
Belgium	1900–1913, 1919–2015
Denmark	1900–2014
West Germany	1956–2013
Spain	1908–2014
Italy	1900–2012
Canada	1921–2011
Luxemburg	1960–2014
the Netherlands	1900–2012
New Zealand (non-Maori)	1901–2008
Norway	1900–2014
Portugal	1940–2012
United States	1933–2014
Finland	1900–2012
France	1900–2014
Switzerland	1900–2014
Sweden	1900–2014

women, and the decrease in the age group 80+ accounted for 13% of the increase in men and 21% of the increase in women.

Thus, in line with the overall trend for developed countries, advanced-age mortality is acquiring an increasingly important role in the overall LE dynamics in Russia, and especially in Moscow. Moreover, the demographic aging process has led to a rapid expansion of the retirement-age population group, and to an increase in the proportion of people in this group who are over the ages of 80, 90, and even 100. These advanced-age groups impose the largest burdens on the healthcare and social security systems. The reliability and precision of mortality estimates derived from demographic statistics have special importance under these conditions. The quality of these estimates affects the reliability of annuity and population-aging predictions; as well as the planning of healthcare, services, and care facilities for the elderly and sick.

For a number of reasons, the quality of the statistical data on advanced-age mortality is unsatisfactory in the majority of developed countries [13, 15, 21, 22]. These problems are largely attributable to incomplete and inaccurate registration of births in the late 19th and early 20th centuries, population census errors, and the erroneous estimation of migration in the intercensus periods. As a result, the numbers of people over the ages of 80 or 90 are overestimated; the ages of living and dead people are overestimated, the gender gap in mortality rates is artificially reduced, and groups of dead or living individuals of ages that end with a zero or a five are erroneously expanded [12]. The unreliable character of advanced-age mortality assessments in Russia, where the completeness and breadth of demographic statistics did not reach a relatively acceptable level until the late 1920s-early 1930s, has long been a focus of demographic research [3, 5]. More recently, the quality of advanced-age mortality statistics in Russia and Moscow in particular has become a burning issue [2, 4]. The most probable reasons for the deterioration in the data are the double-counting of residents during the two most recent censuses; the overestimation of respondents' ages during census interviews; and undocumented migration to other regions of the country and abroad, which has led to the emergence of so-called "statistically immortal" people erroneously believed to have set longevity records.

The mortality coefficients reported for the advanced-age population of Russia, and especially of Moscow, appear to be too low when compared with the high mortality levels observed among adults at younger age. A comparison of the mortality curves for different ages has demonstrated that in 2015, the curves for men and women intersected at age 89 across Russia and at the even lower age of 85 in Moscow [6]. As such intersections have not been observed in any country with reliable demographic statistics, these findings clearly indicate that the quality of the mortality data for the advanced age population is inadequate.

In the present study, the mortality and LE parameters for the populations of Moscow and Russia have been compared to the data for different countries retrieved from the Human Mortality Database (HMD), and refined LE estimates at age 80 have been obtained for Moscow and Russia. The calculations were based on HMD data and a simple regression model. The results of our analyses reveal the extent to which underestimated mortality at ages 80+ corrupted the LE values at birth and at the retirement age (60 for men and 55 for women).

MATERIALS AND METHODS

Data from the Federal State Statistics Service (Rosstat) on the distribution of the dead and the living population with regard to sex, age in full years (up to 100+), and place of residence (administrative divisions of the Russian Federation) in 1989–2015 were used. Age-specific mortality rates based on data of the State Statistics Service, which are available from the Russian database on birth rate and mortality [6], were also used.

In addition, age-specific mortality rates and values from complete life tables for a number of developed countries with reliable mortality statistics were used. The tables were retrieved from the HMD [10], which is the most authoritative source of accurate mortality

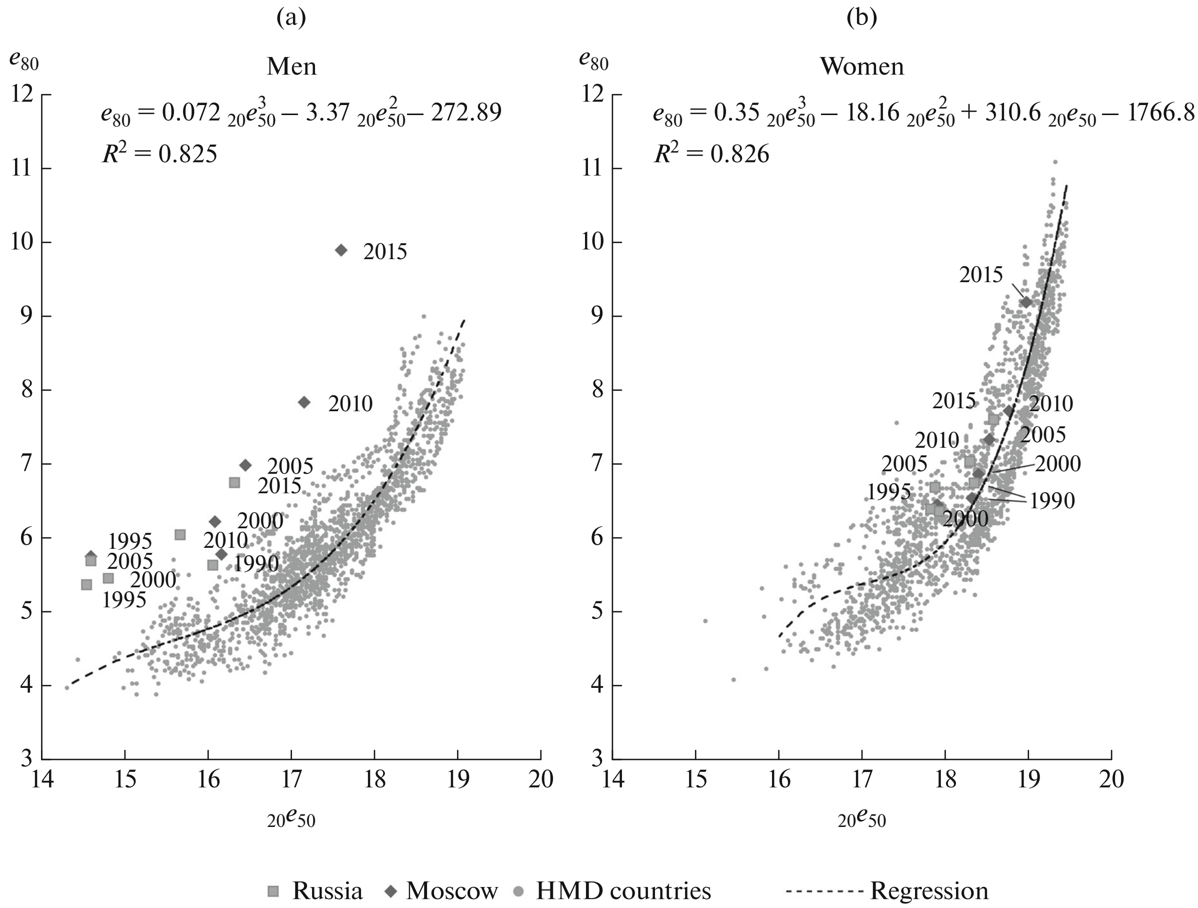

Fig. 1. LE at ages 50–69 and at age 80 in some HMD countries. Data source: HMD 2017.

data. These data can be compared over time and across countries [8] (Table 1).

Method for LE Assessment at Age 80

For the reasons partially described in the introduction and illustrated below (in the section titled "Comparisons between Countries"), mortality over age 80 is likely to be underestimated for Moscow and for Russia. Let us note that V. Kannisto, the author of influential works on mortality at an advanced ages, emphasized the necessity of mortality estimate correction (for economically developed countries) for the 80+ age group [13]. The HMD follows this recommendation by applying the appropriate algorithms to obtain a more precise estimation of mortality at ages 80+ [24].

The method we used to correct the official LE estimates for 80-year-old Moscow residents is based on a comparison with HMD data. We used HMD data for a number of developed countries with high-quality demographic statistics to reveal the relationship between LE for the age interval of 50–69 years (${}_{20}e_{50}$) (LE between the exact ages of 50 and 70 years) and LE at age 80 (e_{80}). We chose the 50- to 69-year age interval because of the distinctive features of older and younger age groups. It is commonly known that the mortality of 15- to 49-year-old residents of Russia (including those of Moscow) is extremely high relative to the international level, as external and alcohol-related causes of death have strong effects on the mortality rate of people in this age group. The age-specific mortality rates for 70–79-year-old residents of Russia and of Moscow may be underestimated to a lesser extent than those for their 80+-year-old counterparts.

In the 1989-2015 period, the LE of 50- to 69-year-old men was 14–17.7 years in Moscow and 14.2–16.2 years in Russia, and the LE of women in the same age group was 17.8–19 years in Moscow and 17.7–18.5 years in Russia. The values of ${}_{20}e_{50}$ and e_{80} from the 1872 life tables for 19 countries listed in the HMD were used to construct the regression model (Table 1).

We assumed that the relationship between ${}_{20}e_{50}$ and e_{80} for the regions of Russia corresponds to that observed in economically developed countries with reliable mortality statistics. The dependence of LE at age 80 on LE at ages 50–69 can be approximated by a cubic polynomial regression in men and women of the selected countries (Fig. 1). Based on the assumption

Table 2. Regression model parameters for men and women

Adjusted R-square	$({}_{20}e_{50})^3$	$({}_{20}e_{50})^2$	${}_{20}e_{50}$	Constant
Men				
0.825	0.0721 (0.0720; 0.0722)	−3.365 (−3.358; −3.372)	52.745 (52.608; 52.883)	−272.893 (−272.828; −272.958
Women				
0.826	0.354 (0.357; 0.352)	−18.163 (−18.278; −18.0149)	310.611 (312.609; 308.613)	−1766.832 (−1779.640; −1754.025)

formulated above, we used the newly developed regression models to estimate the LE of elderly residents of Moscow (Table 2). The 95% confidence interval for the estimates obtained with the regression method was also calculated.

In addition, LE at birth and retirement age was corrected with the average LE estimate at age 80 taken into account. The formula for the correction, which used parameters from the life tables, was as follows: $e_x^{adj} = e_x + (e_{80}^{adj} - e_{80})l_{80}/l_x$, where e_x is the LE at x years of age; e_x^{adj} is the corrected LE estimate at x years of age, and l_x is the number of persons surviving until the age of x years.

We selected the countries for comparison in the section titled "Comparisons Between Countries" based on the similarity of their LE changes with those in Moscow on the one hand, and in the Czech Republic and Hungary on the other, in the 1960s–1980s. Sweden serves as an example of a country with a high LE and a population size comparable to that of Moscow. The mortality data for these countries are of high quality.

The SPSS software package was used to perform the regression analysis and other calculations.

RESULTS AND DISCUSSION

Comparisons between Countries

The relationship between ${}_{20}e_{50}$ and e_{80} observed for mortality statistics in the male population of Russia, and especially of Moscow, was clearly different from the relationship observed in economically developed countries with reliable mortality statistics: the e_{80} values that corresponded to specific ${}_{20}e_{50}$ values were higher than those in other countries (Fig. 1). Conspicuous biases from the model curve were also observed for some Eastern European countries (such as Hungary, Estonia, and Poland). Deviations of this type were not observed for women in Moscow, Russia, or Eastern European countries.

Rapid increase in LE of elderly male and female residents of Moscow was reported starting in 2003, and an especially large increase was observed in 2011. The latter change may be attributable to a compensatory increase in the parameter after a short-term decrease associated with the anomalously hot summer of 2010. However, this decrease was found to be more pronounced in women. Thereafter, the pace of the LE increase again slowed (Fig. 2). A comparison for the 2014-2015 period between LE in Moscow and LE in other countries included in the HMD placed the city at the end of the list, with lower values observed for Lithuania, Latvia, and Ukraine only. However, LE for 70-year-old male Moscow residents was 14.8 years—a value that was in line with those of the first 10 countries in the HMD ranking, and was even higher than those of Belgium, Denmark, and Germany. LE for 80-year-old male residents of Moscow exceeded the corresponding levels reported for all countries included in the HMD after 2011. This finding does not align with the high mortality levels observed at younger ages [6, 10].

As we mentioned above, the excess of female mortality over male mortality in old age is especially distinct in Moscow, even though it is also evident from the mortality statistics for Russia. Since 2011, LE for 80-year-olds in Moscow has been higher among men than among women. A comparison of the age-specific mortality rates for the elderly residents of Moscow and foreign countries, such as Sweden, showed that the mortality level reported for 80–90-year-old residents of Moscow appears to be unreasonably low (Fig. 3). This is especially obvious for men, as the mortality rates reported for 80–82-year-old men were lower in Moscow than in Sweden. Moreover, large fluctuations in the mortality curve (especially for men) were observed for Moscow residents over age 90.

Assessment of LE at Age 80 Based on the Experiences of Countries with Reliable Mortality Statistics for the Elderly

The calculated regression coefficients were used together with the observed LE values in the age interval of 50–69 years to calculate the LE at age 80 for Moscow, and the control levels for Russia, the Central Federal District (CFD) of Russia, Hungary, the Czech Republic, and Sweden.

The model estimates of LE at age 80 were lower than the observed values for all regions of Russia included in the analysis, but substantial sex- and

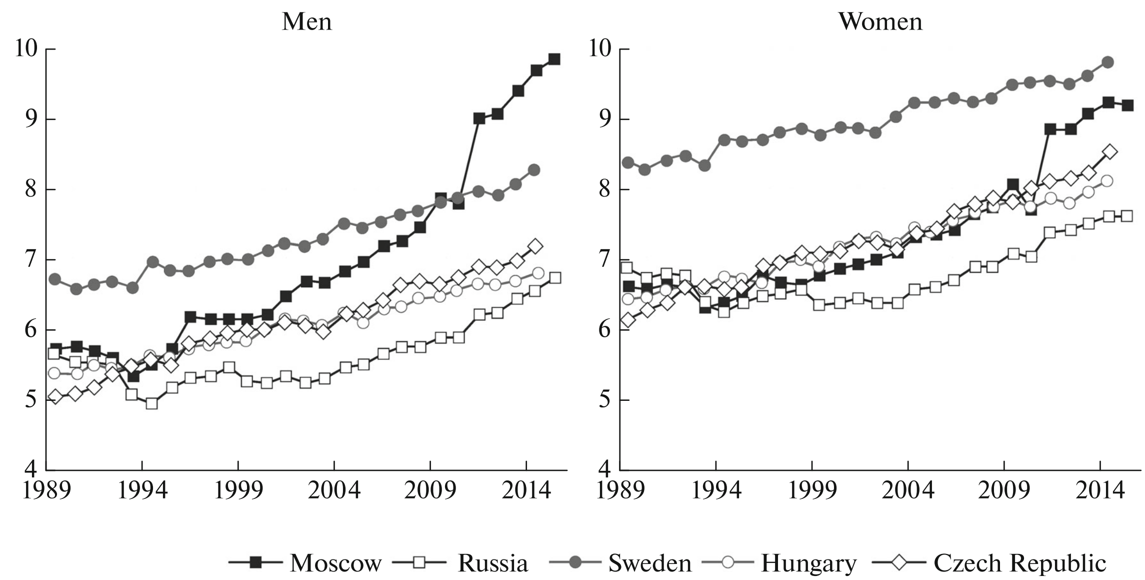

Fig. 2. LE at age 80 in Moscow, Russia, Sweden, Hungary, and the Czech Republic in 1989–2015. Data sources: HMD 2017, Federal State Statistics Service (Rosstat).

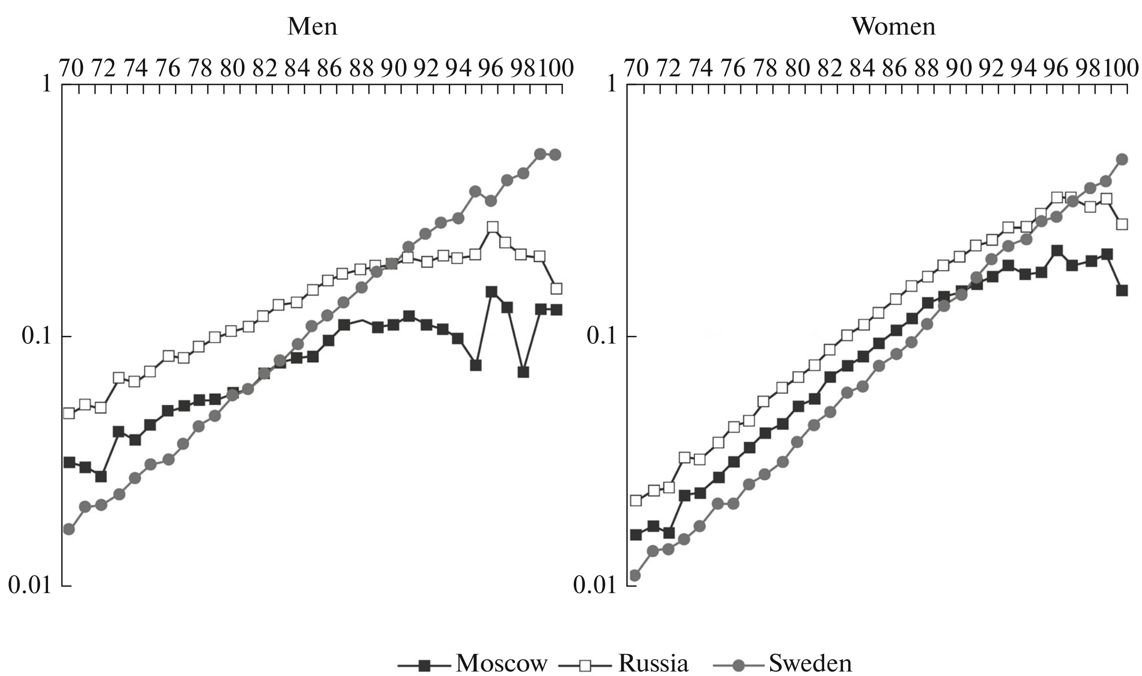

Fig. 3. Age-specific mortality rates at ages 70+ in Moscow, Russia, and Sweden, 2015. Data sources: Statistics Sweden, Federal State Statistics Service (Rosstat), HMD 2017. Values are plotted on the logarithmic scale.

region-specific variation was observed. LE of men and women in the Czech Republic and Sweden was found to be within the 95% confidence interval (CI) of the regression model, whereas the values for men in Hungary and the regions of Russia were, characteristically, found to have exceeded the upper boundary level of the CI.

The empirical values for Moscow males increased faster than the model values from the early 2000s onward, and the difference between the values therefore increased considerably by the end of this period, especially after 2011 (Fig. 4). LE of men in Moscow was significantly higher than the upper CI boundary derived from the regression model-based assessment;

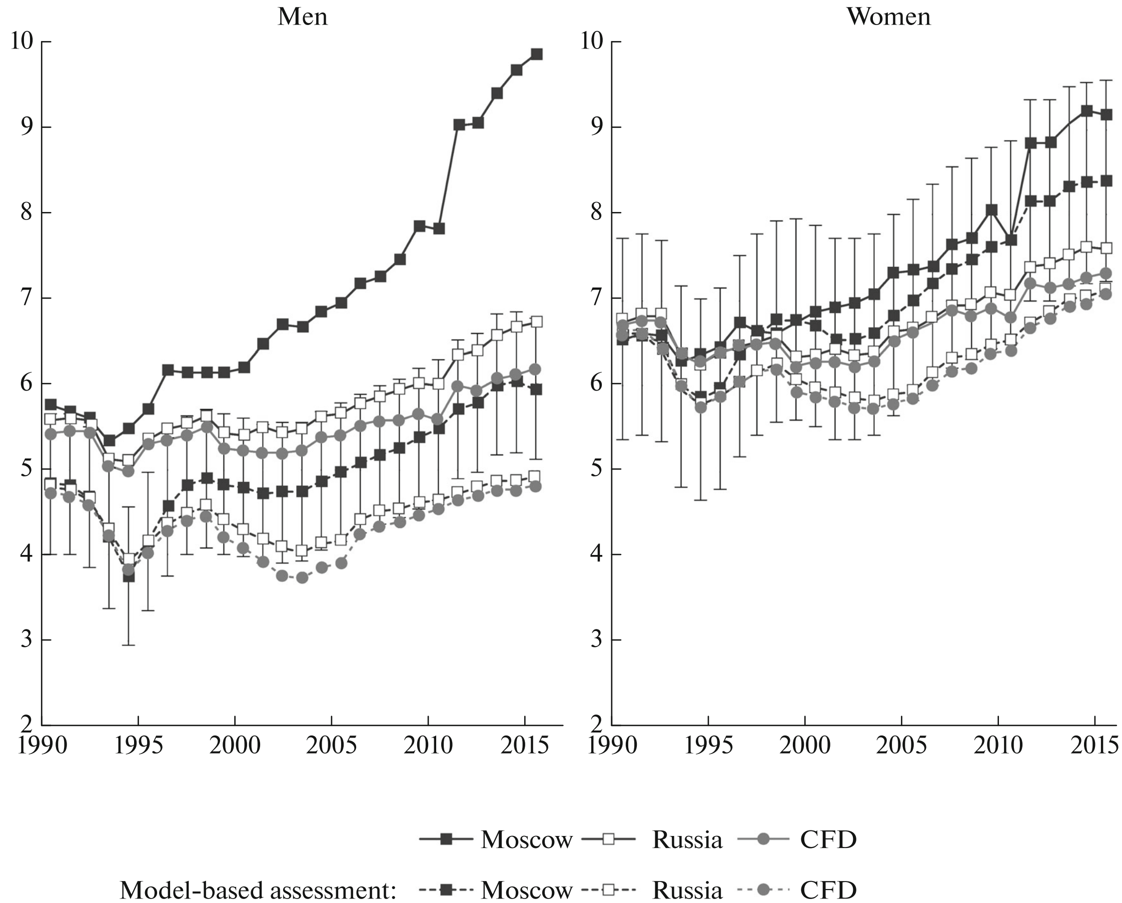

Fig. 4. LE at age 80, the empirical and the model-based estimates, 1990–2015. Source: calculations based on data from the Federal State Statistics Service (Rosstat), results of regression model-based assessment.

the regression model was based on $_{20}e_{50}$ levels for economically developed countries. The LE of men in Moscow was at the upper CI boundary in 1989, and exceeded it by 46% (3.1 years) in 2015.

The model-based estimates of women's LE were also much lower than those inferred from statistical data on mortality, but this difference was less pronounced than that in men, including Moscow. LE of women remained within the CI for model-based values in all of the regions considered (Fig. 4). Still, for women, the deviation of the empirical LE values from the averaged model-based estimates was relatively low (0.2 years on average) in Moscow before the year 2010, and the average expected model-based estimates were even higher than the observed values for some years (Table 3). The gap between the empirical and the model-based estimates increased sharply from 2011 onwards, to almost 0.7 years.

The correction of e_{80} (the replacement of empirical values with the values derived from the model) resulted in a decrease in LE at retirement age in Moscow (by two years in men and by 0.6 years in women). The decrease in the values for men in the CFD and Russia (Moscow not included) was less pronounced (0.4 and 0.5 years, respectively), and the decrease in the values for women was very small (Table 4). The correction of e_{80} resulted in a decrease of LE at birth (by 1.6 years in men and by 0.4 years in women) in Moscow, whereas the parameters for CFD and Russia (Moscow not included) remained almost unaffected.

CONCLUSIONS

The quality of statistical data on the size and the mortality rate of the elderly population becomes especially important as the whole population ages. The accuracy of these data is an issue not only for researchers conducting statistical analysis of mortality changes, but for policy-makers involved in planning the pension system and the healthcare system. These data are also extremely important for Russia at the regional level, especially given the large differences in LE between regions, including among elderly people [23].

We constructed a regression model based on data for a number of HMD countries with reliable mortality statistics and used this model to estimate LE of the elderly residents of Moscow. A similar approach is

Table 3. LE at age 80 as inferred from mortality statistics and the regression model-based estimate, years

Parameter		Men				Women			
		1990	2005	2010	2015	1990	2005	2010	2015
Moscow	Estimate based on statistical data	5.7	6.9	7.8	9.9	6.5	7.3	7.7	9.2
	Estimate based on modeling	4.8	5.0	5.5	5.9	6.6	7.0	7.7	8.4
	Upper boundary, 95% CI	5.6	5.8	6.3	6.8	7.7	8.2	8.9	9.6
CFD (Moscow not included)	Estimate based on statistical data	5.4	5.3	5.6	6.2	6.7	6.6	6.8	7.3
	Estimate based on modeling	4.7	3.9	4.5	4.8	6.6	5.9	6.4	7.1
	Upper boundary, 95% CI	5.5	4.7	5.3	5.6	7.9	7.1	7.6	8.3
Russia (Moscow not included)	Estimate based on statistical data	5.5	5.5	5.8	6.3	6.8	6.6	6.9	7.4
	Estimate based on modeling	4.8	4.1	4.6	4.8	6.6	5.9	6.4	7.0
	Upper boundary, 95% CI	5.6	4.9	5.4	5.7	7.8	7.0	7.6	8.2
Russia	Estimate based on statistical data	5.6	5.6	6.0	6.7	6.8	6.7	7.0	7.6
	Estimate based on modeling	4.8	4.2	4.6	4.9	6.6	5.9	6.5	7.1
	Upper boundary, 95% CI	5.6	5.0	5.4	5.7	7.8	7.1	7.7	8.3
Hungary*	Estimate based on statistical data	5.4	6.1	6.6	6.8	6.5	7.3	7.7	8.1
	Estimate based on modeling	4.8	4.9	5.1	5.4	6.3	6.8	7.0	7.3
	Upper boundary, 95% CI	5.6	5.8	5.9	6.2	7.5	8.0	8.2	8.5
Czech Republic*	Estimate based on statistical data	5.1	6.3	6.7	7.2	6.3	7.4	8.0	8.5
	Estimate based on modeling	5.0	6.0	6.4	6.9	6.9	8.2	8.7	9.1
	Upper boundary, 95% CI	5.8	6.9	7.2	7.7	8.1	9.3	9.8	10.3
Sweden*	Estimate based on statistical data	6.6	7.4	7.9	8.2	8.3	9.2	9.5	9.8
	Estimate based on modeling	7.2	8.3	8.6	8.9	8.7	9.4	10.0	10.2
	Upper boundary, 95% CI	8.0	9.1	9.4	9.7	10.0	10.6	11.2	11.4

* Data for the Czech Republic, Hungary, and Sweden are from 2014.

Data sources: calculations based on data from the Federal State Statistics Service (Rosstat), HMD, results of regression model-based assessment.

used in the Human Life Table Database for the identification of correlations between LE at birth and LE in the last age group [16]. Our use of this approach was based on the assumption that the regularities characteristic of other countries are also applicable to Russia. However, this approach was not designed for identifying overall patterns in mortality ratios at ages of 80+ and at younger ages, as the results obtained are only applicable as the problem outlined in the present study is being solved.

In Russia, population mortality has remained high for a long time, with levels becoming especially high during periods of socioeconomic crisis. We might therefore assume that the relatively low mortality of the elderly population is due to the selective elimination of the most vulnerable individuals at younger ages. However, numerous studies have shown a positive correlation and no or only very weak negative correlation—between mortality at young and old ages [7, 20].

In the absence of reliable statistical data, the extrapolation of age-specific mortality coefficients is often used to estimate mortality at advanced ages. We used the Gompertz model to derive estimates of LE for advanced-age residents of Moscow from the age-specific mortality coefficient for 50- to 69-year-olds. But in contrast to our expectations, LE levels we inferred from these data were overestimated, especially for women. This finding may be attributable to the values for the 50–69 age group, which are influenced by both factors that lead to mortality overestimation in the

Table 4. LE at birth and at retirement age as inferred from mortality statistics and as estimated with the e_{80} correction taken into account, years*

Parameter		Men 1990	Men 2005	Men 2010	Men 2015	Women 1990	Women 2005	Women 2010	Women 2015
LE at birth									
Moscow	Estimate based on statistical data	64.9	66.7	69.9	73.0	74.0	76.3	78.1	80.3
	Corrected estimate	64.7	66.2	69.1	71.4	74.0	76.1	78.1	79.9
CFD (Moscow not included)	Estimate based on statistical data	63.6	57.8	62.2	65.5	74.8	72.6	74.7	76.7
	Corrected estimate	63.5	57.7	62.0	65.2	74.8	72.2	74.6	76.6
Russia (Moscow and St. Petersburg not included)	Estimate based on statistical data	63.7	58.3	62.4	65.2	74.1	74.3	76.8	78.4
	Corrected estimate	63.5	58.1	62.2	64.9	74.0	74.0	76.5	78.1
Russia	Estimate based on statistical data	63.8	58.9	63.1	65.9	74.3	72.5	74.9	76.7
	Corrected estimate	63.6	58.7	62.8	65.5	74.2	72.1	74.6	76.4
LE at retirement age (60 years for men and 55 years for women)									
Moscow	Estimate based on statistical data	14.9	16.8	18.5	20.7	23.3	25.2	26.4	28.3
	Corrected estimate	14.6	16.0	17.4	18.7	23.2	25.0	26.3	27.7
CFD (Moscow not included)	Estimate based on statistical data	14.5	12.7	13.9	15.3	23.8	22.8	24.0	25.4
	Corrected estimate	14.3	12.4	13.6	14.9	23.8	22.5	23.8	25.3
Russia (Moscow and St. Petersburg not included)	Estimate based on statistical data	14.7	12.9	14.2	15.5	23.7	22.6	24.0	25.3
	Corrected estimate	14.4	12.6	13.9	15.0	23.6	22.2	23.7	25.1
Russia	Estimate based on statistical data	14.7	13.3	14.6	16.0	23.6	22.8	24.2	25.6
	Corrected estimate	14.4	12.9	14.2	15.3	23.5	22.5	23.9	25.3

* LE at birth and at retirement age was corrected with the averaged model-based e_{80} estimate taken into account.

working-age population (external and alcohol-related causes of death) and factors that lead to mortality underestimation in the elderly population (probably due to the overestimation of the size of the elderly population). It may be assumed that these factors tend to cancel each other out for the 50-69 age group, but because the behavior of individual age-specific mortality coefficients is unpredictable, extrapolation for the assessment of mortality at advanced age cannot be used.

Our model based on HMD data for countries with reliable mortality statistics showed that there was a systematic deviation of the parameters from the expected values and a disproportionally high estimate of LE at old ages relative to the values observed for younger men in Moscow. The underestimation of the mortality rate of the elderly population of Moscow was especially severe for men, and this estimation bias appears to have increased since the mid-2000s, along with a rise in LE. These problems worsened after 2011. LE of elderly women in Moscow also increased dramatically during that period, and the bias from the expected value became more pronounced. Nonetheless, LE of women remained within the confidence interval in Moscow (i.e., the LE was similar to that of all countries and regions analyzed), whereas LE for 80-year-old men exceeded the upper boundary of the confidence interval by three years in 2015.

Thus, an imbalance between the sexes was observed for both the mortality rate and the degree of putative underestimation of this parameter for the elderly population in Moscow. LE of 80-year olds inferred from mortality statistical data for Moscow was 2.5 years higher for men than for women, whereas a comparison of model-based estimates indicated that this value was 2.5 years higher for women than for men. This finding suggests that the data for men are more prone to being influenced by factors that lead to the underestimation of mortality parameters for elderly Moscow residents.

Researchers share the opinion that discrepancies between the current estimates and census data on the sizes of certain population groups can arise due to the following major factors: the failure to take all migrants into account in running records for the population, the double-counting of the population during censuses, and the overestimation of the respondents' ages [2, 4]. Double-counting is regarded as the major factor in the overestimation of the elderly population, with the "majority of the elderly population 'counted twice' in the census" reportedly being located "in Moscow, Moscow oblast, St. Petersburg, and Leningrad oblast" [4]. A similar degree of mortality rate underestimation for men and women would be expected if this factor predominated.

Given the male–female imbalance in the levels of mortality underestimation in Moscow, we should consider whether the higher migration mobility of men is a factor in the double-counting of elderly people, who may be simultaneously registered in the census at both a primary place of residence and a registered domicile. Such cases may occur among men whose primary place of residence is both within and outside of Moscow if their primary place of residence differs from their registered domicile. It is important to note that this factor could affect both the population size and the number of deaths registered at the site of the deceased's primary residence, even if the person's place of residence is reported as Moscow in the census.

As we pointed out above, the overestimation of the number of elderly people is not unique to Russia. The correction of data on the elderly population is the conventional approach used to address this problem. For instance, the HMD bases its estimates on the extinct generation method [12, 24] rather than official statistical data on the size of the population aged 80+. Moreover, data from the Pension Capital Fund have been used to correct data on the number of elderly residents of Germany [15]. The contradictions in statistical data discussed in the present study show that the correction of census results for specific age and sex groups is justified.

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