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Article

Decomposition of life expectancy gaps by age between the Republic of Tuva and Moscow using the Arriaga method

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This study investigates the differences in life expectancy between Moscow and the Republic of Tuva in Russia by applying the Arriaga decomposition method. Using official mortality data from 2023, we have constructed life tables for both regions, revealing a life expectancy at birth of 76.9 years in Moscow and 66.7 years in Tuva, resulting in a gap of approximately 10.3 years. The decomposition analysis has shown that the majority of the life expectancy difference is attributed to higher mortality rates in young and middle adulthood (20–49 years) in Tuva. Mortality differences in infancy and old age also contribute to the gap, but to a lesser extent.

The findings reveal that age groups corresponding to young and middle adulthood make the largest contributions to the overall life expectancy disparity between the two regions. The study highlights that while differences exist at all stages of life, addressing mortality among working-age adults would have the greatest impact on narrowing the gap.

The aim of the study is to quantify the age-specific contributions to the life expectancy gap between Moscow and Tuva and to identify the critical age groups most responsible for the observed differences. By analyzing the decomposition of mortality differences across age groups, the study provides a detailed understanding of the demographic mechanisms driving regional disparities in life expectancy within Russia.

Keywords: *Arriaga decomposition; life expectancy; mortality; Russian region; Moscow; Republic of Tuva; Russia; age-specific mortality; demographic analysis*

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Статья

Декомпозиция различий в ожидаемой продолжительности жизни по возрастным группам между Республикой Тыва и городом Москвой с применением метода Арриаги

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В данном исследовании анализируются различия в ожидаемой продолжительности жизни между Москвой и Республикой Тыва в России с применением метода декомпозиции Арриаги. На основе официальных данных о смертности за 2023 год были построены таблицы смертности для обоих регионов, согласно которым ожидаемая продолжительность жизни при рождении составляет 76,9 года в Москве и 66,7 года в Республике Тыва, что формирует разрыв приблизительно в 10,3 года. Декомпозиционный анализ показал, что основная часть этой разницы обусловлена повышенной смертностью в молодом и среднем зрелом возрасте (20–49 лет) в Республике Тыва. Различия в смертности в младенческом и старшем возрастах также вносят вклад в указанный разрыв, но в меньшей степени. Полученные результаты демонстрируют, что именно возрастные группы, соответствующие молодому и среднему зрелому возрасту, обеспечивают наибольший вклад в общую разницу ожидаемой продолжительности жизни между двумя регионами. В исследовании подчёркивается, что, хотя отличия наблюдаются на всех этапах жизненного цикла, снижение смертности среди трудоспособного взрослого населения окажет наибольшее влияние на уменьшение разрыва.

Целью исследования является количественная оценка возрастных факторов, определяющих разницу в ожидаемой продолжительности жизни между Москвой и Республикой Тыва, и выявление ключевых возрастных групп, наиболее ответственных за наблюдаемые различия.

Анализ разложения возрастных вкладов позволяет детально понять демографические механизмы, лежащие в основе региональных различий в ожидаемой продолжительности жизни в России.

Ключевые слова: *декомпозиция Арриаги; продолжительность жизни; смертность; регион России; Москва; Республика Тыва; Россия; возрастоспецифическая смертность; демографический анализ*

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Introduction

Life expectancy varies widely across regions of the Russian Federation, reflecting deep socioeconomic and health inequalities. Moscow, the nation's capital in western Russia, consistently reports one of the highest life expectancies in the country, benefiting from advanced healthcare facilities, higher incomes and better living conditions. In contrast, the Republic of Tuva, located in southern Siberia bordering Mongolia, is geographically remote with a predominantly rural population. Although Moscow and Tuva differ in their formal status — Moscow being a federal city and Tuva being a republic — from an administrative perspective both are constituent entities of the Russian Federation. This makes their comparison within a single analytical framework appropriate. While Tuva is rich in indigenous culture and strong community traditions, it currently experiences a significantly lower life expectancy compared to other regions of Russia. Tuva's population (approximately 337,544[1] in 2024) faces significant economic challenges, and healthcare access is limited compared to Moscow. Meanwhile, Moscow's population (about 13.1 million[2] in 2024) is urban, economically developed, and it has far greater infrastructure and resources supporting health and well-being. These pronounced differences in geography, population size and socioeconomic conditions make Moscow and Tuva an insightful case study for regional health disparities.

According to official Rosstat statistics for 2021, life expectancy at birth across Russia's federal subjects varies by more than a decade, from below 66 years in several Siberian and Far Eastern regions, including the Republic of Tuva, to over 78 years in Moscow and a few other high-performing regions[3]. This visual context underlines why examining the gap between these two regions is important, as they occupy opposite ends of Russia's internal life expectancy spectrum. In 2023, according to our calculations, life expectancy at birth in Moscow was around 77 years, markedly higher than in Tuva (around 67 years). This 10-year gap raises questions about which age groups contribute the most to the difference and what underlying factors are at play.

Previous studies of regional mortality in Russia, analyzing data for the post-Soviet period from the early 1990s to the late 2010s, have noted that disparities are often driven by differences in adult mortality, particularly among working-age males, and by varying access to healthcare and lifestyle factors (Timonin et al., 2017). By selecting Moscow and Tuva, this study focuses on a best-case versus worst-case scenario within one country, allowing for a detailed decomposition of the life expectancy gap. In the following sections, we construct life tables for each region and apply Arriaga's age-decomposition method to quantify the contribution of each age group to the overall life expectancy difference. This approach provides insight into the critical ages where interventions could significantly improve longevity in regions such as Tuva, where life expectancy is currently lower.

Methods

Data Sources.

The primary data sources for this analysis were the *Moscow Statistical Yearbook 2024*[4] and the *Statistical Yearbook of the Republic of Tuva 2024*[5], published by the Federal State Statistics Service of Russia (Rosstat). These publications provide detailed mortality data and population statistics for the year 2023. From these sources, we obtained the age-specific mortality rates for each region, which serve as the basis for life table construction. The data cover both sexes combined (total population) of Moscow and Tuva for all age intervals from birth through 85 years and above.

[1] See: The resident population of the Russian Federation by municipalities as of January 1, 2024 [online] *Rosstat*. Available at: https://rosstat.gov.ru/storage/mediabank/Chisl_MO_01-01-2024.xlsx (accessed 15.03.2025). (In Russ.).
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[4] *Moscow statistical yearbook 2024*: A statistical book / Moscow and Moscow Oblast Territorial Body of the Federal State Statistics Service (Mosstat). Moscow, 2024. (In Russ.).
[5] *Statistical yearbook of the Republic of Tuva 2024*: A statistical book / Krasnoyarskstat. Krasnoyarsk, 2024. (In Russ.).

Life Table Construction (Auger et al., 2014)

Using the mortality data, we constructed complete life tables for Moscow and Tuva for the year 2023. The life table is a standard demographic tool that summarizes the mortality experience of a hypothetical birth cohort (often of 100,000 births) as it ages, given the age-specific mortality rates of a particular period. We followed conventional life table methodology:

— *Initial Cohort and Mortality Rates* (${}_nm_x$): We began with a radix (starting population) of l_0 = 100,000 newborns for each hypothetical cohort. For each age interval (denoted by x to x+n, e.g., 0, 1–4, 5–9, ..., 80–84, and 85+), the age-specific mortality rate ${}_nm_x$ was taken from the yearbooks. This rate is the annual mortality rate for that age group (for grouped ages, an average over the interval). For example, in 2023 the infant mortality rate (under 1 year, m_0) in Moscow was around 0.0040, whereas in Tuva it was about 0.0062 (per person-year), indicating higher infant mortality in Tuva.

— *Probability of Dying* (${}_nq_x$): We converted each age-specific mortality rate into a probability of dying within that age interval. For a small age interval (like one year or an open-ended final interval), ${}_nq_x$ can be approximated by n_nm_x / $1+n(1-{}_na_x){}_nm_x$, where a_x is the average fraction of the interval lived by those who die in the interval (for infancy, we used standard convention a = 0.3; for other ages often a = 0.5). For wider age groups (e.g., 5-year groups), a similar formula is used. This yielded, for example, a probability of dying before age 1 of 0.00399 in Moscow and of 0.00618 in Tuva (consistent with the mortality rates above). For ages 1–4, Moscow's mortality probability in 2023 was 0.00120, whereas Tuva's was 0.00200; thus, in that four-year interval, the risk of death was higher in Tuva than in Moscow, a contrast that will influence the decomposition results.

— *Survivor and Death Distribution* (l_x, ${}_nd_x$): Starting with l_0 = 100,000, we computed the number of survivors at the beginning of each subsequent age interval using $l_{x+1} = l_x - {}_nd_x$. The number of deaths in the interval ${}_nd_x$ is then ${}_nd_x = {}_nq_x \times l_x$. This stepwise computation was carried out for each age interval up to the last open-ended interval (85+). For instance, out of 100,000 newborns, about l_1 = 99,601 would survive to age 1 in Moscow (since d_0 = 399 infant deaths), whereas about l_1 = 99,382 would survive in Tuva (with d_0 = 618 deaths under age 1, reflecting higher infant mortality).

— *Person-Years Lived* (${}_nL_x$) *and Total Number of Person-Years Lived* (T_x): For each interval, we calculated ${}_nL_x$, the number of person-years lived between ages x and x+n by the cohort. For all intervals except the last, ${}_nL_x$ is approximately $n(l_x+l_{x+n})/2$ (the trapezoidal rule, assuming a roughly linear decline within the interval). For the final open interval (85+), L_{85+} is often calculated as l_{85+}/m_{85+}, where m_{85+} is the mortality rate at 85+ (or by assuming an exponential distribution of deaths beyond 85). Using the life table values, we then computed $T_x = T_{x+n} + {}_nL_x$, the total number of person-years remaining in the cohort at age x. By construction, T_0 (total person-years lived by the cohort from birth onward) divided by the starting cohort l_0 yields the life expectancy at birth: $e_0 = T_0/l_0$.

Applying this process yielded complete life tables (summarized in Table 1 for Moscow and in Table 2 for Tuva). Key outcomes from these life tables are the life expectancy at birth and at other ages. In Moscow, e_0 (life expectancy at birth in 2023) was calculated to be 76.99 years, whereas in Tuva it was 66.70 years. This confirmed a life expectancy gap of approximately 10.3 years favoring Moscow. The life tables also reveal that at every age, the number of survivors l_x is consistently higher in Moscow's cohort than in Tuva's, reflecting higher cumulative mortality in Tuva. For example, by age 50, about 88,985 out of 100,000 are still alive in Moscow, compared to only 79,594 in Tuva — a sizable difference by mid-life. These life tables form the basis for the subsequent decomposition of the life expectancy gap.

Arriaga's Decomposition Method (Arriaga, 1984)

In order to identify the contribution of each age group to the overall difference in life expectancy between Moscow and Tuva, we employed the Arriaga decomposition method. This method, originally formulated by Eduardo Arriaga, breaks down the gap in life expectancy into age-specific components. The underlying principle is to assess how differences in mortality at each age contribute to the difference in overall life expectancy.

Using Moscow as the reference (higher life expectancy) and Tuva as the comparison, the formula for the contribution of a given age interval x to x+n is as follows:

$$ {}_n\Delta_x = \underbrace{\left(\frac{l_x^{Tuva}}{l_0}\right)\left(\frac{{}_nL_x^{Moscow}}{l_x^{Moscow}} - \frac{{}_nL_x^{Tuva}}{l_x^{Tuva}}\right)}_{\text{Direct effect (term 1)}} + \underbrace{\left(\frac{T_{x+n}^{Moscow}}{l_0}\right)\left(\frac{l_x^{Tuva}}{l_x^{Moscow}} - \frac{l_{x+1}^{Tuva}}{l_{x+1}^{Moscow}}\right)}_{\text{Indirect effect (term 2)}} $$

where ${}_n\Delta_x$ is the contribution (in years) to the life expectancy gap attributable to mortality differences in the age interval x, x+n. In this equation, l_x^{Tuva} is the number of survivors at age x in Tuva's life table (as a fraction of the initial 100,000, since we divide by l_0), ${}_nL_x^{Moscow}$ and ${}_nL_x^{Tuva}$ are the person-years lived in that age interval in the Moscow and Tuva life tables respectively, and T_{x+n}^{Moscow} is the total person-years remaining in the Moscow life table above age x+n (i.e., for all ages older than the interval in question). The term 1 represents the direct effect: the difference in years lived in that age interval, weighted by the proportion of the cohort that reaches that age in Tuva. The second term represents the indirect effect: the impact on the life expectancy gap of having fewer survivors entering the next age interval due to Tuva's higher mortality in the current interval. In other words, if more people die in Tuva between x and x+n, fewer remain to enjoy the years beyond x+n, compounding the life expectancy loss. This second term also inherently captures any interaction effects when mortality differences exist across multiple consecutive age intervals, as the survivor deficit carries forward to all subsequent ages.

For the open-ended age interval, there will be only a direct effect, and the following equation applies:

$$ {}_\infty\Delta_x = \left(\frac{l_x^{Tuva}}{l_0}\right)\left(\frac{T_x^{Moscow}}{l_x^{Moscow}} - \frac{T_x^{Tuva}}{l_x^{Tuva}}\right) $$

After computing Δe_x^{x+n} for each age group, we verify that summing these contributions over all age groups reproduces the total life expectancy gap:

$$ \Delta e_x^{x+n} = e_0^{Moscow} — e_0^{Tuva} = 76.99–66.70 = 10.29 \text{ years}. $$

This additivity is an important check for the correctness of the decomposition. The result is a breakdown of the 10.3-year gap into contributions attributable to differences in mortality in infancy, childhood, young adulthood, middle age and old age. We also computed the percentage contribution of each age group by dividing the age-specific gap Δe_x^{x+n} by the total gap; this gives a sense of the relative importance of each age interval on a percentage scale.

Results

Life Expectancy Differences

In order to analyze mortality patterns and calculate life expectancy in Moscow and Tuva for 2023, we constructed complete life tables for both regions using official age-specific mortality rates.

Table 1. Life Table for Moscow in 2023
Таблица 1. Таблица дожития в Москве (2023)

Age	*Age-specific mortality rate (ASMR)*	*Probability of dying between exact age x and x+n*	*Number of deaths between age x and x+n*	*Number of survivors from birth to exact age x*	*Person-years lived between age x and x+n*	*Total number of person-years lived after exact age x*	*Life expectancy at age x*
	${}_nm_x$	${}_nq_x$	${}_nd_x$	l_x	${}_nL_x$	T_x	e_x
<1	0,0040	0,00399	399	100 000	99 711	7 698 853	76,99
1–4	0,0003	0,00120	119	99 601	398 084	7 599 142	76,30

5–9	0,0002	0,00100	99	99 481	497 158	7 201 058	72,39
10–14	0,0002	0,00100	99	99 382	496 661	6 703 899	67,46
15–19	0,0007	0,00349	347	99 283	495 546	6 207 238	62,52
20–24	0,0013	0,00648	641	98 936	493 076	5 711 693	57,73
25–29	0,0020	0,00995	978	98 295	489 028	5 218 616	53,09
30–34	0,0028	0,01390	1 353	97 317	483 201	4 729 588	48,60
35–39	0,0036	0,01784	1 712	95 964	475 539	4 246 387	44,25
40–44	0,0050	0,02469	2 327	94 252	465 441	3 770 849	40,01
45–49	0,0065	0,03198	2 940	91 925	452 273	3 305 408	35,96
50–54	0,0081	0,03970	3 532	88 985	436 093	2 853 135	32,06
55–59	0,0108	0,05258	4 493	85 452	416 029	2 417 042	28,29
60–64	0,0156	0,07507	6 078	80 959	389 602	2 001 012	24,72
65–69	0,0197	0,09388	7 030	74 882	356 833	1 611 410	21,52
70–74	0,0264	0,12383	8 402	67 852	318 255	1 254 577	18,49
75–79	0,0364	0,16682	9 917	59 450	272 456	936 322	15,75
80–84	0,0542	0,23866	11 822	49 533	218 109	663 866	13,40
85+	0,0846	1,00000	37 711	37 711	445 757	445 757	11,82

Source: study results obtained by the authors and based on the Moscow Statistical Yearbook 2024[1].

Источник: результаты исследования, полученные авторами на основе Московского статистического ежегодника (2024 г.).

Table 2. Life Table for Tuva in 2023
Таблица 2. Таблица дожития в Туве (2023)

Age	*Age-specific mortality rate (ASMR)*	*Probability of dying between exact age x and x+n*	*Number of deaths between age x and x+n*	*Number of survivors from birth to exact age x*	*Person-years lived between age x and x+n*	*Total number of person-years lived after exact age x*	*Life expectancy at age x*
	$_nm_x$	$_nq_x$	$_nd_x$	l_x	$_nL_x$	T_x	e_x
<1	0,0062	0,00618	618	100 000	99 553	6 670 012	66,70
1–4	0,0005	0,00200	199	99 382	396 996	6 570 459	66,11
5–9	0,0003	0,00150	149	99 183	495 545	6 173 463	62,24
10–14	0,0005	0,00250	247	99 035	494 555	5 677 918	57,33
15–19	0,0012	0,00598	591	98 787	492 460	5 183 362	52,47
20–24	0,0033	0,01636	1 607	98 196	486 965	4 690 903	47,77
25–29	0,0043	0,02127	2 055	96 589	477 811	4 203 938	43,52
30–34	0,0072	0,03536	3 343	94 535	464 317	3 726 127	39,42
35–39	0,0074	0,03633	3 313	91 192	447 677	3 261 810	35,77
40–44	0,0093	0,04544	3 994	87 879	429 411	2 814 133	32,02
45–49	0,0105	0,05116	4 291	83 885	408 699	2 384 722	28,43
50–54	0,0106	0,05163	4 110	79 594	387 697	1 976 023	24,83
55–59	0,0161	0,07739	5 841	75 485	362 819	1 588 326	21,04
60–64	0,0258	0,12118	8 440	69 643	327 117	1 225 507	17,60

[1] *Moscow statistical yearbook 2024* : A statistical book / Moscow and Moscow Oblast Territorial Body of the Federal State Statistics Service (Mosstat). Moscow, 2024. (In Russ.).

65–69	0,0338	0,15583	9 537	61 204	282 174	898 390	14,68
70–74	0,0490	0,21826	11 277	51 666	230 138	616 216	11,93
75–79	0,0737	0,31117	12 568	40 389	170 527	386 078	9,56
80–84	0,1000	0,40000	11 129	27 821	111 286	215 551	7,75
85+	0,1601	1,00000	16 693	16 693	104 265	104 265	6,25

Source: study results obtained by the authors and based on the *Statistical Yearbook of the Republic of Tuva 2024*[1].

Источник: результаты исследования, полученные авторами на основе Статистического ежегодника Республики Тыва (2024 г.).

The life-table results for Moscow and Tuva highlight a striking disparity in survival across all ages. Life expectancy at birth in Moscow in 2023 was 76.99 years, versus only 66.70 years in Tuva, confirming a gap of approximately 10.29 years. This means that, on average, individuals in Tuva live almost a decade less than those in Moscow. The gap persists, and in some cases widens, across various milestone ages:

— At age 15 (adolescence), the remaining life expectancy in Moscow was about 62.5 years, compared to 52.5 years in Tuva. By this age, the gap is already 10 years, reflecting higher childhood and teenage mortality in Tuva (with the exception of the anomaly in early childhood noted above).

— At age 30 (young adulthood), life expectancy in Moscow was about 48.6 additional years, whereas in Tuva it was only 39.4 years. The gap at 30 is roughly 9.2 years, very similar to the gap at birth, implying that much of the life expectancy difference emerges by young adulthood.

— At age 50 (middle age), someone in Moscow could expect about 32.1 more years, versus 24.8 years for someone in Tuva — a gap of around 7.3 years remaining at age 50. This suggests that while the absolute gap narrows slightly by age 50 (because a higher proportion of the most vulnerable individuals in Tuva do not survive to that point), a substantial difference remains even in middle age.

— At age 70 (elderly), life expectancy in Moscow was about 18.5 years versus 11.9 years in Tuva, yielding a gap of 6.6 years among those who survive to 70. This indicates that, even at older ages, mortality in Tuva is higher, trimming the remaining years of life more rapidly than in Moscow.

These figures underline that the life expectancy gap is not due to a single age group but is the cumulative result of mortality differences at nearly every stage of life. However, the magnitude of those differences varies by age. The decomposition analysis pinpoints these variations.

Age-wise Contributions to the Gap

Applying the Arriaga method, we quantified how each age interval contributed to the 10.29-year Moscow–Tuva life expectancy gap.

Figure 1 summarizes the findings, and key values are described here. Overall, the majority of the gap was driven by higher mortality in Tuva among young and middle-aged adults, whereas some age intervals in childhood made negligible contributions:

— *Infancy (0) and Childhood (1–14 years):* Most childhood age groups had relatively small contributions to the life expectancy gap, which is expected because childhood mortality in absolute terms is low in both regions. The 1–4-year age group showed a small positive contribution of about +0.06 years — indicating only a slight excess mortality in Tuva at this age. In contrast, the infant age group (< 1 year) contributed around +0.17 years to the gap, reflecting higher infant mortality in Tuva. Taken together, ages 0–4 added roughly +0.23 years to the gap. Ages 5–14 contributed very marginally (on the order of a few hundredths of a year each) to the gap, since mortality for school-age children is very low in both regions.

— *Young Adult and Middle Ages (20–49 years):* These age groups collectively formed the largest component of the gap. Notably, the 30–34-year age group contributed approximately +0.95 years to the gap (about 9 % of the total difference) — the single largest age-specific contribution. This means that excess mortality in Tuva at ages 30–34 (for example, due to accidents, violence or health issues) costs nearly a full year of life expectancy relative to Moscow. The neighboring age groups also showed high contributions: for instance, 25–29, 35–39

[1] *Statistical yearbook of the Republic of Tuva 2024* : A statistical book / Krasnoyarskstat. Krasnoyarsk, 2024. (In Russ.).

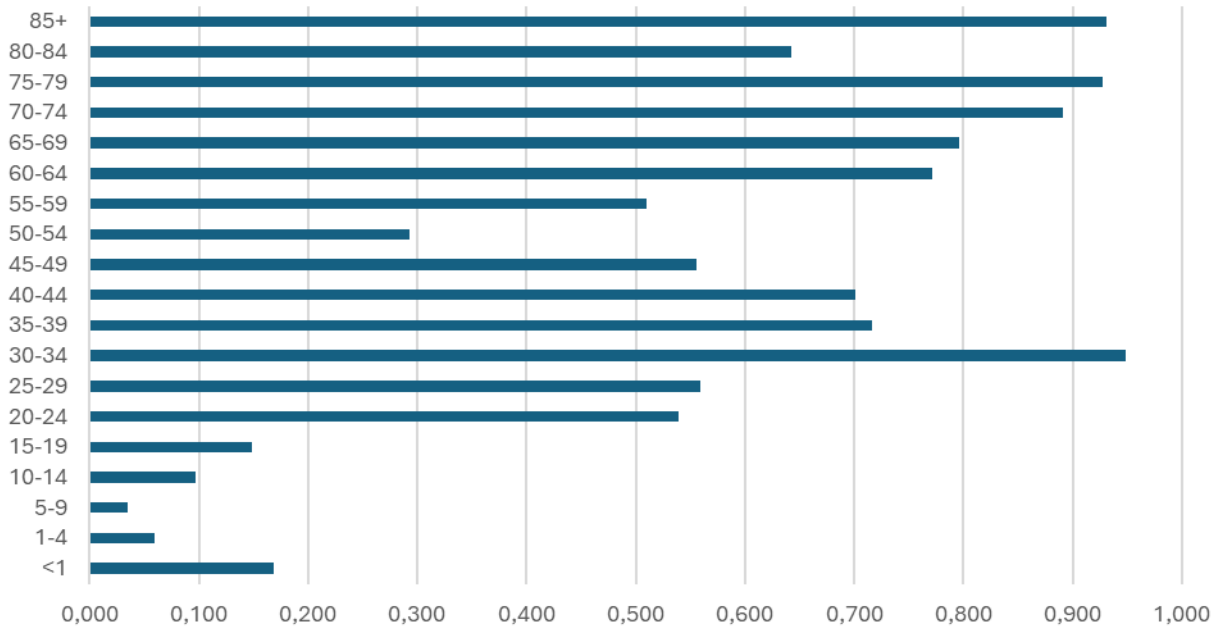

Fig. 1. Age-specific contributions to the life expectancy gap between Moscow and Tuva, 2023
Source: calculated by the authors and based on Tables 1 and 2.
Рис. 1. Вклад возрастных групп в разницу ожидаемой продолжительности жизни между Москвой и Тувой (2023)
Источник: рассчитано авторами на основе таблиц 1 и 2.

and 40–44 each likely contributed on the order of 0.55–0.70 years each to the gap. These results point to the young working-age population (approximately 20–44) as a critical period where Tuva faces much higher mortality risks than Moscow, greatly widening the life expectancy divide. By the time the cohort reaches middle age (around 50), a substantial portion of the gap has already been realized due to earlier losses in Tuva.

— *Older Working Ages and Early Elderly (50–69 years):* These age intervals also contributed positively to the gap, though slightly less per interval than the younger adult ages. For example, mortality differences in the 50–54, 55–59 and 60–64 groups each accounted for a few tenths of a year of the gap per group (0.29, 0.51, and 0.77 years, respectively). Cumulatively, however, the 50–69 range still added several years to the gap. Many individuals in Tuva do not survive into these older ages at the rates seen in Moscow (as evidenced by the lower l_x in Tuva's life table for these ages). This results in fewer person-years lived at older ages and thus a lower life expectancy. By age 70, as noted, the cumulative difference realized is already around 6–7 years, which is exactly the cumulative result of differences up to that age.

— *Elderly (70+ years):* At older ages, the contributions per interval decline, largely because relatively fewer people survive to those ages in both populations (especially in Tuva). Nonetheless, the higher mortality in Tuva's elderly (for example, from chronic diseases that are better managed or occur later in Moscow) continues to add to the gap. Each of the intervals (70–74, 75–79, 80–84) contributed on the order of a few tenths of a year (0.89, 0.93, and 0.64 years, respectively). The final open-ended interval (85+) added about 0.93 years. By age 85, only about 16.7% of the original cohort is alive in Tuva, versus around 37.2% in Moscow. This difference means that Moscow has more survivors and thus more years lived at 85 and above, contributing a small final difference. The 85+ age group's contribution was purely direct (no indirect effect, as explained), and was one of the smaller components, reflecting that relatively few individuals reach that age, especially in Tuva.

Summing across all age groups, the decomposition's age-specific contributions added up to the total gap of 10.29 years, validating the calculation. The largest positive contributor (30–34 with +0.948 years) and the small positive contribution of 1–4 (+0.059 years) are particularly notable, as highlighted by the decomposition results. In percentage terms, the 30–34 age group alone accounts for about 9% of the gap.

The young adult ages (20–39) together account for roughly 40–50% of the gap, underscoring that premature adult mortality is a principal driver of Tuva's low life expectancy. Meanwhile, the contribution of age 1–4 is only about 0.6%, illustrating that early-childhood mortality plays a comparatively minor role in shaping the overall difference. Since contributions at ages 0–4 are modest, early-life mortality slightly widens (rather than narrows) the gap, whereas the vast majority of the disparity emerges later in life.

In summary, Moscow's higher life expectancy is mainly due to substantially lower mortality in adulthood and older ages compared to Tuva. The decomposition shows that if Tuva could achieve the same mortality rates as Moscow in the young adult and middle age intervals, the life expectancy gap would shrink dramatically. Conversely, even if infant and child mortality in Tuva were brought fully in line with Moscow, it would only modestly affect the overall gap (perhaps around half a year's difference, given the small absolute numbers of deaths at those ages). This indicates that public health and policy efforts aimed at reducing mid-life mortality in Tuva (for example, by preventing accidents, violence, alcohol-related deaths and improving medical care for treatable conditions in those age ranges) could yield the most significant gains in closing the life expectancy gap.

Discussion

The present study confirms that Moscow and the Republic of Tuva occupy opposite ends of the Russian life expectancy spectrum. In 2023, the gap in life expectancy at birth reached 10.29 years, with nearly half of this difference generated by excess mortality in Tuva at young and middle adult ages (20–49 years), and the single largest age-specific contribution arising at ages 30–34. This pattern underscores that the life expectancy divide is primarily a consequence of premature adult mortality rather than of differences at very young or very old ages.

Comparison with previous studies of regional mortality in Russia

Our findings are consistent with earlier research documenting pronounced interregional inequalities in life expectancy in Russia. Studies using decomposition techniques for the post-Soviet period have shown that the gap between the best- and worst-performing regions can reach 10–15 years, especially among men, and that these disparities are largely driven by adult mortality (Timonin et al., 2017). The magnitude of the 10-year gap observed here between Moscow and Tuva is therefore comparable to the differences reported in previous work between large metropolitan areas and more remote regions of Russia.

Age-specific decompositions of regional differences in Russia, based on stepwise replacement algorithms, have repeatedly shown that young and middle adulthood (approximately 20–44 or 20–49 years) contributes the bulk of interregional life expectancy gaps, with external causes, cardiovascular diseases and alcohol-related mortality playing a central role (Shchur, Timonin, 2020). Our Arriaga decomposition yields a similar age profile: the cohort in Tuva loses many years of life between ages 20 and 49 relative to Moscow, while infant and early-childhood mortality adds only a small fraction to the total differential. This parallel suggests that the Moscow–Tuva contrast is not an outlier but rather a particularly sharp example of the broader Russian pattern in which working-age mortality is the main driver of regional inequality in longevity.

Tuva in the national context

A growing body of research describes Tuva as one of the regions with the most unfavorable mortality situation in Russia. Analyses of preventable mortality show that the Republic of Tuva consistently ranks among the leaders in standardized rates of avoidable deaths, as well as that a large share of these losses is associated with behavioral and healthcare-amenable causes (Sabgaida et al., 2023). Studies of the socio-demographic situation in Tuva at the beginning of the 21st century likewise emphasize its combination of high mortality, low life expectancy and a relatively young age structure compared to Russia as a whole and to Eastern Siberia (Erdynieva, 2023).

Research on social insecurity and living conditions in Tuva and other traditionally pastoral, Buddhist regions (Kalmykia, Buryatia) highlights persistent economic depression, limited employment opportunities and deficits in social infrastructure (Gunaev, Badmaeva, Kovanova, 2019). These findings resonate with our interpretation of the life expectancy gap: the concentration of excess mortality in young and middle adulthood is consistent with a context where economic hardship, alcohol-related problems, injuries and violence are widespread, and where access to timely and high-quality medical care is constrained. The high contribution of ages 30–34 in our decomposition can be viewed as a quantitative reflection of this broader social vulnerability.

Moscow as a longevity leader

Conversely, Moscow is repeatedly identified in national and international studies as one of the Russian regions with the highest life expectancy, lowest levels of premature years of life lost and the most favorable indicators of preventable mortality (Timonin et al., 2020). Analyses of regional health inequalities stress that large metropolitan areas such as Moscow and St. Petersburg have benefited the most from improvements in healthcare, reductions in alcohol-related mortality and socioeconomic growth since the mid-2000s, whereas small towns and rural regions have lagged behind (Shchur et al., 2021).

Our results align with this "metropolitan advantage": compared to Tuva, Moscow shows much lower mortality at nearly all ages, but especially at working ages where differences in access to advanced medical technologies, emergency services and chronic disease management are most pronounced. The life-table evidence that nearly 89% of the hypothetical cohort in Moscow is still alive at age 50, versus about 80% in Tuva, illustrates how accumulated survival advantages in the capital translate into markedly longer life expectancy.

Interpreting mechanisms in light of existing theoretical and empirical work

The pattern observed in this study supports the broader theoretical framework that views Russian mortality differentials through the lens of social determinants of health and avoidable mortality. Decomposition studies at the national level show that improvements in life expectancy in the 2000s and 2010s were largely achieved through reductions in deaths from cardiovascular diseases and external causes among working-age adults, and that further gains depend on continued progress in these domains (Ivanova, Semenova, Sabgaida, 2021). Our findings suggest that Tuva has benefited less from these favorable trends than Moscow, with persistently high rates of preventable mortality and an especially heavy burden of alcohol- and injury-related deaths, as documented by regional analyses (Sabgaida et al., 2023).

At the same time, studies of regional deprivation and mortality indicate that Tuva combines some of the highest mortality rates in the country with high levels of socioeconomic disadvantage and infrastructural deficits (Zelenina, 2024). In this perspective, the Moscow–Tuva gap can be interpreted as an extreme case of the more general association between regional socioeconomic conditions and survival in Russia: regions with higher incomes, more diversified economies and stronger healthcare systems achieve longer life expectancy, while remote, economically depressed regions struggle to reduce premature mortality (Ivaschenko, 2005; Shartova, Tikunov, Chereshnya, 2021).

Our results therefore corroborate the hypothesis that the main mechanism behind the Moscow–Tuva difference is not a unique local factor but a cumulative effect of known determinants — poverty, social disadvantage, behavioral risks and unequal access to effective healthcare — acting with particular intensity in Tuva and mitigated to a greater extent in Moscow.

Implications and directions for further research

From a policy perspective, the decomposition results — considered alongside previous evidence on preventable mortality and regional deprivation (Andreev et al., 2003) — indicate that the largest potential gains in narrowing the Moscow–Tuva life expectancy gap lie in reducing premature adult mortality in Tuva. This is consistent with national-level estimates showing that a substantial share of Russian mortality is theoretically avoidable through improvements in healthcare efficiency and primary prevention, especially among young and middle-aged adults (Nikoloski, Shkolnikov, Mossialos, 2023).

Future research could extend the present analysis by incorporating cause-specific decomposition, which would allow a more detailed comparison of the contribution of cardiovascular diseases, external causes and other conditions to the Moscow–Tuva gap (Danilova et al., 2020; Kuznetsova, 2020), and by exploring gender-specific patterns, given the strong male disadvantage documented in prior studies (Kalabikhina, 2001; Muraveva, 2012). In addition, linking regional mortality patterns to longitudinal changes in socioeconomic policies, healthcare investments and alcohol control measures would help clarify which interventions have been most effective in reducing premature mortality in other parts of Russia, and thus which strategies may be most promising for Tuva (Neufeld et al., 2020; Brainerd, 2021).

Overall, situating our results within the existing literature shows that the Moscow–Tuva contrast both reflects and amplifies well-known regional inequalities in Russian mortality (Shartova, Tikunov, Chereshnya,, 2021). The study contributes to this field by providing a detailed age-specific decomposition for one of the most extreme regional pairs, thereby quantifying how much of the life expectancy divide is generated at different stages of the life course and reinforcing the centrality of adult survival as a target for reducing health inequalities within the Russian Federation.

Conclusion

The comparative assessment of mortality in Moscow and the Republic of Tuva for 2023 demonstrates a persistent and substantial life expectancy differential of about 10.29 years. Arriaga's decomposition confirms that nearly half of this disparity originates in young and middle adulthood (20–49 years), with the single largest age-specific contribution arising at ages 30–34. Additional, though smaller, contributions accumulate in the following two decades, and late-life mortality differences reinforce the gap among those who survive beyond 70. Infant and child mortality accounts for only a minor share of the overall difference.

These findings indicate that the life expectancy gap is produced by a cumulative cascade of excess mortality in Tuva that begins in early working ages and compounds throughout the life course. Elevated risks linked to external causes, chronic disease management and differential access to timely medical care emerge as underlying mechanisms. Consequently, the most effective gains in narrowing the regional gap would be achieved by targeting preventable deaths in the 20–49 age range — particularly those associated with injuries, lifestyle-related conditions and delayed treatment of acute events — while simultaneously strengthening health-system capacity and socioeconomic conditions that influence survival at older ages.

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