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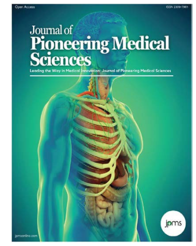

Sex Disparities and Secular Trends in Life Expectancy at Birth and Age 60: An Ecological Analysis of 185 Countries and Territories

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Abstract **Background:** The COVID-19 pandemic has reversed years of accumulated longevity gains worldwide. While sex differences in life expectancy at birth are well documented, global evidence for older age groups remains limited. This study describes 2000–2021 trends in life expectancy at birth and at age 60 across 185 countries and territories, quantifies sex gaps in longevity and their cross-national variation at both ages and evaluates the impact of COVID-19 on longevity gains and disparity patterns. **Methods:** An ecological trend analysis was performed using standardized data from the WHO Global Health Observatory. Two indicators were calculated separately by sex: Life expectancy at birth and remaining life expectancy at age 60. Sex gaps were defined as female life expectancy minus male life expectancy for each indicator. All global estimates were presented as unweighted arithmetic means at the country level. **Results:** Unweighted global life expectancy at birth rose from 66.98 years in 2000 to a peak of 72.62 years in 2019, before declining by 1.33 years to 71.29 in 2021. Remaining life expectancy at age 60 followed a nearly identical pattern, increasing from 18.05 years in 2000 to a pre-pandemic peak of 19.97 years in 2019 and then falling by 1.22 years to 18.75 in 2021. Females consistently showed longer survival, with mean sex gaps of 4.84 years at birth and 2.75 years at age 60, reflecting a substantially smaller female survival advantage in older populations. Cross-national variation in life expectancy exceeded 40 years at birth across the full sample of country-years. **Conclusion:** Two decades of global longevity gains have been reversed by COVID-19, for both life expectancy at birth and at age 60. The female survival advantage is observed across all national populations but diminishes substantially at older ages. Persistent cross-national disparities highlight the need for gender-sensitive health policies and targeted post-pandemic recovery strategies.

Key Words Life Expectancy, Sex Differences, COVID-19, Global Health, Aging, Ecological Analysis

INTRODUCTION

Global life expectancy has increased markedly over 50 years amid an uneven global epidemiologic transition. Reductions in infectious disease, maternal mortality and under-five mortality have contributed the largest share of these survival gains, while gains from chronic disease prevention and care remain clustered in high-income settings and are partly offset by adverse risk factor trends in some regions [1, 2]. A female survival advantage exists in nearly all national populations, with large cross-regional variation in gap size. This disparity arises from subtle biological differences combined with social, behavioral and structural drivers, such as gendered risk-taking, occupational exposures, unequal health care access and wider societal gender inequality [3].

In high-income countries, continuing increases in overall longevity are now mainly driven by rising life expectancy among those aged 60 and older, an indicator closely linked to population ageing and the planning of health and long-term care services for older populations [4]. Criticaally, global evidence on sex-specific disparities in remaining life expectancy at age 60 remains sparse, limiting the evidence base for aging-focused health policy and planning. Large-scale initiatives such as the Global Burden of Disease study have produced long-term, nationally representative data on sex gaps in overall longevity [5], but age-stratified sex gap patterns at older ages have not been systematically characterized across a full global sample.

Following the arrival of COVID-19, decades of consistent longevity growth have reversed across most high-income and upper-middle-income countries with full, dependable mortality data. Age and sex patterns of these losses remain poorly described globally, as most standardized analyses are limited to high-income settings [6]. Only a small number of studies have quantified age-stratified mortality burdens across working-age and older adult populations on a global scale.

This study has three primary objectives: To describe temporal trends in life expectancy at birth and remaining life expectancy at age 60 across 185 countries and territories from 2000 to 2021; to quantify sex disparities in longevity at both age benchmarks and examine cross-national variation in gap magnitude; and to evaluate the impact of the COVID-19 pandemic on accumulated longevity gains and sex disparity patterns. These objectives are addressed through an ecological trend analysis using standardized data from the WHO Global Health Observatory, covering 185 countries and territories over the full study period.

METHODS

Study Design and Data Source

An ecological trend analysis was conducted using nationally aggregated data from the WHO GHO repository [7]. Two standardized period life table indicators were extracted: life expectancy at birth and remaining life expectancy at age 60, stratified by sex (males, females, both sexes combined).

The final analytic sample comprised 185 countries and territories with complete standardized life expectancy data spanning the full 2000–2021 period; jurisdictions without full-study-period WHO data were excluded.

No ethical approval or participant informed consent was required for this study. All data are publicly accessible, de-identified population-level aggregates with no individual identifiers and no human subjects were directly recruited or studied in this work.

Variable Definitions

Both outcome variables were treated as continuous measures and reported in years. Country-year sex gaps were calculated as female minus male life expectancy for both indicators; positive values indicate longer female survival.

Statistical Analysis

All analyses and visualizations were performed in Python 3.11 (*pandas, SciPy, matplotlib and seaborn*), with core analysis code available upon request for reproducibility.

Descriptive statistics were generated for all sex-stratified indicators across the full country-year sample. Annual unweighted country-level arithmetic means, stratified by sex, were used to describe 2000-2021 trends and quantify 2020-2021 pandemic deviations; this approach treats each country as an independent unit and equally represents smaller populations, unlike population-weighted estimates dominated by large-population nations. 95% confidence intervals were calculated via normal approximation of the standard error of the mean, assuming an approximately normal distribution of country-level life expectancy values.

Distributional features of country-year sex gaps were summarised for both indicators. Populations were ranked by 2021 all-sex life expectancy at birth, with the top 10 presented.

RESULTS

Descriptive Characteristics of the Dataset

The analytical dataset comprised 4070 country-year observations from 185 countries and territories, spanning the 2000 to 2021 period. Full descriptive statistics for life expectancy at birth and at age 60, broken down by sex, are provided in Table 1 and their distributions across all country-year observations are displayed in Figure 1. Average life expectancy was higher among females than males at both age benchmarks, with wide variation across countries; a small subset of country-year observations showed male life expectancy exceeding female levels.

Table 1: Descriptive Statistics of Life Expectancy by Indicator and Sex

Indicator	Sex Group	N	Mean	SD	Min	Median	Max
Life expectancy at birth	Both sexes	4070	70.15	8.63	39.96	72.29	84.66
	Female	4070	72.61	8.97	36.60	75.32	87.37
	Male	4070	67.77	8.42	40.86	69.26	82.39
Life expectancy at age 60	Both sexes	4070	19.05	3.19	10.08	18.81	26.85
	Female	4070	20.36	3.38	10.75	20.42	29.07
	Male	4070	17.62	3.13	9.08	17.33	25.46

Notes: All values are presented in years. N, Number of Observations, SD, Standard Deviation

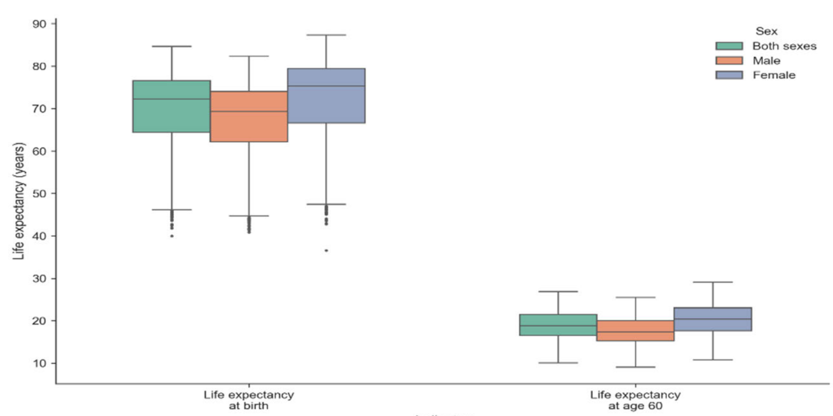

Figure 1: Distribution of Life Expectancy by Indicator and Sex

Table 2: Annual Global Mean Life Expectancy by Indicator and Sex, 2000-2021

	Life expectancy at birth			Life expectancy at age 60		
Year	Both sexes	Male	Female	Both sexes	Male	Female
2000	66.98 (65.57, 68.40)	64.58 (63.23, 65.93)	69.47 (67.98, 70.97)	18.05 (17.62, 18.48)	16.60 (16.19, 17.01)	19.39 (18.93, 19.85)
2001	67.31 (65.90, 68.71)	64.93 (63.59, 66.28)	69.77 (68.28, 71.25)	18.18 (17.74, 18.61)	16.74 (16.32, 17.16)	19.50 (19.04, 19.97)
2002	67.54 (66.14, 68.93)	65.19 (63.86, 66.52)	69.97 (68.50, 71.45)	18.21 (17.77, 18.65)	16.79 (16.36, 17.21)	19.53 (19.06, 20.00)
2003	67.81 (66.43, 69.19)	65.49 (64.17, 66.80)	70.22 (68.76, 71.68)	18.25 (17.81, 18.69)	16.83 (16.40, 17.25)	19.57 (19.10, 20.04)
2004	68.15 (66.78, 69.51)	65.83 (64.53, 67.14)	70.54 (69.09, 71.98)	18.39 (17.94, 18.83)	16.97 (16.53, 17.40)	19.70 (19.23, 20.18)
2005	68.50 (67.16, 69.84)	66.15 (64.87, 67.44)	70.93 (69.52, 72.35)	18.50 (18.05, 18.94)	17.07 (16.63, 17.51)	19.82 (19.34, 20.30)
2006	68.94 (67.62, 70.25)	66.58 (65.32, 67.84)	71.38 (69.99, 72.76)	18.68 (18.22, 19.13)	17.26 (16.81, 17.70)	19.99 (19.50, 20.47)
2007	69.31 (68.03, 70.58)	66.92 (65.69, 68.15)	71.77 (70.42, 73.12)	18.79 (18.34, 19.25)	17.36 (16.92, 17.81)	20.12 (19.63, 20.60)
2008	69.65 (68.40, 70.90)	67.25 (66.04, 68.46)	72.12 (70.80, 73.43)	18.91 (18.46, 19.37)	17.48 (17.03, 17.92)	20.24 (19.75, 20.72)
2009	70.04 (68.82, 71.26)	67.65 (66.46, 68.83)	72.50 (71.23, 73.78)	19.05 (18.59, 19.51)	17.62 (17.17, 18.07)	20.37 (19.88, 20.85)
2010	70.31 (69.07, 71.55)	67.97 (66.78, 69.16)	72.71 (71.41, 74.01)	19.12 (18.65, 19.59)	17.70 (17.24, 18.15)	20.42 (19.93, 20.91)
2011	70.72 (69.53, 71.92)	68.35 (67.18, 69.52)	73.15 (71.91, 74.38)	19.29 (18.83, 19.76)	17.87 (17.42, 18.33)	20.59 (20.09, 21.08)
2012	71.04 (69.88, 72.20)	68.65 (67.51, 69.79)	73.48 (72.28, 74.67)	19.40 (18.95, 19.86)	17.99 (17.54, 18.44)	20.69 (20.20, 21.17)
2013	71.35 (70.21, 72.50)	68.96 (67.83, 70.09)	73.79 (72.62, 74.96)	19.54 (19.08, 19.99)	18.13 (17.68, 18.57)	20.81 (20.33, 21.30)
2014	71.51 (70.36, 72.65)	69.10 (67.96, 70.23)	73.97 (72.80, 75.14)	19.61 (19.15, 20.07)	18.21 (17.76, 18.66)	20.88 (20.40, 21.37)
2015	71.69 (70.57, 72.81)	69.29 (68.17, 70.40)	74.15 (73.01, 75.28)	19.65 (19.19, 20.10)	18.25 (17.80, 18.70)	20.91 (20.43, 21.39)
2016	71.95 (70.85, 73.05)	69.54 (68.44, 70.64)	74.42 (73.30, 75.53)	19.75 (19.29, 20.20)	18.34 (17.89, 18.79)	21.03 (20.54, 21.51)
2017	72.17 (71.09, 73.26)	69.77 (68.68, 70.86)	74.63 (73.54, 75.73)	19.82 (19.37, 20.27)	18.42 (17.98, 18.86)	21.10 (20.62, 21.58)
2018	72.42 (71.35, 73.49)	70.01 (68.94, 71.08)	74.88 (73.80, 75.96)	19.92 (19.47, 20.37)	18.49 (18.05, 18.94)	21.21 (20.73, 21.69)
2019	72.62 (71.57, 73.67)	70.25 (69.19, 71.30)	75.04 (73.97, 76.11)	19.97 (19.51, 20.42)	18.55 (18.11, 19.00)	21.25 (20.77, 21.74)
2020	72.05 (71.03, 73.07)	69.51 (68.49, 70.53)	74.71 (73.67, 75.74)	19.26 (18.80, 19.72)	17.63 (17.17, 18.09)	20.80 (20.32, 21.29)
2021	71.29 (70.26, 72.32)	68.90 (67.87, 69.93)	73.75 (72.71, 74.80)	18.75 (18.28, 19.22)	17.31 (16.85, 17.78)	20.08 (19.59, 20.57)

Notes: All values are unweighted country-level arithmetic means rounded to two decimal places. 95% confidence intervals are shown in parentheses. Source: WHO Global Health Observatory, 2000-2021

Table 3: Sex Gap in Life Expectancy by Indicator

Indicator Name	Country-Year Observations	Mean Gap	SD Gap	Min Gap	Max Gap
Life expectancy at birth (years)	4070	4.84	2.35	-7.33	18.70
Life expectancy at age 60 (years)	4070	2.75	1.49	-4.55	8.34

Notes: Sex gaps calculated as female minus male life expectancy. Source: WHO Global Health Observatory, 2000-2021

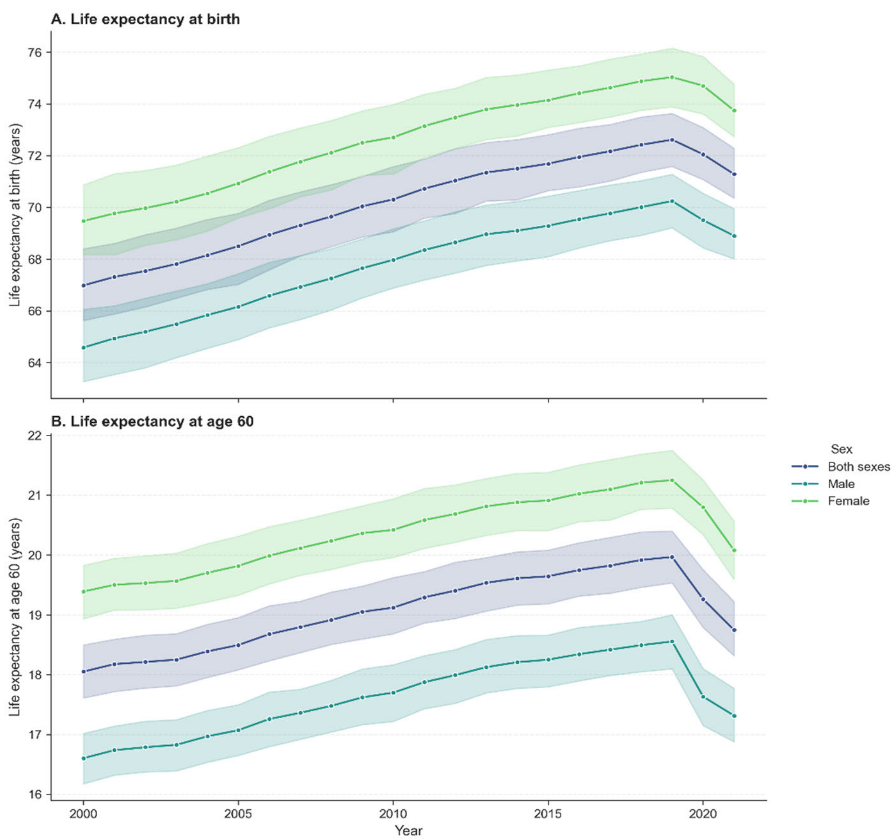

Figure 2: Temporal Trends in Sex-Specific Life Expectancy, 2000-2021

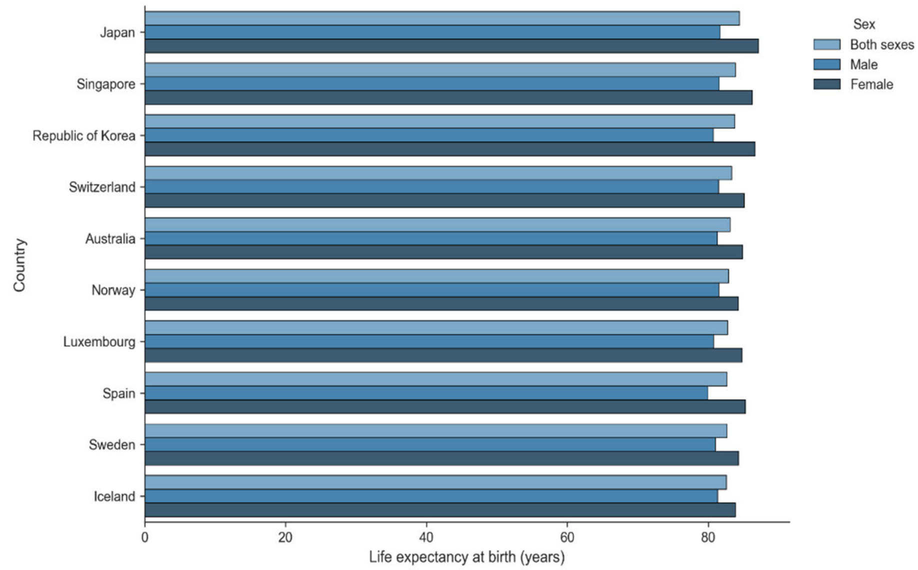

Figure 3: Top 10 Countries by Life Expectancy at Birth (2021)

Temporal Trends in Global Life Expectancy

Unweighted global life expectancy rose steadily across both age groups from 2000 to 2019 and fell sharply during the COVID-19 pandemic, with annual means and 95% confidence intervals reported in Table 2 and visualized as shaded bands in Figure 2.

Life expectancy at birth rose from 66.98 years (2000) to a 72.62-year peak (2019), a 5.64-year gain, before falling 1.33 years to 71.29 years by 2021. Remaining life expectancy at age 60 followed the same pattern, falling 1.22 years from the 2019 peak of 19.97 to 18.75 years in 2021.

Sex Disparities in Life Expectancy

Country-year sex gaps, defined as female life expectancy minus male life expectancy, are outlined in Table 3.

The average sex gap across all country-year observations was 4.84 years at birth and 2.75 years at age 60, indicating that the female survival advantage shrinks considerably in older age groups. Gap size varied widely across populations, with negative values seen in a small number of countries.

Cross-National Variation in 2021

Top-ranked populations by all-sex life expectancy were concentrated in high-income East Asia, Western Europe and Oceania, led by Japan. Female life expectancy exceeded male levels across all 10 top-ranked jurisdictions (Figure 3).

DISCUSSION

Drawing on standardized population data from 185 countries and territories spanning 2000 to 2021, this ecological analysis characterizes global trajectories of life expectancy at birth and at age 60, alongside sex disparities in both indicators. Three core patterns emerge from the data: 20 years of steady longevity gains followed by a sharp pandemic reversal, a universal female survival advantage narrowing at older ages and persistent cross-national inequality linked to epidemiologic transition.

Global birth-period life expectancy rose steadily 1990-2010, driven by falling infectious mortality and shifts in metabolic and behavioral risk factors [8,9]. The reduction in life expectancy at birth in 2020 (versus expected levels based on pre-pandemic trends) represents one of the largest short-term longevity reversals in decades, as documented in multi-country analyses [6]. COVID-19 mortality follows a strong age gradient, with fatality rising sharply with advancing age [10]. This finding extends prior birth-focused research by confirming that pandemic mortality impacts extend deeply into older adult populations.

The well-documented female survival advantage in life expectancy at birth arises from biological underpinnings modulated by behavioral, social and environmental factors [11]. Biologically, estrogen-mediated cardioprotective effects and sex-specific differences in immune function are proposed mechanisms underlying this gap [12]. Historical sex differences in smoking prevalence are a major driver of sex gaps in overall life expectancy, accounting for roughly 40% of the female survival advantage across European national populations on average [13]. These drivers also explain the wide cross-national variation in gap magnitude observed in our study.

The magnitude of the sex longevity gap decreases gradually with increasing age, with a remaining gap of 2.75 years at age 60 consistent with well-established age patterns of male excess mortality and no uniform global shift in the magnitude of this gap occurred during the pandemic period. Cross-national birth cohort evidence from developed countries verifies that the male-to-female mortality ratio peaks at ages 50-70, driven primarily by cardiovascular disease. Smoking-attributable fatalities account for roughly 30% of this excess male mortality at ages 50-70 in 1900-1935 birth cohorts and the ratio falls to a baseline of around

1.18 by advanced old age [14]. Population-level data from 63 countries show large cross-national variation, with the male disadvantage in COVID-19 mortality exceeding all-cause sex differences in most settings [15]. This variation across age groups and settings indicates the sex survival gap is not a fixed biological trait, but is shaped by cohort behavioral exposures, baseline chronic disease susceptibility differences and disease-specific pathophysiology.

The over 40-year cross-national variation in life expectancy at birth across 185 countries and territories reflects persistent global health inequality. Cross-national studies show that publicly funded health systems are independently associated with longer life expectancy alongside socioeconomic determinants. Populations with publicly funded health coverage consistently achieve higher life expectancy, even after adjustment for education, economic stability and select built environment factors [16]. This divergence aligns with distinct stages of the epidemiologic transition: early-transition settings face high mortality from infectious disease and malnutrition, while high-income late-transition settings see greater longevity with a shift to degenerative and lifestyle-related diseases as leading causes of death [17]. These patterns indicate that narrowing global survival gaps and supporting equitable post-pandemic recovery require expanded universal health coverage, targeted sex-informed public health interventions and sustained investment in social determinants to accelerate epidemiologic progress in disadvantaged populations.

This study has several notable strengths. Standardized, nationally representative WHO data covering 185 populations over 22 years offer a comprehensive global view of longevity trends and sex-specific survival gaps. The inclusion of both life expectancy at birth and remaining life expectancy at age 60 enables direct comparison of sex dis-parity patterns across the life course and explicit quantification of pandemic impacts on older adult populations. The use of unweighted country-level means provides a distributional perspective on national health outcomes that complements conventional population-weighted global estimates.

Several limitations should be acknowledged and considered when interpreting the findings. The ecological study design uses national aggregate data, so individual-level causal conclusions cannot be drawn from the results. Unweighted country-level estimates differ from population-weighted metrics and reflect national-level outcome distributions rather than the average survival experience of the global population. Da-ta are only available through 2021, meaning subsequent post-pandemic recovery trends and long-term impacts of post-acute COVID-19 sequelae cannot be evaluated in the present analysis.

CONCLUSION

Using a large global panel dataset, this study confirms two decades of longevity growth followed by pandemic reversal, quantifies the age gradient of sex gaps in life expectancy and documents persistent cross-national disparities. Future research should track post-pandemic life expectancy recovery trajectories, examine context-specific sex gap drivers across income groups and evaluate targeted policy interventions to reduce global health disparities.

Acknowledgement

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Authors Contribution

TX contributed to the conception and design of the study, acquired and preprocessed the country-level life expectancy data from the WHO Global Health Observatory, performed all statistical analyses and graphical visualizations, quantified sex-specific survival gaps and secular trends and drafted the original manuscript. XH supervised the study design, provided methodological guidance on demographic and epidemiological interpretation and critically revised the manuscript for substantive intellectual content. All authors have read and approved the final version of the manuscript.

Ethical Statement

This article does not contain any studies with human participants or animals conducted by any of the authors.

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