CLINICAL RESEARCH STUDY

THE AMERICAN JOURNAL of MEDICINE®

Sex differences in all-cause and cause-specific mortality and years of life lost in the United States, 2000-2023

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ABSTRACT

BACKGROUND: A persistent mortality gap exists between males and females in the United States. We describe temporal, age-specific, cause-specific trends in mortality with respect to sex differences.

METHODS: Data from individuals with national death certificate data from 2000 to 2023 available in CDC WONDER were collected. We estimated sex-specific age-adjusted mortality rates (AAMR) and years of potential life lost (YPLL) by 5-year age groups, year, and cause of death. Excess mortality was defined as the difference between male and female AAMR and YPLL for each subgroup.

RESULTS: Males exhibited higher AAMR than females from 2000 to 2023. Despite excess male AAMR decreasing from 291 per 100,000 in 2000 to 216 in 2014, excess YPLL remained stable. After approximately 2014, excess YPLL mirrored excess AAMR trends and increased markedly, reaching 8.1 million years in 2023—a burden concentrated in younger and middle-aged men. External causes of death were the largest contributors to excess YPLL in men aged 25-44, while circulatory diseases dominated among men over 55.

CONCLUSIONS: Excess male mortality is persistently elevated in cardiovascular causes and increasingly concentrated in external causes in young and middle-aged males. Prevention and care strategies targeted to these drivers may reduce the gap. Results may be influenced by death certificate misclassification, competing risks of death changing over time, and differences in race/ethnicity subgroups.

 • The American Journal of Medicine (2026) 139:1015−1022

KEYWORDS: Sex differences in mortality; Trends in sex-based mortality; years of life lost; external causes of death; cardiometabolic mortality

All authors had access to the data and were involved in writing the manuscript.

Credit Authorship Contribution Statement: Adith S. Arun: Writing − review & editing, Writing − original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Brandon Yan:** Writing − review & editing, Methodology, Investigation. **Kushal T. Kadakia:** Writing − review & editing, Methodology, Investigation. **Ji Chen:** Writing − review & editing, Visualization, Formal analysis. **Frederick Warner:** Writing − review & editing, Visualization, Formal analysis. **Yuan Lu:** Writing − review & editing, Methodology, Investigation. **Jeremy S. Faust:** Writing − review & editing, Writing − original draft, Supervision, Methodology, Investigation. **Harlan M. Krumholz:** Writing − review & editing, Writing − original draft, Visualization, Methodology, Investigation, Conceptualization.

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https://doi.org/10.1016/j.amjmed.2026.03.037

Introduction

In 2021, the gap in life expectancy between males and females in the United States widened to 5.8 years, the largest observed since 1996, driven by disproportionately high male mortality from COVID-19, unintentional injuries, heart disease, suicide, and homicide.[1] Although prior research identified the causes driving the widening gap, the timing of its reversal, its evolution across age groups and leading causes of death, and its broader impact on premature mortality remain unclear.

Existing studies have documented overall trends in sex-based mortality differences both globally and within the United States.[1-6] To our knowledge, we present the first systematic analysis of male-female mortality trends in the United States over time, age group, and cause. This work aims to help create new narrative frames around sex differences in mortality that could inform public policies to shape population-level health outcomes. To address these gaps, we used national mortality data from 2000 to 2023 to evaluate sex differences in age-adjusted mortality rates (AAMR) and years of potential life lost (YPLL) across leading causes of death and individuals less than 85 years of age. Our goal was to clarify when, where, and how excess male mortality occurs, thereby providing data to guide targeted public health interventions.

CLINICAL SIGNIFICANCE

- Males lost 8 million more years of life relative to females in 2023, up 14% from 2000.
- Male mortality rates are increasing in younger adults (age 18-44) relative to females, and these deaths are concentrated in external causes of death accelerating since mid-2010s.
- Cardiometabolic risk is a primary contributor to sex-based mortality differences starting in middle age.

Methods

Outcomes

We used national death certificate data from the Centers for Disease Control and Prevention Wide-ranging ONline Data for Epidemiologic Research for the years 2000 to 2023.[7] We obtained annual life expectancy by 5-year age groups and sex (i.e., male, female) from the National Center for Health Statistics (NCHS) life tables.[8] We obtained the annual number of deaths and population size in 5-year age groups up to, but not including, 85 years old for each sex (male and female). These data were obtained for all causes of death and primary causes of death by International Classification of Diseases (ICD)-10 (Supp. Table 1). The U00-U99 ICD codes, reserved for special causes (eg, SARS, SARS-CoV-2), were excluded from cause-specific analyses since death data were only available in 2001 and 2020-2023. Medical causes of death were defined as all deaths except for deaths due to external causes (V01-Y89 ICD codes).

Construction of measures

The crude rate, or simply mortality rate, is the deaths observed in a certain category (ie, age group and year) divided by the population for that category gathered directly from CDC WONDER. The AAMR was calculated by weighting the crude death rate by the fraction of individuals in that age group per the 2000 population.[9] The excess AAMR was defined as the AAMR for males minus females. Excess AAMR is a simple, interpretable measure that quantifies the difference in age-adjusted mortality rates between males and females (AAMR male minus AAMR female). Because sex reflects biological, social and behavioral exposures, excess measures should be interpreted descriptively and are not intended to imply causal attribution to any single factor.

The YPLL rate, defined as the number of years a person would have lived had they not died at the given age, was estimated by multiplying the 5-year age group crude death rate by the associated sex-specific age-specific White life expectancy for that year.[10] Sex-specific age-specific White life expectancy offers a consistent upper-bound reference because it was the longest life expectancy available across all study years in the NCHS life tables. This choice influences the absolute level of YPLL but enables comparisons of trends over time and across causes. The excess YPLL rate was defined as the estimated YPLL of males minus the estimated YPLL of females. The excess YPLL number in each age group was defined as the YPLL number in males (YPLL male rate multiplied by the male population) minus the YPLL number in females (YPLL female rate multiplied by the female population).

For ease of visualization in specific multi-panel figures, we grouped causes by whether they reached an AAMR of at least 20 per 100,000 in any study year (circulatory diseases, external causes of death, digestive diseases, infections, neoplasms, neurological diseases, endocrine and metabolic diseases, and respiratory diseases) to reduce visual clutter and highlight conditions with the largest mortality burden. Results from each of the 17 conditions are reported in the supplement when not reported in the main text. The Yale Institutional Review Board waived this study from review because it used publicly available deidentified data.

For age- and cause-specific summaries, we pooled calendar years into 2000-2005, 2006-2012, 2013-2019, and 2020-2023. We sought to separate the COVID-19 era into a distinct grouping, hence the 2020-2023 classification. The remaining years were split into three groups to yield interpretable summaries of joint age, year, and cause-specific summaries.

Data analysis

All analyses were conducted using R version 4.1.2. Code to replicate the analyses is freely distributed online.[11] This study followed the STROBE reporting guideline.

Results

Sex-specific temporal trends in overall and cause-specific mortality and years of potential life lost

The proportion of males in the population consistently declined with age in each year from 2000 to 2023 (Fig. 1A). Males accounted for 51.1% to 51.2% of the population from 2000 to 2023 (Supp. Fig. 1). As time progressed, the fraction of older adults who were male increased, but was still lower than the fraction of the population that was male at birth. Population size and age structure over time are described in Supplementary Fig. 1. Additionally, all-cause crude mortality rates for males begin to separate from females at age 18 (Fig. 1B, dashed vertical line). But, when subset to only medical causes of death (i.e., excluding external causes of death), mortality rates for males and females begin to separate later in life around age 40 (Fig. 1C, dashed vertical line). The later age at which mortality curves separate for medical causes compared with all causes is preserved when considering subsets of years: 2000-2019,2020-2022,2023 (Supp. Fig. 2). The excess AAMR per 100,000 declined from 291 in 2000 to 216 in 2014. It then rose steadily to 226 in 2019 before spiking to a high of 286 in 2021 amidst the COVID-19 pandemic, before declining to 232 by 2023 (Fig. 1D). In contrast, excess YPLL remained relatively stable from 2000 (7 million) through 2014 (6.8 million), before steadily rising to 7.6 million in 2019. This was followed by a sharp increase to 9.7 million in 2020 at the onset of the pandemic and a decline to 8.1 million by 2023 (Fig. 1E).

We next examined cause-specific trends in excess AAMR and YPLL from 2000 to 2023 (Fig. 2, Supp. Figs. 3-5). Excess AAMR from neoplasms and respiratory diseases declined steadily during the study period, except for a temporary reversal for respiratory diseases during the pandemic (Fig. 2A). Circulatory disease−related excess AAMR declined until 2012 and then plateaued. Excess AAMR per 100,000 for digestive diseases declined from 10.5 in 2000 to 9.3 in 2019 before spiking to 10.9 in 2021 and returning to 9.4 in 2023. In contrast, excess AAMR from metabolic and endocrine diseases rose gradually across the entire period from 5.5 in 2000 to 12.7 in 2023 (Fig. 2A). Excess YPLL patterns largely mirrored those of excess AAMR, with some divergence in digestive and circulatory diseases (Fig. 2B). Specifically, during the period of plateau in excess AAMR in circulatory (2011-2019) and digestive (2004-2019) diseases, excess YPLL trended upwards (Fig. 2). In 2023, 2.3 million and 288,337 extra lives were lost from circulatory diseases and digestive diseases, respectively, for males relative to females.

We examined the contribution of each cause-specific excess AAMR to the all-cause excess AAMR for each year from 2000 to 2023 (Fig. 3). The average contribution to the total excess AAMR was 34.8%, and 19.2% for circulatory diseases and neoplasms, respectively. Neoplasms accounted for 22.5% of the excess in 2000 to 13.0% in 2023. Respiratory diseases declined from 7.9% in 2000 to 4.2% in 2023. Endocrine and metabolic diseases rose from 1.9% contribution to 5.5% contribution from 2000 to 2023.

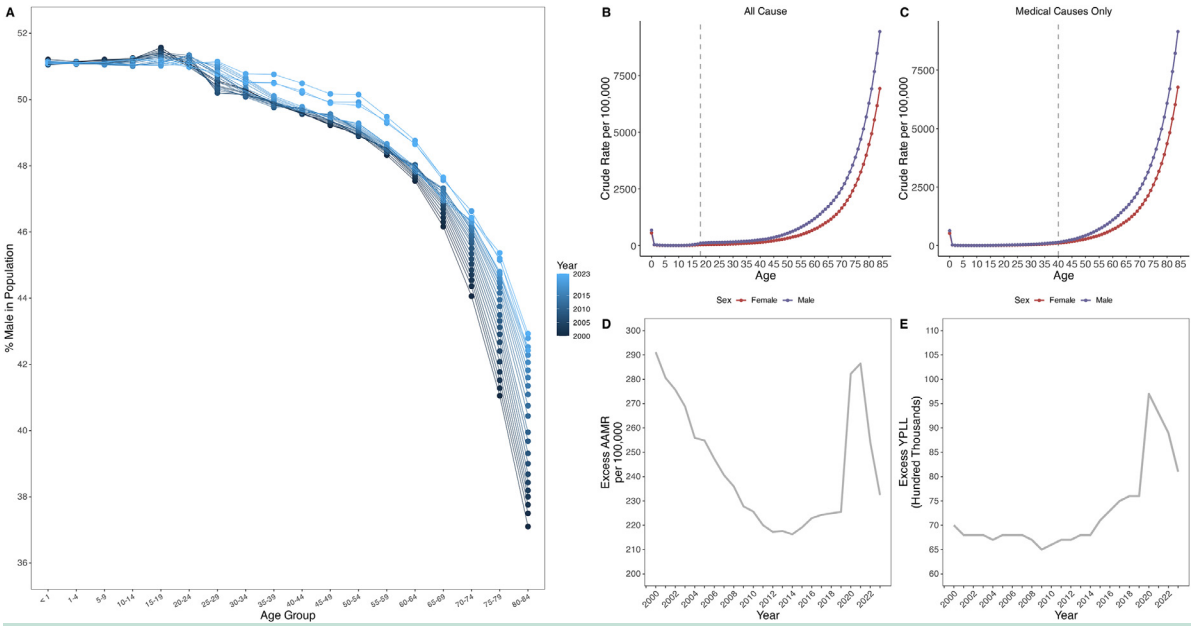

Fig. 1 (**A**) Percentage of the U.S. population that is male in each age group for each year from 2000 to 2023. (**B**) All-cause crude mortality rate for males and females for each age from 0 to 85 from 2000 to 2023. (**C**) Crude mortality rate for medical causes only, all causes excluding external causes of death ICD Chapter, for males and females for each age from 0 to 85. (**D**) Excess AAMR per 100,000 for all causes of death from 2000 to 2023. (**E**) Excess YPLL for all causes of death from 2000 to 2023. Abbreviations: AAMR = age-adjusted mortality rate; YPLL = years of potential life lost

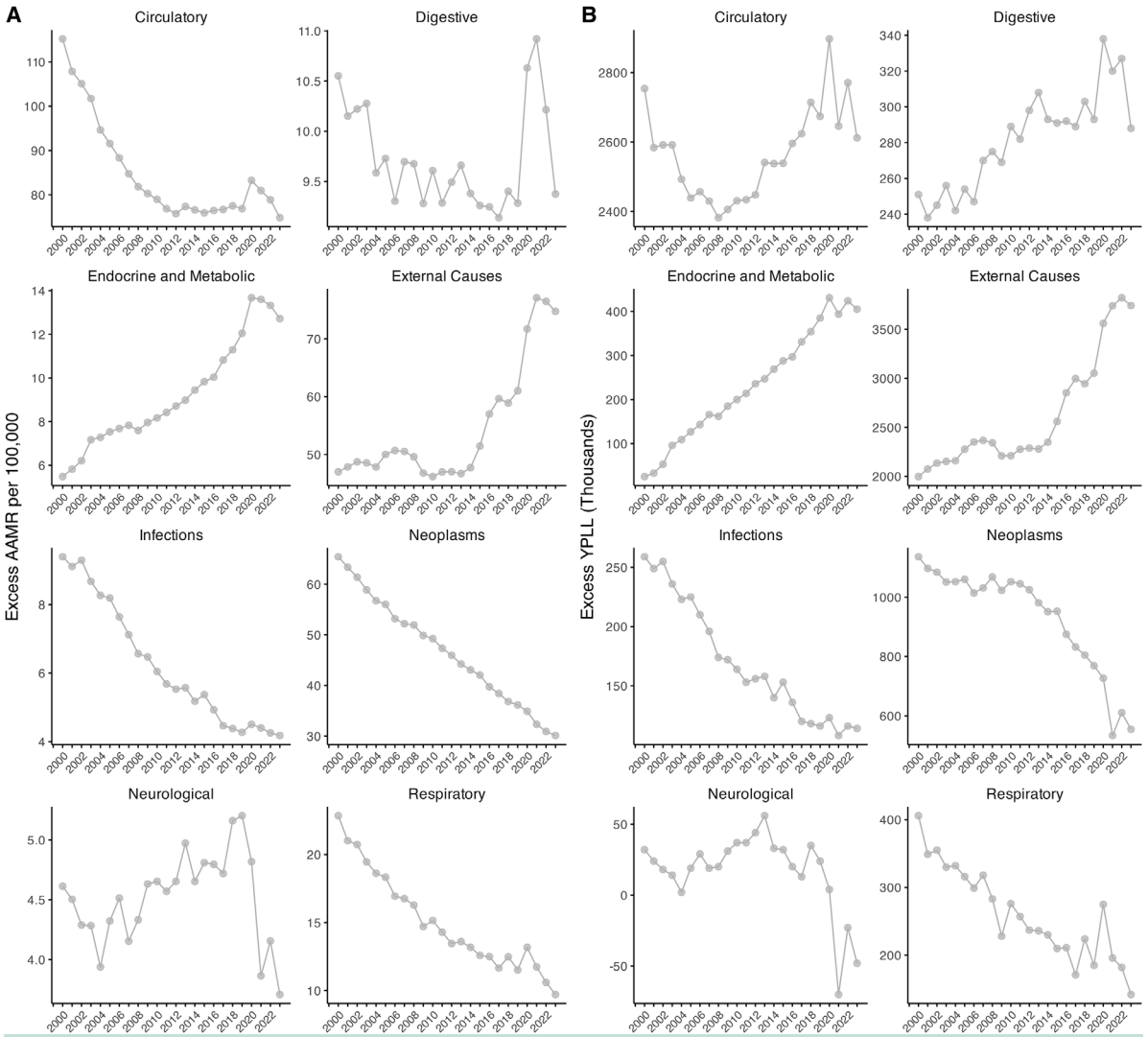

Fig. 2 (**A**, **B**) Cause-specific excess AAMR and excess YPLL from 2000 to 2023 for causes with at least one yearly AAMR greater than or equal to 20 per 100,000, respectively.

Musculoskeletal and connective tissue excess AAMR was negative, indicating a greater female AAMR than male AAMR for each year, though that difference closed during the study period from −0.56% in 2000 to −0.05% in 2023. In absolute terms, there were 26,829 extra YPLL for females relative to males in 2023 due to musculoskeletal and connective tissue diseases.

Excess AAMR among men remained relatively stable until 2014, ranging between 46 per 100,000 to 51. After 2014, excess AAMR rose sharply, reaching an all-time high of 77 per 100,000 in 2021 (Fig. 2). This was followed by a slight decline to 75 in 2023, still above the pre-pandemic level of 61 in 2019. In 2023, there were 3.7 million extra YPLL for males compared with females. Notably, external causes of death, the second highest contributor to overall excess AAMR after circulatory diseases during the study period, experienced a steady increase from 16.1% in 2000 to 32.2% in 2023 (Fig. 3).

Age-based trends in sex-specific overall and cause-specific mortality differences

All-cause excess death rate increased with age over the 24-year study period. However, within age groups, all-cause excess death rates declined from 2000 to 2019 before rising during the pandemic (Supp. Fig. 6A,B). During 2020-2023, excess YPLL rates were markedly elevated in adults aged 25-44 and 55-69 (Supp. Fig. 6C,D)

We examined cause-specific excess death rates and YPLL across 5-year age groups during four periods: 2000-2005, 2006-2012, 2013-2019, and 2020-2023 (Fig. 4). Among middle-aged adults (30-54 years), circulatory diseases, external causes, endocrine and metabolic diseases, and digestive diseases had the highest excess death and YPLL rates. In adults older than 55 years, circulatory diseases, neoplasms, and respiratory diseases were the leading contributors. The largest excess YPLL rates occurred for

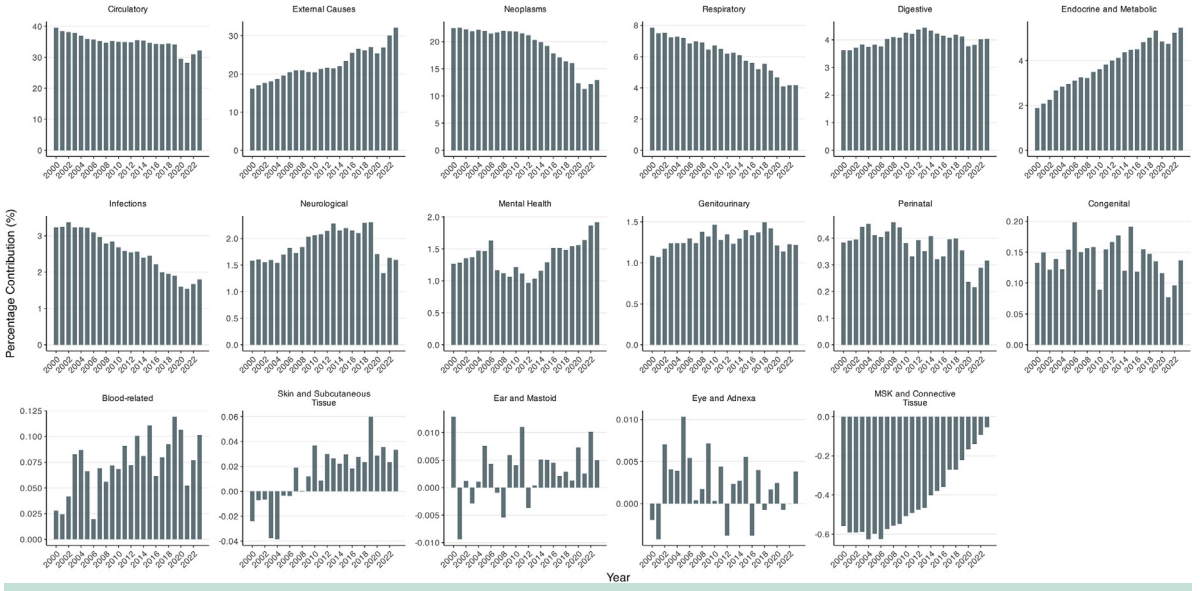

Fig. 3 Percent contribution of cause-specific excess AAMR to all-cause excess AAMR from 2000 to 2023 for each cause of death.

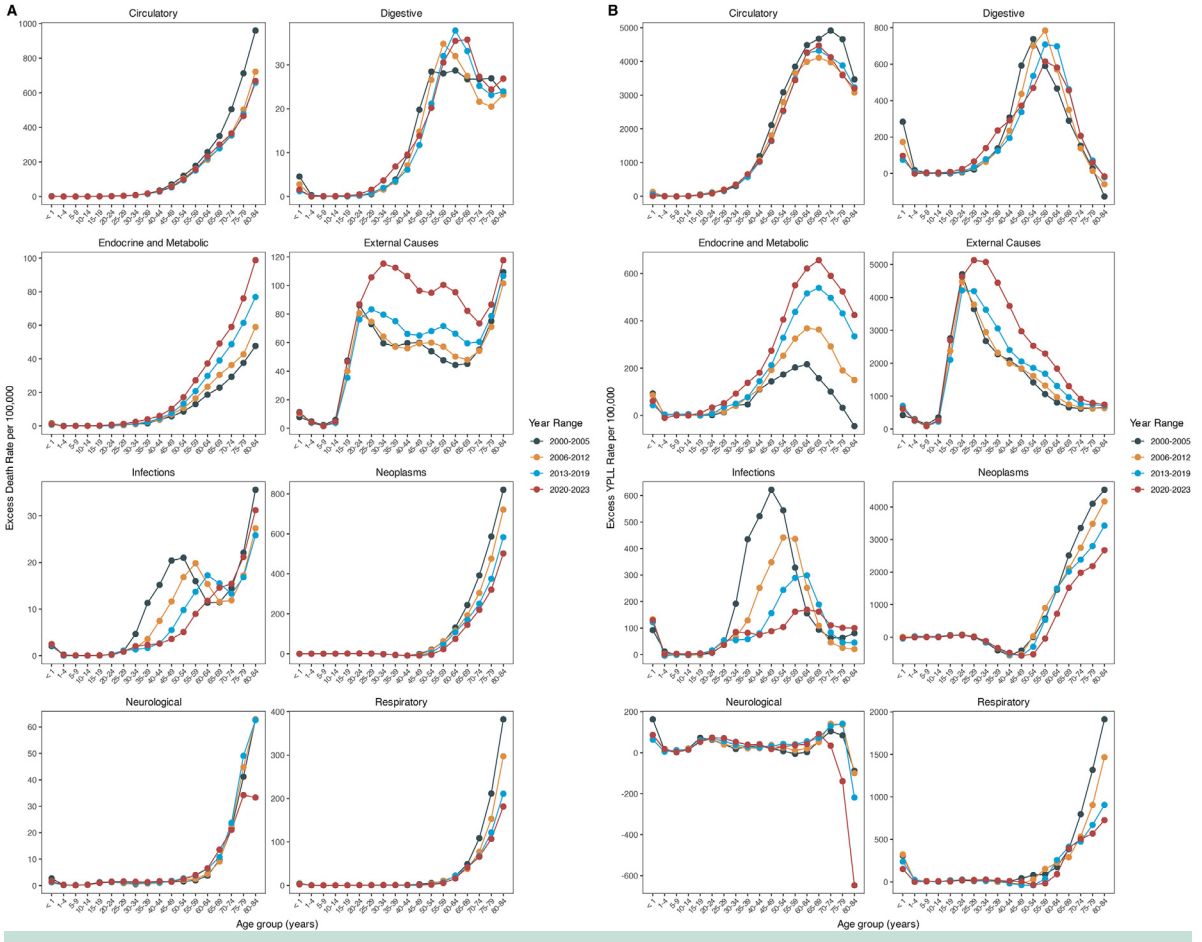

Fig. 4 (**A**, **B**) Cause-specific excess death rate per 100,000 and excess YPLL rate per 100,000 by age group for the years 2000-2005, 2006-2012, 2013-2019, 2020-2023 for causes with at least one yearly AAMR greater than or equal to 20 per 100,000, respectively.

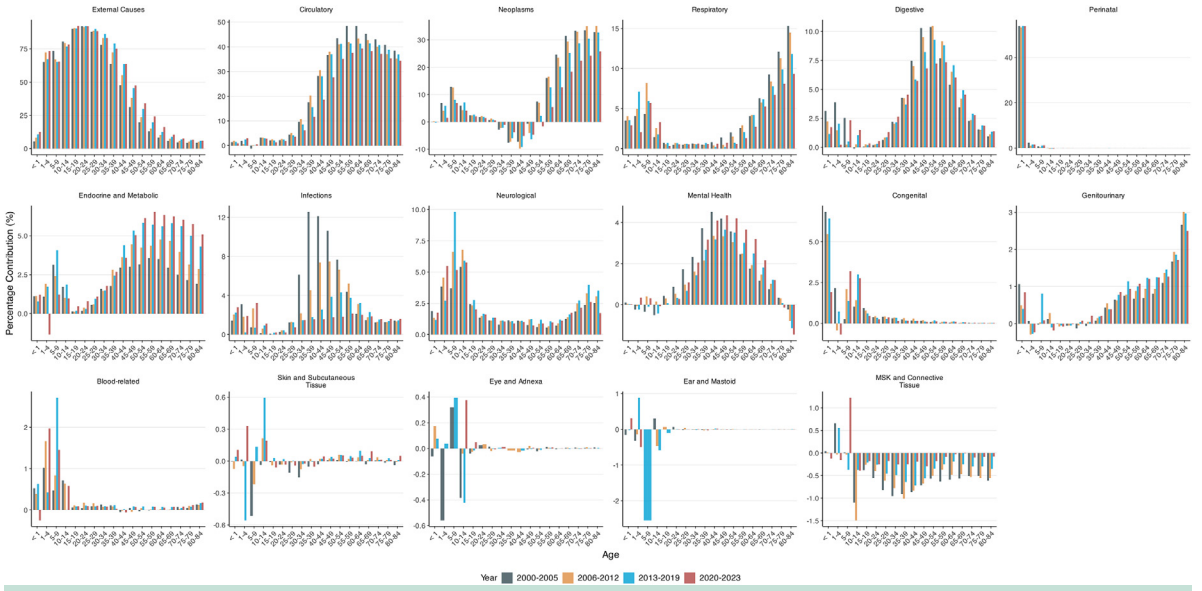

Fig. 5 Percent contribution of cause-specific excess mortality rate to all-cause mortality rate in each age group for each cause of death across four distinct intervals: 2000-2005, 2006-2012, 2013-2019, and 2020-2023.

circulatory diseases in adults aged 60-74 years and external causes in those aged 25-34 years, corresponding to 12,856 and 10,208 excess years of life lost per 100,000, respectively, during 2020-2023. Females had higher mortality from musculoskeletal and connective tissue diseases after age 10 (Supp. Fig. 7). In 2020-2023, the largest excess death rate for these diseases was 1.4 per 100,000, corresponding to 55 excess YPLL per 100,000 for females (Supp. Fig. 8).

We also compared the percentage contribution of each cause-specific excess death rate to total excess death rate within each age group (Fig. 5). From 2000-2023, external causes accounted for more than 50% of total excess death rate among those aged 1-34 years, but contributed less in older groups. Circulatory diseases accounted for 18.6% and 27.6% of the total excess death rate in adults aged 40-44 and 45-49 years, respectively, and averaged 36.4% in adults aged 50-84 years. In older adults, neoplasms were the second largest contributor, followed by respiratory diseases. Females aged 30-49 years had higher mortality from neoplasms than males, and females younger than 15 years and aged 80-84 years had higher mortality from mental health conditions than males of the same age.

Discussion

Our national analysis of mortality data from 2000 to 2023 reveals a striking trend: while the gap in AAMR between males and females has modestly declined since 2000, the absolute burden of premature male mortality, has grown substantially, reaching more than 8.1 million excess YPLL among males in 2023. The divergence between overall mortality rates and premature death burden reflects a troubling shift. Excess male mortality is increasingly concentrated in younger and middle-aged adults, where each death carries more years of lost life and societal impact.

Although females have long outlived males in high-income countries, most prior studies have focused on life expectancy or AAMR trends in isolation. By pairing AAMR and YPLL across two decades, age groups, and causes of death, our analysis provides a more nuanced and policy-relevant understanding of the male survival gap. We show that the pandemic accelerated, but did not initiate, the rise in male mortality relative to females and that external causes and metabolic disease are driving an increasing share of premature mortality in males. Moreover, the male mortality disadvantage we observed was broad-based and persistent across the entire 24-year study period. Males experienced higher age-adjusted mortality rates than females in nearly all years, and in nearly every 5-year age group from adolescence through late life. This pattern was consistent across most major causes of death.

While females had higher mortality rates from a small subset of conditions (e.g., musculoskeletal and connective tissue disease and mental health in older age groups), these accounted for a fraction of the overall excess burden, which remained concentrated among males. One factor that may contribute to the observed greater female mortality rate in connective tissue diseases is that females are more likely to develop autoimmune diseases like Sjogren's disease or systemic lupus erythematosus.[12] While biological differences between sexes, such as hormonal influences on cardiovascular and immune function, may contribute to some baseline mortality gap, they do not account for the sharp rise in excess external causes of death among males in recent decades. Two million additional years of life were lost to external causes for males relative to females in 2000. Still, that number has grown to 3.7 million in 2023.

The steep gradient in YPLL among males in young and middle adulthood points to preventable, socially patterned risks. Males are more likely than females to engage in behaviors such as smoking, excessive alcohol consumption, substance use, and firearm ownership, and are less likely to seek care or mental health services, all of which contribute to leading causes of death with large sex disparities.[13-16] These patterns may reflect not only personal preference but also norms around masculinity that discourage vulnerability and help-seeking behavior.[17,18] The rise in deaths from suicide, overdose, and alcoholic liver disease—sometimes referred to as "deaths of despair"—may reflect broader economic and psychosocial dislocation, particularly among males without stable roles in families or communities.[19-21] These deaths are not evenly distributed but may reflect systemic failures to engage and support males at risk. Upstream strategies that address the structural determinants of risk, such as educational disconnection, economic insecurity, incarceration, and social isolation, may be beneficial in preventing premature male mortality from these external causes.

Our analysis also underscores the substantial contribution of cardiovascular disease to excess male mortality, particularly in later life. Despite overall declines in circulatory disease mortality over the past two decades, males continue to experience higher age-adjusted mortality rates from cardiovascular conditions compared with females.[6] This disparity has remained stable or even widened in certain age groups, resulting in millions of excess YPLL annually amongst males.[22] Hypertension, dyslipidemia, diabetes, and lifestyle risk factors often go underrecognized and undertreated in males, especially those who are younger or less engaged in routine care.[23]

This study has several limitations. We relied on death certificate data, which may be subject to misclassification of sex or cause of death. We did not stratify by race and ethnicity. Because mortality levels, population-level age structure, and cause-of-death patterns differ across racial and ethnic groups in the United States, our estimates reflect population-average sex differences and may mask important heterogeneity at the intersection of sex and race/ethnicity. YPLL estimates are dependent on the underlying population counts and therefore is impacted both by population numbers and mortality. In addition, our use of White life expectancy as the YPLL reference may differentially weight groups with shorter life expectancy, affecting the absolute magnitude of YPLL. When attributing the percentage contribution of causes to overall excess mortality, we did not account for competing risks in the underlying probability of surviving to older ages as major causes (eg, cardiovascular disease) declined, which can shift the distribution of deaths across causes. Finally, our use of population-level data precludes an analysis of individual-level risk factors or healthcare access, which may help explain the observed patterns.

In conclusion, from 2000 to 2023, males in the United States experienced consistently higher mortality rates and an increasing burden of premature death relative to females. Rising mortality rates in younger males due to external causes of death, persistent cardiovascular mortality burden in older males, and rising metabolic disease mortality are primary drivers of the male mortality gap. Complementary policy and health-system priorities include expanding access to evidence-based substance use disorder treatment (including medications for opioid use disorder) and harm-reduction services, implementing violence prevention strategies (e.g., firearm safety), and improving early detection and control of cardiometabolic risk factors among men who are less engaged in routine care. The mortality gap between males and females widened during the pandemic and is now heavily concentrated in young and middle-aged adults. The challenge is not simply to understand these disparities but to act on them, with renewed investment in prevention, care delivery, and policies that better support the health and lives of males across the life course.

Declaration of competing interest

KTK has received fees from the Common Health Coalition unrelated to this manuscript. HMK, in the past three years, has received options for OpenEvidence, Element Science and Identifeye and payments from F-Prime for advisory roles. He was a co-founder of and held equity in Hugo Health. He is a co-founder of and holds equity in Refactor Health and ENSIGHT-AI. He is a co-founder of medRxiv and is on the Board of openRxiv (non-paid, volunteer). He is associated with research contracts through Yale University from Janssen, Kenvue, Novartis, and Pfizer. YL has received research grants from the United States National Institutes of Health, the Patient-Centered Outcomes Research Institute, and the Sentara Research Foundation outside of this work. All other authors have reported that they have no relationships relevant to the contents of this paper to disclose

ACKNOWLEDGMENT

Funding: ASA is supported by the National Institute on Aging of the National Institutes of Health. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institute on Aging or the National Institutes of Health under Award Number T35AG049685. No other funding was used for this work.

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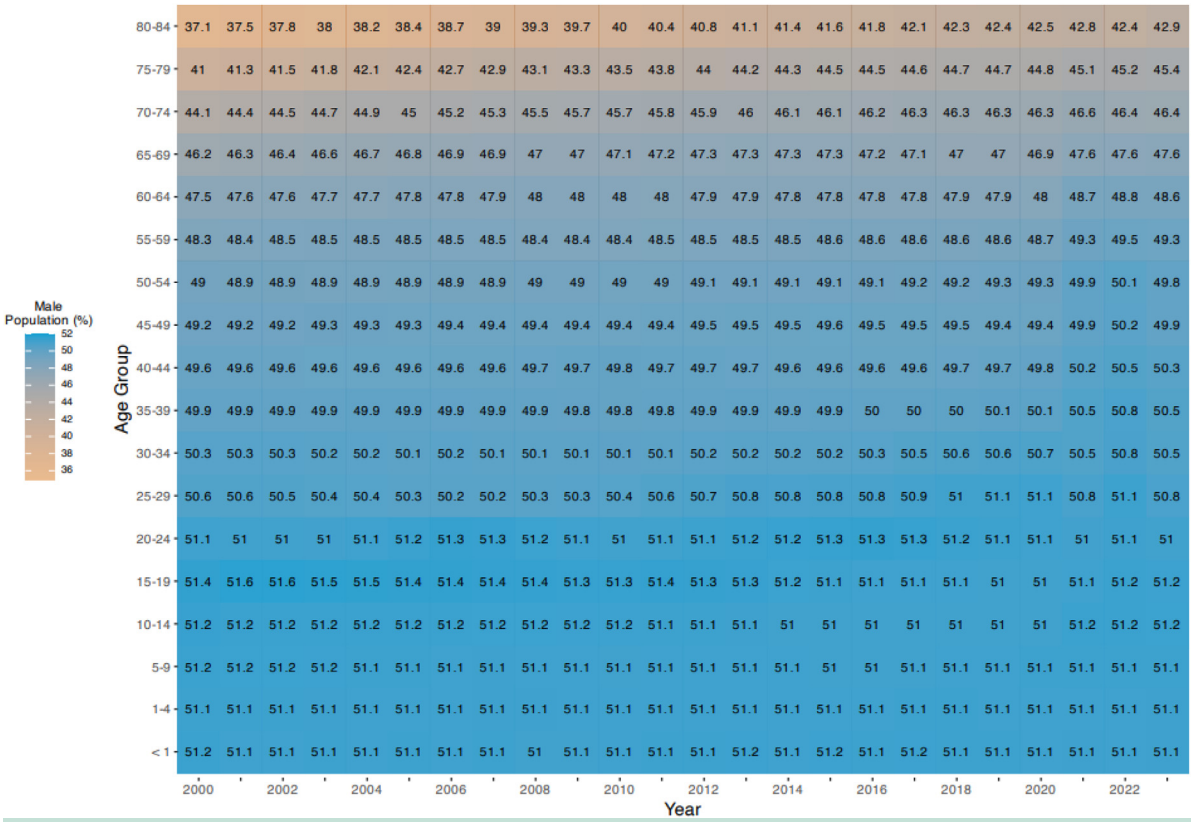
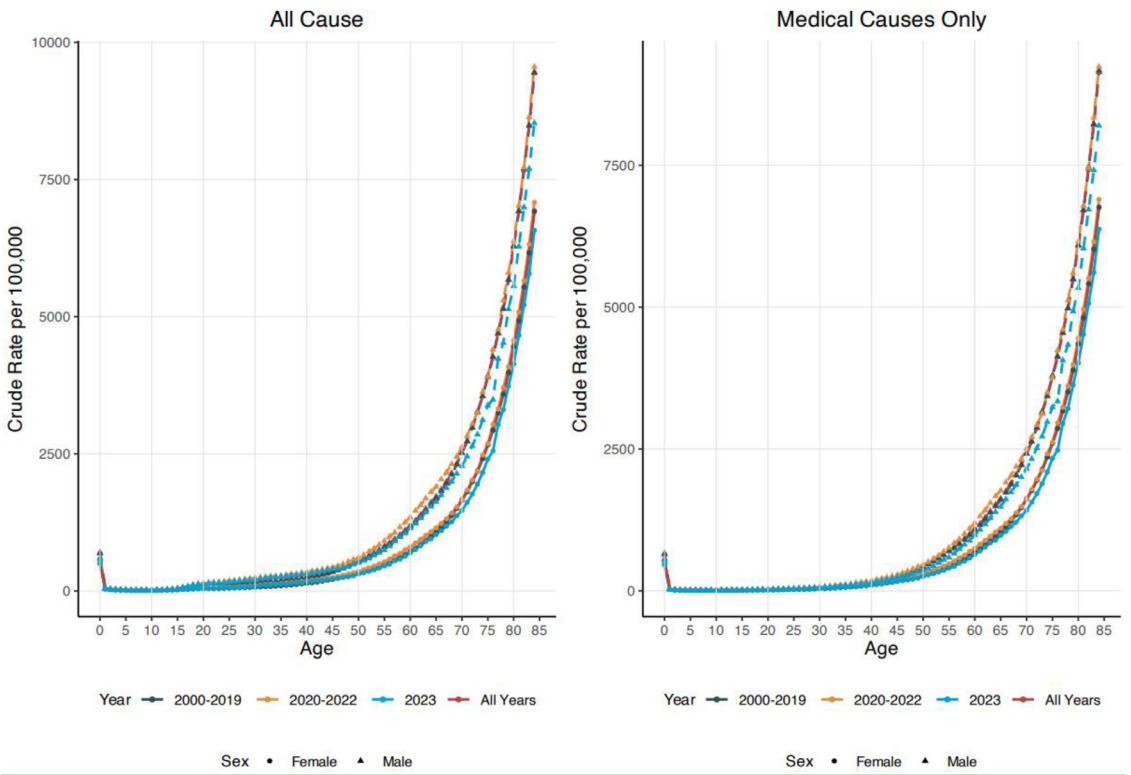
Supplementary Data

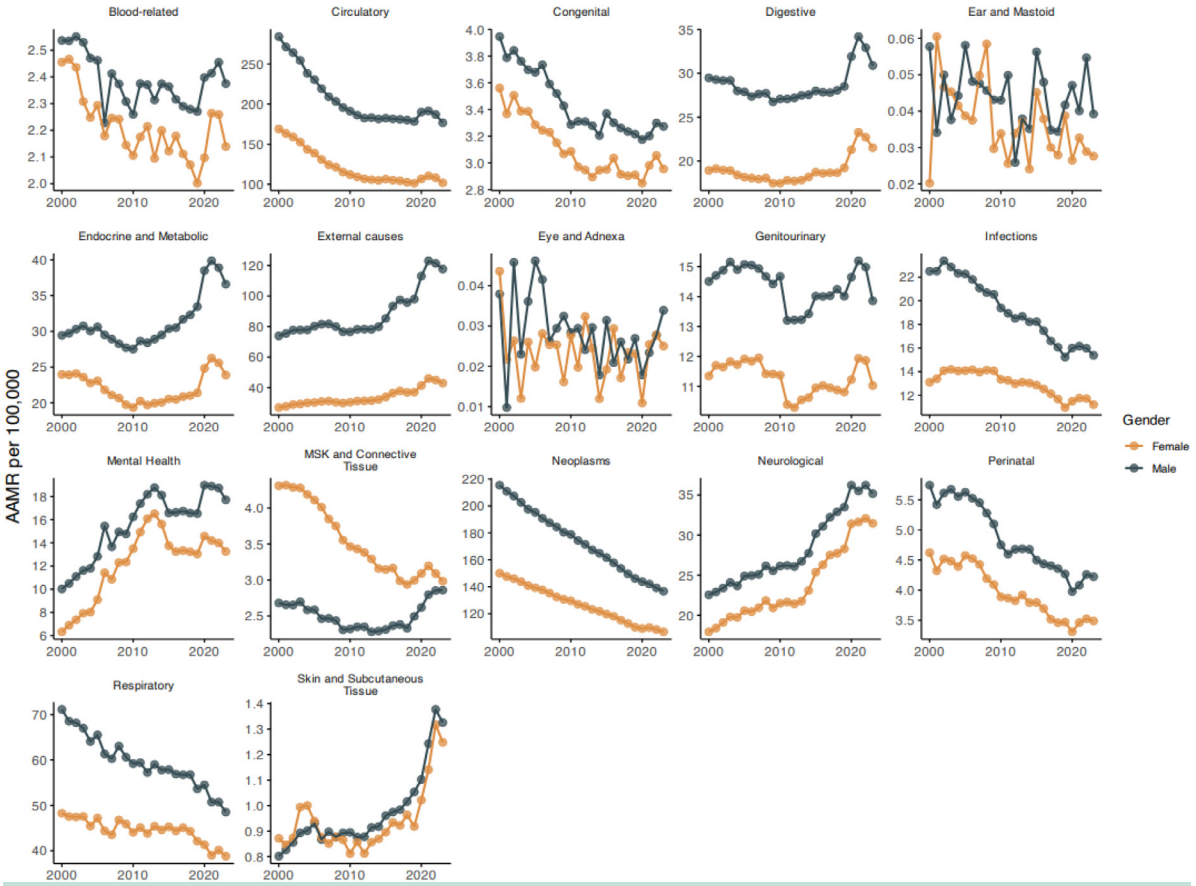
Supplementary data to this article can be found online at https://doi.org/10.1016/j.amjmed.2026.03.037.



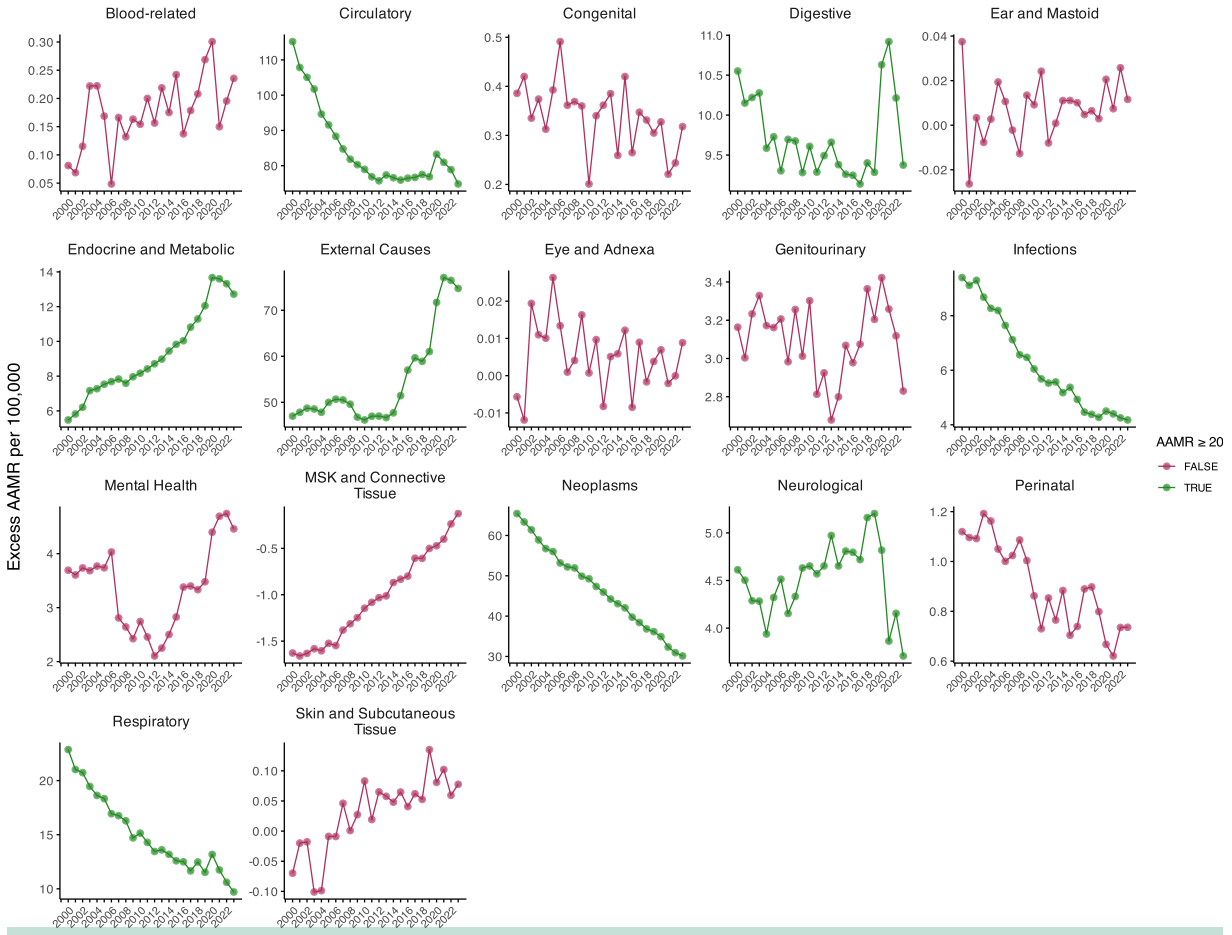
Supplemental Fig. 1 Percent of US population that is male at each age group and year from 2000 to 2023.



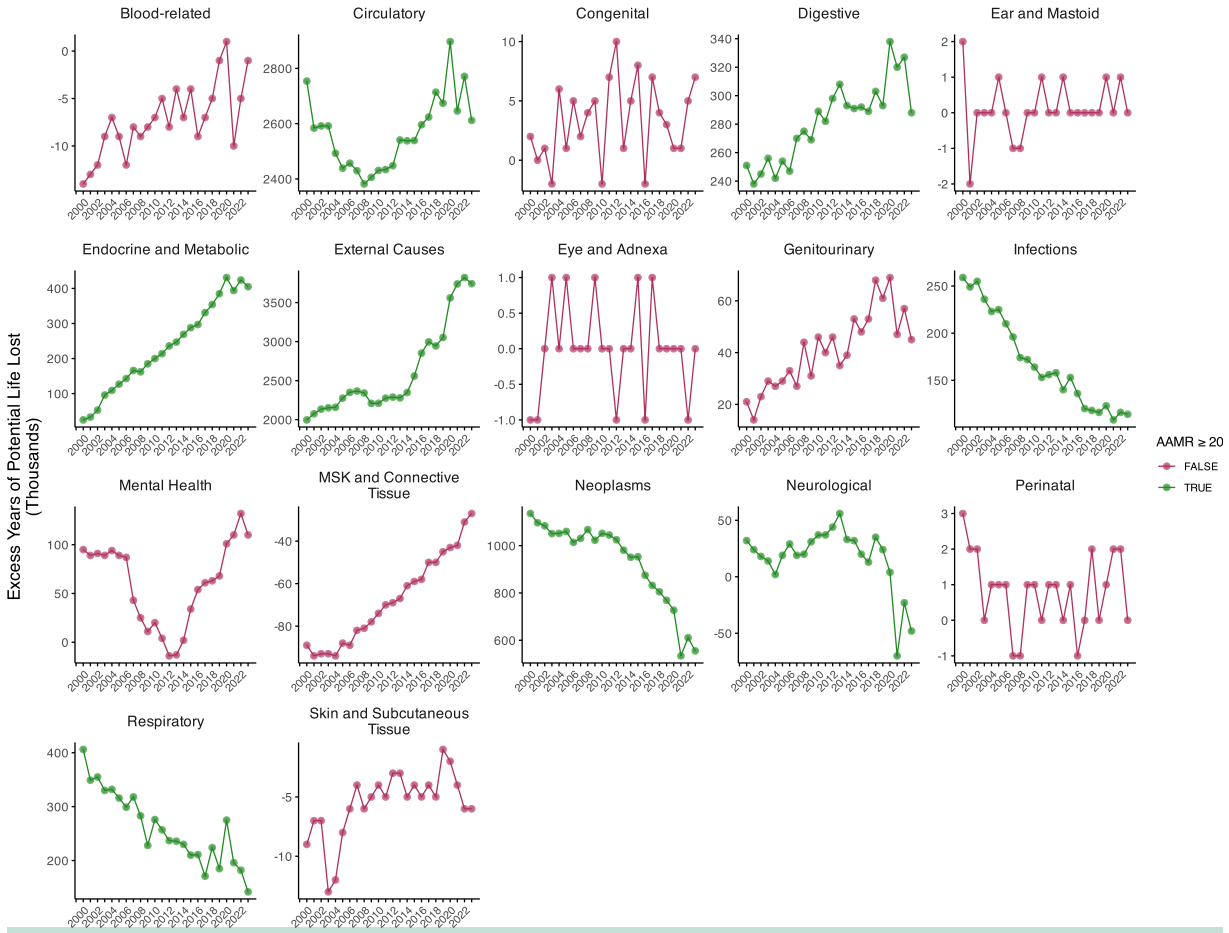
Supplemental Fig. 2 All cause and medical causes only (excluding external causes of death) crude mortality rate for males and females for all years (2000-2023), 2000-2019, 2020-2022, and 2023.



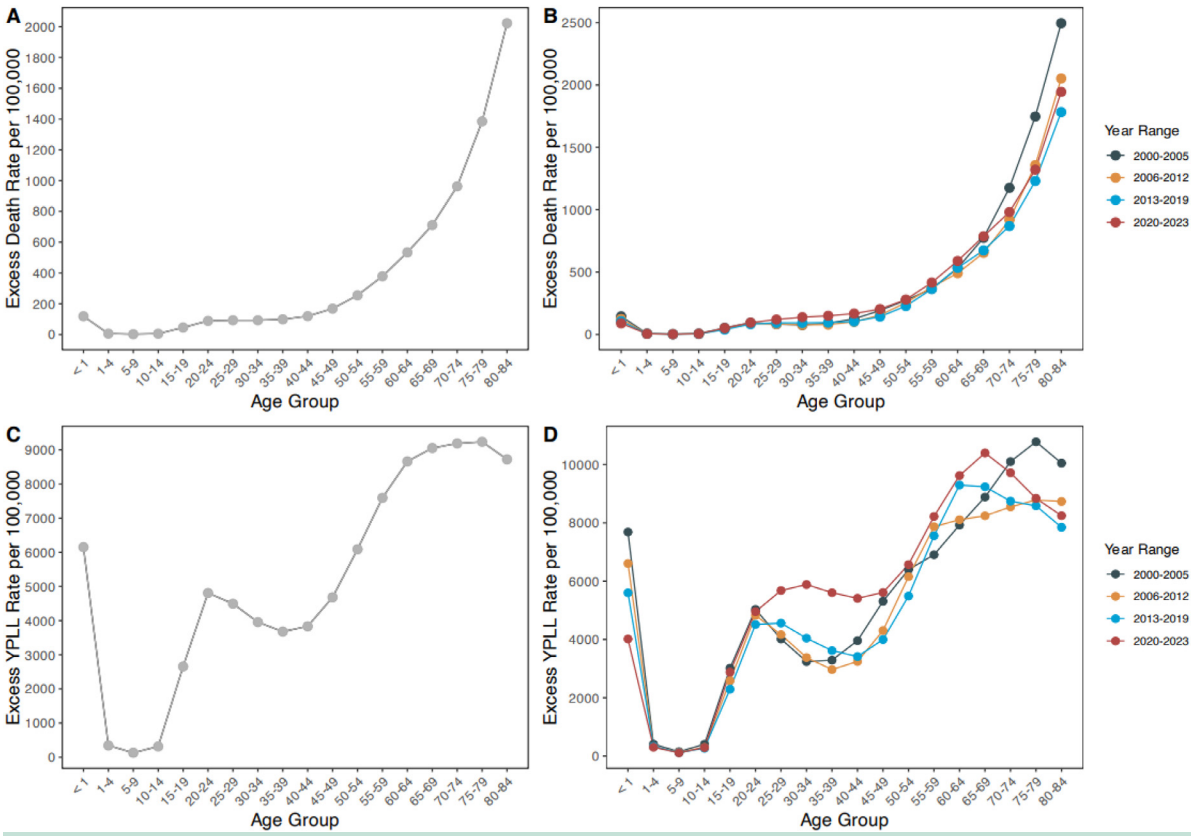
Supplemental Fig. 3 Age-adjusted mortality rate per 100,000 for males and females each year from 2000 to 2023 stratified by ICD chapter.



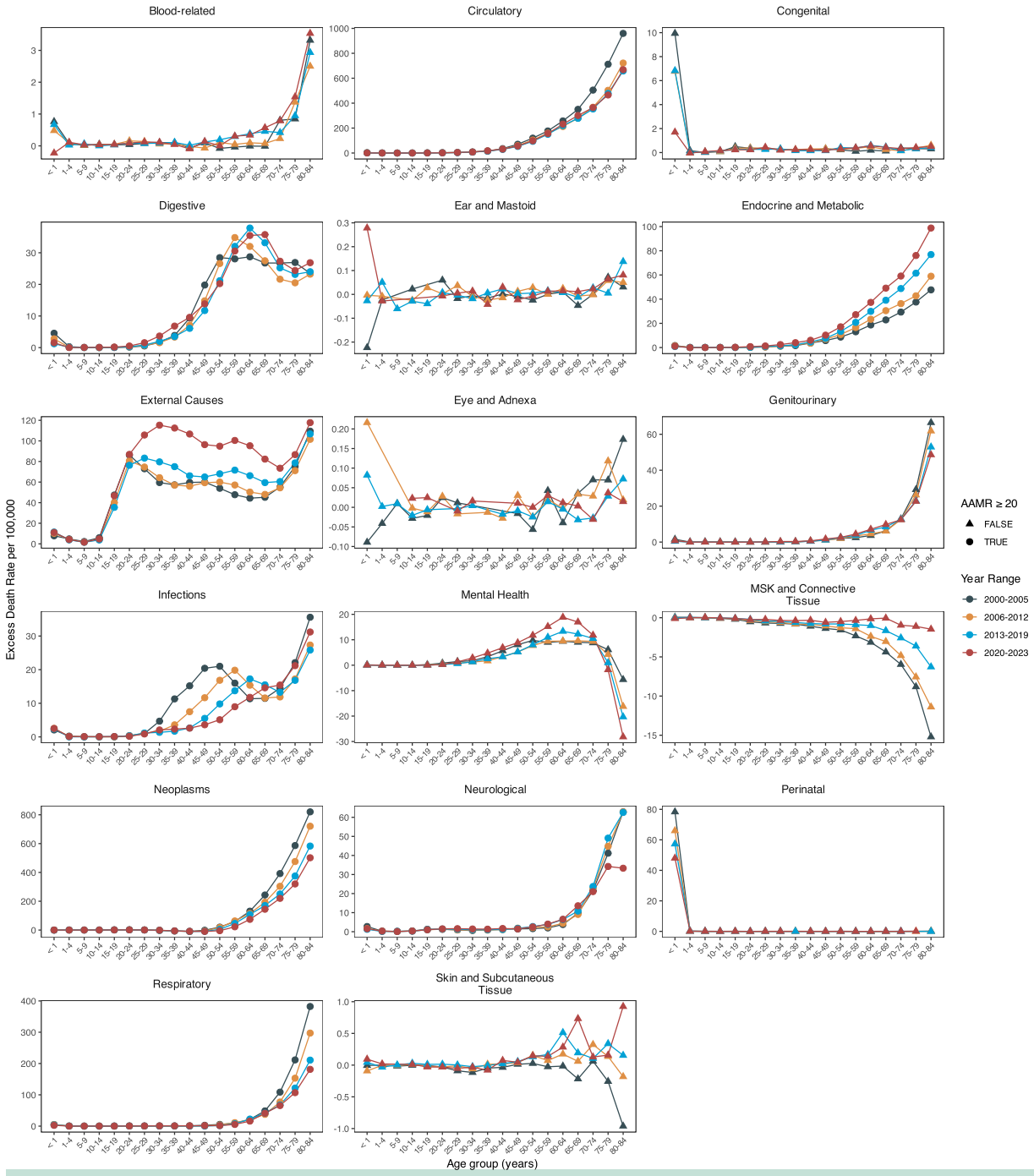
Supplemental Fig. 4 Excess age-adjusted mortality rate per 100,000 each year from 2000 to 2023 stratified by ICD chapter.



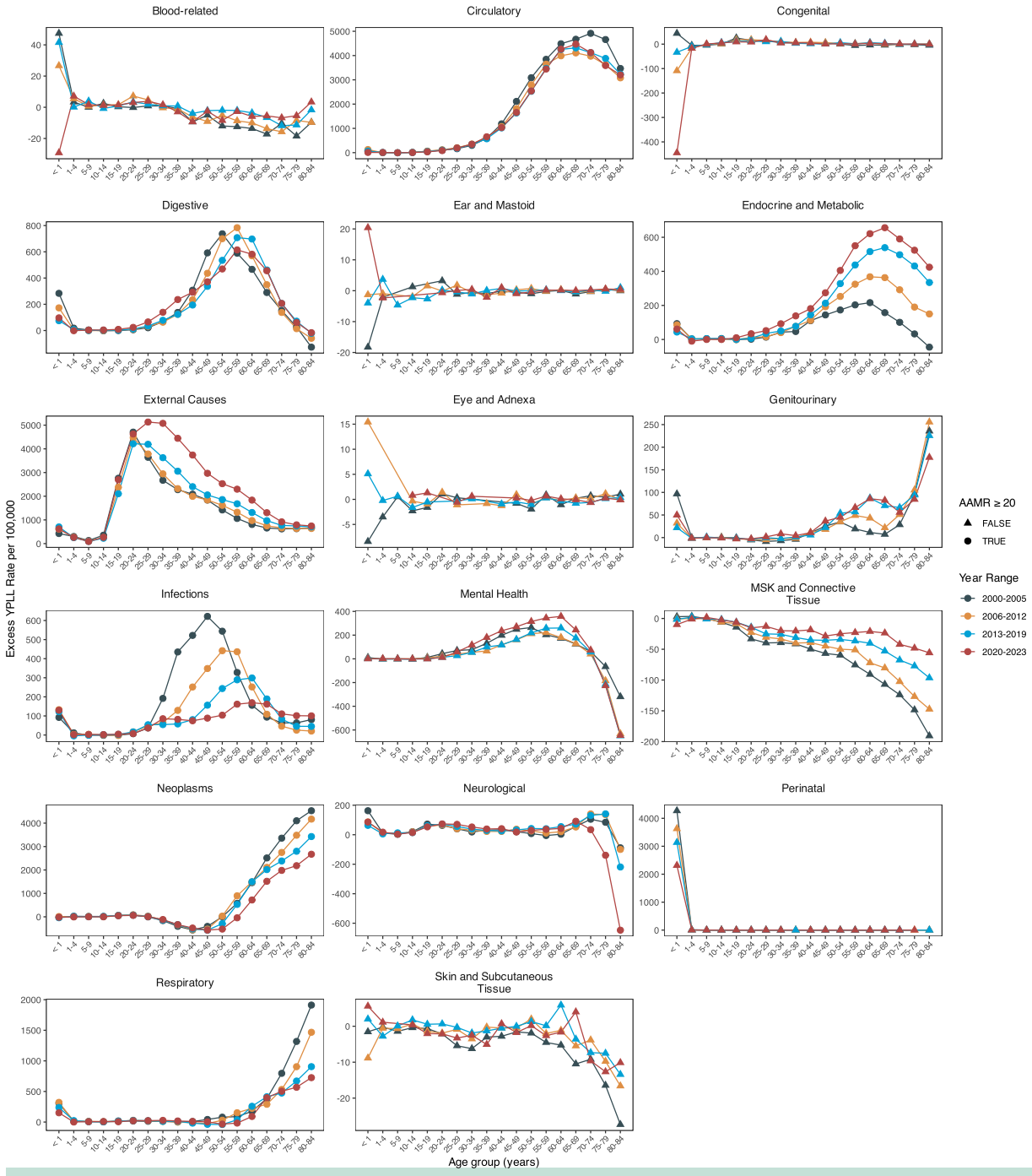
Supplemental Fig. 5 Excess years of potential life lost expressed in thousands of years by year from 2000 to 2023 stratified by ICD chapter.



Supplemental Fig. 6 (**A**) Excess death rate per 100,000 from 2000 to 2023 for each age group. (**B**) Excess death rate per 100,000 for each age group from 2000-2005, 2006-2012, 2013-2019, 2020-2023. (**C**) Excess years of potential life lost per 100,000 from 2000 to 2023 for each age group. (**D**) Excess years of potential life lost per 100,000 for each age group from 2000-2005, 2006-2012, 2013-2019, 2020-2023.



Supplemental Fig. 7 Excess death rate per 100,000 for each age group, interval year period, and ICD chapter.



Supplemental Fig. 8 Excess years of potential life lost (YPLL) rate expressed per 100,000 life years for each age group, interval year period, and ICD chapter.

Supplemental Table 1 ICD chapter codes and their corresponding disease categories

ICD Code	Disease Name	Any yearly AAMR at least 20 per 100,000 from 2000 to 2023
A00-B99	Infections	Yes
C00-D48	Neoplasms	Yes
D50-D89	Blood-related	No
E00-E88	Endocrine and Metabolic	Yes
F01-F99	Mental Health	No
G00-G98	Neurological	Yes
H00-H57	Eye and Adnexa	No
H60-H93	Ear and Mastoid	No
I00-I99	Circulatory	Yes
J00-J98	Respiratory	Yes
K00-K92	Digestive	Yes
L00-L98	Skin and Subcutaneous Tissue	No
M00-M99	MSK and Connective Tissue	No
N00-N98	Genitourinary	No
O00-O99	Pregnancy	No
P00-P96	Perinatal	No
Q00-Q99	Congenital	No
R00-R99	Not Elsewhere Classified	No
U00-U99	Special Purposes	Yes post-2020. Count data only available in 2001,2020, 2021,2022. Thus, was omitted.
V01-Y89	External Causes	Yes