Declines in U.S. Life Expectancy in the Wake of COVID-19: Differences by Race/Ethnicity and Relative to Other High-Income Countries

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DECLINES IN U.S. LIFE EXPECTANCY IN THE WAKE OF COVID-19:

DIFFERENCES BY RACE/ETHNICITY AND RELATIVE TO OTHER HIGH-INCOME COUNTRIES

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ABSTRACT

Objective: To estimate changes in life expectancy from 2010 through 2020 across U.S. population groups and peer nations.

Design: Life expectancy in 2010, 2017, and 2020 was estimated for the U.S. population, by sex and race-ethnicity, and for 18 high-income countries. Data for the United States and peer countries were obtained from the National Center for Health Statistics and Human Mortality Database, respectively. Life expectancy in 2020 was estimated by simulating life tables from estimated age-specific mortality rates in 2020 and allowing for 10% random error.

Main Outcome Measures: Life expectancy at birth and ages 25 and 65 years. Estimates for 2020 are reported as medians along with 5th and 95th percentiles.

Results: In 2010, 2017, and 2020, respectively, life expectancy at birth was 78.66, 78.61, and 76.90 (76.63, 77.08) years in the United States and averaged 80.60, 81.74, and 81.55 (81.40, 81.70) years in peer countries. The decrease in U.S. life expectancy between 2017 and 2020 was largely attributable to the COVID-19 pandemic. The decrease was nine times greater than that experienced by peer countries, widening the life expectancy gap from 3.13 in 2017 to 4.65 years in 2020. U.S. life expectancy decreased disproportionately among people of color, declining by 3.87, 3.12, and 1.18 years, respectively, in Hispanic, non-Hispanic Black, and non-Hispanic White populations. Among Hispanic and non-Hispanic Black populations, declines were 16-20 times the average in peer countries. Progress since 2010 in reducing the U.S. Black-White life expectancy gap was erased between 2017 and 2020, and a longstanding Hispanic life expectancy *advantage* was almost eliminated.

Conclusions: The United States experienced a much larger decrease in life expectancy between 2017 and 2020 than did other high-income nations, with pronounced losses among people of color. A longstanding and widening U.S. health disadvantage, high death rates in 2020, and continued inequitable impacts on people of color are products of policy choices and systemic racism.

INTRODUCTION

In 2020, COVID-19 became the third leading cause of death in the United States[1] and was thus expected to substantially lower life expectancy for that year (see Box). The United States experienced more deaths from COVID-19 than any other country in the world and among the highest per capita mortality rates.[2] That the United States would experience a larger decrease in life expectancy in 2020 than peer nations has been suspected but not established empirically. Americans entered the pandemic at a distinct disadvantage relative to other high-income peer nations: improvements in overall life expectancy have not kept pace with those in peer countries since the 1980s[3], and in 2011 U.S. life expectancy plateaued and then decreased for 3 consecutive years, further widening the mortality gap with peer countries.[4]

The impact of the pandemic on life expectancy extends beyond deaths attributed directly to COVID-19.[5] Studies have found an even larger number of excess deaths during the pandemic, inflated by undocumented COVID-19 deaths and by deaths from non-COVID-19 causes resulting from disruptions caused by the pandemic (e.g., diminished access to health care, economic pressures, behavioral crises).[6,7,8] People of color and certain age groups have been disproportionately affected.[9,10,11] Research on how the pandemic affected life expectancy is only just emerging[12,13] and few studies have examined declines in 2020 life expectancy across racial-ethnic groups or how these declines compare to those of peer nations.

METHODS

The study estimated life expectancy at birth and at ages 25 and 65 years, examining the U.S. population (in aggregate and by sex and race-ethnicity) and the average for 18 high-income countries (in aggregate and by sex). Data were calculated for three years: 2010, 2017 (the most recent year for which peer nation data were widely available), and 2020. Estimates for 2019 would have been preferable to isolate the effect of the COVID-19 pandemic but reliable data were lacking. However, observed changes in life expectancy between 2017 and 2020 were largely attributable to the events of 2020. Peer country data did not include information on race or ethnicity. Although many U.S. individuals self-identify as Latino or Latina, this study uses "Hispanic" to maintain consistency with data sources. "White" and "Black" hereafter refer to those who do not identify as Hispanic or Latinx.[14]

U.S. life tables for 2010[15] and 2017[16] provided life expectancy estimates for the United States. Weekly age-specific death counts among the total U.S. male and female populations and among the U.S. Black, White, and Hispanic male and female populations for years 2017 and 2020 were obtained from the National Center for Health Statistics (NCHS) AH Excess Deaths by Sex, Age, and Race file.[17] Mid-year population estimates by age, sex, and race-ethnicity for U.S. male and female populations in years 2015-2019 were obtained from the U.S. Census Bureau.[18] Population counts for 2020 were estimated from age-specific trends in U.S. population estimates across years 2015-2019. The NCHS and U.S. Census data were merged at ages 0-14,15-19, … 80-84, 85+ years to calculate age-specific death rates (m_x) for 2017 and 2020 among U.S. male and female populations in aggregate and by sex and by race-ethnicity.

To derive life expectancy estimates for 2010 and 2017, 5-year abridged life tables for male and female populations of the peer countries were obtained for those years from the Human Mortality Database[19] (direct sources[20,21] were used for Israel and New Zealand). Weekly death counts by country for ages 0-14, 15-64, 65-74, 75-84, and 85+ years were obtained from the Human Mortality Database-Short Term Mortality Fluctuations (HMD-STMF) files. Peer countries included 18 high-income democracies with adequate HMD data for analysis: Austria, Belgium, Denmark, Finland, France, Germany, Israel, Italy, Netherlands, New Zealand, Norway, Republic of South Korea, Portugal, Spain, Sweden, Switzerland, Taiwan, and the United Kingdom. Australia, Canada, and Japan were omitted because of incomplete mortality data.

To arrive at life expectancy estimates for 2020, age-specific mortality rate ratios between 2020 m_x and 2017 m_x in the NCHS-Census data were estimated for U.S. populations. For populations in peer countries, average 2020 m_x and 2017 m_x in the HMD-STMF data were estimated for ages 0-14, 15-64, 65-74, 75-84, and 85+ years. Age-specific mortality rate ratios between 2020 m_x and 2017 m_x in the HMD-STMF data were estimated for each peer country in aggregate and by sex. The 2020 probabilities of death, q_x, for ages 0-1, 1-4, 5-9, … 90-94, 95-99, 100+ years were estimated separately for U.S. male and female populations and for male and female race-ethnic-specific populations in 2020 by multiplying the 2017 official m_x[16] by the 2020-2017 rate ratio estimates derived from the NCHS-U.S. Census data, and calculating $q_x = (m_x*n)/(1+m_x*a_x)$ where n is the width of the age interval.[22] Probabilities of death, q_x, for each peer country in 2020 were estimated by multiplying q_x in HMD life tables by the 2020-2017 rate ratios in the HMD-STMF data.

Using Python (version 3.9.1), 50,000 5-year abridged 2020 life tables were simulated for each U.S. sub-population using q_x derived from the estimated 2020 m_x, a_x derived from 2017 official life tables[16] and random 10% error in the q_x estimate. For peer country populations, 50,000 5-year abridged 2020 life tables were simulated using the estimated 2020 q_x, average 2017 a_x values in the HMD 2017 life tables, and random 10% error in the q_x estimates. Although the text only presents median estimates of 2020 life expectancy at birth and at ages 25 and 65 years, the tables also provide the 5^{th} (P_5) and 95^{th} (P_{95}) percentiles. The online supplement provides further details on methods.

RESULTS

United States

After a small decrease of 0.05 years between 2010 and 2017, U.S. life expectancy at birth decreased by an estimated 1.71 years (or 2.2%) between 2017 and 2020 (**Table 1**). The proportional decrease in life expectancy at ages 25 and 65 years was even greater (3.1% and 5.3%, respectively). U.S. men experienced a larger decrease in overall life expectancy than women, in both absolute (1.99 years vs. 1.32 years) and relative terms (2.6% vs. 1.6%).

Between 2017 and 2020, U.S. life expectancy decreased disproportionately among people of color (**Table 2**). In the Black population, it decreased by 3.12 years (4.2%), 2.6 times the decrease in the White population (1.18 years, 1.5%). The decrease was even larger among Hispanic individuals (3.87 years, 4.7%), 3.3 times the decrease among Whites, and the ratio was greater among men (3.5) than women (3.0).

The disproportionate decrease in life expectancy in the U.S. Black population during 2017-2020 reversed years of progress in reducing the Black-White mortality gap (**Figure 1**). Although the gap in life expectancy at birth between Black and White populations decreased from 4.07 years in 2010 to 3.64 years in 2017, the gap increased to 5.58 years in 2020. Historically, the U.S. Hispanic population has had a higher life expectancy than the White population.[23,24] Although that advantage widened between 2010 and 2017 (from 2.61 years to 3.30 years, respectively), it decreased to 0.61 years in 2020 (**Table 2**) and was entirely reversed among Hispanic men (-0.22 years).

United States versus Peer Countries

In both 2010 and 2017, the average life expectancy at birth in 18 high-income countries (80.60 and 81.74 years, respectively) exceeded that of the United States (78.66 and 78.61 years, respectively). These peer countries also experienced much smaller declines in life expectancy between 2017 and 2020 (**Tables 1 and 3**). The overall decrease in life expectancy in the United States (1.71 years) was 9.0 times greater than the average of these peer countries (0.19 years) (**Figure 2**). The gap in life expectancy between the United States and the peer country average grew from 1.94 years in 2010, to 3.13 years in 2017 and 4.65 years in 2020. By 2020, life expectancy at birth was 5.20 and 4.08 years shorter for U.S. males and females, respectively, than the peer country average for their sex (**Tables 1 and 3**).

These disparities were even starker for people of color **(Figure 3)**. Among U.S. Black men and women, the decrease in life expectancy at birth was 15.5 times and 25.5 times greater, respectively, than the average decrease for men and women in peer countries. The corresponding figures are even larger for the U.S. Hispanic population, with declines in life expectancy at birth an estimated 20.6 times and 28.5 times higher among men and women, respectively, compared to their counterparts in peer countries. Between 2010 and 2020, gaps in the life expectancy of U.S. Black and Hispanic women and that of women in peer countries grew by 2.99 years and 3.16 years, respectively. Among men, the corresponding figures are 4.50 years and 5.33 years, respectively.

DISCUSSION

Long before COVID-19 appeared, the United States was at a distinct disadvantage relative to other high-income nations in terms of health and survival.[3,25,26,27,28] A 2013 report by the National Research Council and Institute of Medicine demonstrated that the United States began losing ground relative to other high-income countries in the 1980s, with higher rates of morbidity and mortality for multiple conditions.[3] A recent report by the National Academies of Sciences, Engineering, and Medicine found that this gap widened further through 2017 and that the greatest relative increase in U.S. mortality occurred among young and middle-aged U.S. adults (ages 25-64 years). Increased mortality in this age group was due largely to deaths from drug use, suicide, cardiometabolic diseases, and other chronic illnesses and injuries.[29] Between 2015 and 2017, while life expectancy continued to increase in other countries, U.S. life expectancy decreased by 0.3 years,[4] a three-year decline that generated considerable public concern[30] but is now eclipsed by the large 2020 declines reported here. Even countries with much lower per capita incomes now outperform the United States.[31,32,33,34] According to data for 36 OECD member countries, the gap in life expectancy between the United States and the OECD increased from 0.9 to 2.2 years between 2010 and 2017.[35,36]

This study shows that the life expectancy gap widened further after 2017. U.S. life expectancy fell dramatically between 2017 and 2020, a drop 9 times the average loss experienced by 18 high-income peer nations and the largest decrease since 1943 during World War II.[37] The conditions that produced a U.S. health disadvantage prior to the arrival of COVID-19 are still in place, but the predominant cause for this large decline was the COVID-19 pandemic: in 2020, all-cause mortality in the United States increased by more than 20 percent.[8]

The large decreases in life expectancy reported here, and the excess deaths reported in several studies of 2020 death counts[6,7,8], reflect the combined effects of: (a) deaths directly attributable to COVID-19, (b) deaths in which COVID-19 infection was unrecognized or undocumented; and (c) deaths from non-COVID-19 health conditions, exacerbated by limited access to health care and by widespread social and economic disruptions produced by the pandemic (e.g., unemployment, food insecurity, homelessness).[5,38] Many of these are products of national, state, and local policy decisions and (in)actions that influenced viral transmission and management of the pandemic.[39] These policies span healthcare, public health, employment, education, and social protection systems. A variety of organizations are tracking these decisions internationally for ongoing research and development.[40,41,42,43]

The extraordinary consequences of COVID-19 in the United States reflect not only the country's mishandling of the pandemic[39,44,45,46] but also deeply rooted factors that put the country at a health disadvantage long ago.[47] For much of the public, it was the pandemic itself that drew attention to these longstanding conditions, including major deficiencies in the U.S. health care and public health systems, widening social and economic inequality, and stark inequities and injustices experienced by Black, Brown, and Indigenous Americans and other systematically marginalized and excluded groups. Many studies have documented that rates of COVID-19 infections, hospitalizations, and deaths are significantly higher among Black and Hispanic individuals compared to White people, due to heightened viral exposure, a higher prevalence of comorbid conditions (e.g., diabetes), and diminished access to healthcare.[48,49]

This study adds to this growing body of evidence, revealing extreme differences in life expectancy reductions during the COVID-19 pandemic based on race-ethnicity. Decreases in life expectancy among Black and Hispanic people were approximately 2-3 times greater than losses among White people, and far larger than those experienced in peer countries. Decreases among U.S. Black and Hispanic men were approximately 16-21 times greater than that of men in other high-income countries and decreases among U.S. Black and Hispanic women were 26-29 times greater. Progress made between 2010 and 2017 in reducing the Black-White gap in life expectancy in the United States was erased between 2017 and 2020. Life expectancy among Black men fell to 68.10 years, a level not seen since 1999.[50] The U.S. Hispanic life expectancy advantage was fully erased among men and nearly erased among women.

Evidence of disproportionate reductions in life expectancy among people of color comes at a time of increasing attention to the root causes of racial inequities in health, wealth, and wellbeing. Chief among these are the systems of power in the United States that structure opportunity and assign value in ways that unfairly disadvantage Black, Brown and Indigenous people, while unfairly advantaging White people. [51,5253,54,55,56,57] Many of the same factors placed people of color at greater risk from COVID-19.[58,59,60,61] The higher prevalence of comorbid conditions among many racialized or marginalized groups is itself a reflection of unequal access to the social determinants of health (e.g., education, income, justice) and not their race/ethnicity or other socially-determined constructs. Low-income communities and women have also been disproportionately affected by the pandemic.[62,63] Diminished access to COVID-19 vaccines and vaccine hesitancy, rooted in a community's mistrust of systems that have mistreated them, could exacerbate these disparities. These affect not only Black and Hispanic populations but other marginalized groups. American Indian and Alaska Native people, for example, have some of the worst health outcomes of any group in the United States, but data limitations did not allow separate calculations for this important population.

This study has several other limitations. First, 2020 life expectancies were simulated using preliminary mortality data, which are subject to errors (e.g., undercounting, mismatching between death and population counts) and often vary across racial-ethnic populations and countries. Second, the 2020 q_x values used to generate life tables for peer populations could have been biased by the wide age ranges used in the HMDB-STMF. Third, definitions for peer countries vary; this study's list differs slightly from the 16 high-income countries used in several cross-national comparisons.[3,25,26] Three large high-income democracies—Australia, Canada, and Japan—were excluded because of incomplete data. Fourth, this study compared 2020 life expectancy with 2017 values; the pandemic's effect would be better isolated by comparisons with 2019 life expectancy, but data were lacking for this calculation. Fifth, race-ethnicity data for the U.S. population and for 2020 deaths were incomplete,[64] likely underestimating the extent and size of racial inequalities. Reports suggest that COVID-19 and all-cause mortality in 2020 were alarmingly high in American Indian and Alaskan Native populations.[65] Finally, this study uses the average for peer countries; values for individual countries could vary.

This study aligns closely with prior research. In a recent analysis of deaths between January and June 2020, Arias et al. found that U.S. life expectancy decreased by 1.0 years between 2019 and 2020, including reductions of 0.8 years among White people and reductions of 2.7 years and 1.9 years, respectively, among Black and Hispanic individuals.[13] Andrasfay and Goldman estimated that life expectancy from January to mid-October 2020 was 1.1 years below expected values, including a reduction of 0.7 years among White populations and 2.1 and 3.1 years, respectively, among Black and Hispanic populations.[12] Neither study examined changes in life expectancy in other countries.

The mortality outcomes examined here, in the research literature, and in the daily news represent only part of the burden of COVID-19; for every death, a larger number of infected individuals experience acute illness, and many face long-term health and life complications.[66] It remains unclear whether some of these long-term complications will affect how quickly U.S. life expectancy will rebound in the coming years. Morbidity and mortality during the pandemic have ripple effects through families, neighborhoods, and communities. One study estimated that each death leaves behind an average of nine bereaved family members.[67] The pandemic will have short- and long-term effects on the social determinants of health, changing living conditions in many communities and altering life-course trajectories across age groups. Fully understanding the health consequences of these changes poses a daunting but important challenge for future research.

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COMPETING INTEREST

All authors have completed the ICMJE uniform disclosure form and declare: no support from any organisation for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work in the previous three years, no other relationships or activities that could appear to have influenced the submitted work.

PATIENT AND PUBLIC INVOLVEMENT

It was not possible to involve patients or the public in the design, conduct, reporting, or dissemination plans of our research. We hope to disseminate the findings to the public.

TEXT BOX

The meaning of life expectancy during a pandemic

Life expectancy is a widely used statistic for summarizing a population's mortality rates at a given time. It reflects how long a group of people can expect to live were they to experience at each age the prevailing age-specific mortality rates of that year. Life expectancy estimates are sometimes misunderstood. We cannot know what *future* age-specific mortality rates will be for people born or living today, but we do know the *current* rates. Computing life expectancy (at birth, or age 25, or age 65) based on those rates is valuable for understanding and comparing a country's mortality profile over time or across places at a given point in time. Estimates of life expectancy during the COVID-19 pandemic, such as those reported here, can help clarify which people or places were most affected, but they do not offer predictions of how long any group of people will live. Although life expectancy is likely to recover in time to pre-pandemic levels, past pandemics have demonstrated that survivors can be left with lifelong consequences, depending on their age and other socio-economic circumstances.[2]

1. Riley JC. *Rising Life Expectancy: A Global History*. Cambridge, United Kingdom: Cambridge University Press; 2001.

2. lmond D. Is the 1918 influenza pandemic over? Long-term effects of in utero influenza exposure in the post-1940 US population. *Journal of Political Economy*. 2006;114(4):672-712.

Table 1. U.S. Life Expectancy at Birth, Age 25 Years, and Age 65 Years: 2010, 2017, and 2020					
				Change in life expectancy (y, P_5, P_{95})	
	2010	**2017**	**2020 (y, P_5, P_{95})**	**2017 vs 2010**	**2020 vs 2017**
Life expectancy at birth					
Total	78.66	78.61	76.90 (76.73, 77.08)	-0.05	-1.71 (-1.88; -1.53)
Females	81.04	81.10	79.78 (79.61, 79.95)	0.06	-1.32 (-1.49; -1.15)
Males	76.20	76.10	74.11 (73.93, 74.29)	-0.10	-1.99 (-2.17; -1.81)
Life expectancy at age 25					
Total	54.71	54.66	52.94 (52.76, 53.11)	-0.05	-1.72 (-1.90, -1.55)
Females	56.87	56.92	55.56 (55.39, 55.73)	0.05	-1.36 (-1.53, -1.19)
Males	52.44	52.36	50.36 (50.19, 50.54)	-0.08	-2.00 (-2.17, -1.82)
Life expectancy at age 65					
Total	19.13	19.40	18.38 (18.20 – 18.56)	0.27	-1.02 (-1.20, -0.84)
Females	20.33	20.60	19.67 (19.50 – 19.85)	0.27	-0.93 (-1.10, -0.75)
Males	17.70	18.04	16.96 (16.78 – 17.14)	0.34	-1.08 (-1.26, -0.90)

Authors' analysis of data from the National Center for Health Statistics-U.S. Census Bureau and Human Mortality Database.

P_5, P_{95}: 5th and 95th percentiles of 50,000 simulated life expectancies using 10% random uncertainty around the 2020 q_x estimates.

Table 2. U.S. Life Expectancy at Birth, Age 25 Years, and Age 65 Years, by Race-Ethnicity: 2010, 2017, and 2020

	Life expectancy (y)			Change in life expectancy (P_5, P_{95})	
	2010	**2017**	**2020 (P_5, P_{95})**	**2017 vs. 2010**	**2020 vs. 2017**
LIFE EXPECTANCY AT BIRTH					
Total					
Hispanic	81.40	81.82	77.95 (77.78, 78.13)	0.42	-3.87 (-4.04, -3.69)
Non-Hispanic Black	74.72	74.88	71.76 (71.57, 71.95)	0.16	-3.12 (-3.31, -2.93)
Non-Hispanic White	78.79	78.52	77.34 (77.17, 77.51)	-0.27	-1.18 (-1.35, -1.01)
Female					
Hispanic	83.82	84.31	81.46 (81.30, 81.63)	0.49	-2.85 (-3.01, -2.68)
Non-Hispanic Black	77.72	78.08	75.53 (75.35, 75.71)	0.36	-2.55 (-2.73, -2.37)
Non-Hispanic White	81.11	80.98	80.03 (79.86, 80.20)	-0.13	-0.95 (-1.12, -0.78)
Male					
Hispanic	78.72	79.10	74.56 (74.39, 74.74)	0.38	-4.54 (-4.71, -4.36)
Non-Hispanic Black	71.43	71.51	68.10 (67.90, 68.29)	0.08	-3.41 (-3.61, -3.22)
Non-Hispanic White	76.41	76.09	74.78 (74.64, 74.96)	-0.32	-1.31 (-1.45, -1.13)
LIFE EXPECTANCY AT AGE 25 YEARS					
Total					
Hispanic	57.30	57.73	53.87 (53.70, 54.04)	0.43	-3.86 (-4.03, -3.69)
Non-Hispanic Black	51.38	51.59	48.56 (48.37, 48.75)	0.21	-3.03 (-3.22, -2.84)
Non-Hispanic White	54.75	54.46	53.22 (53.05, 53.39)	-0.29	-1.24 (-1.41, -1.07)
Female					
Hispanic	59.51	60.05	57.12 (56.96, 57.28)	0.54	-2.93 (-3.09, -2.77)
Non-Hispanic Black	54.00	54.39	51.83 (51.66, 52.02)	0.39	-2.56 (-2.73, -2.37)
Non-Hispanic White	56.87	56.69	55.69 (55.52, 55.85)	-0.18	-1.00 (-1.17, -0.84)
Male					
Hispanic	54.78	55.16	50.65 (50.48, 50.84)	0.38	-4.51 (-4.68, -4.32)
Non-Hispanic Black	48.39	48.52	45.23 (45.04, 45.43)	0.13	-3.29 (-3.48, -3.09)
Non-Hispanic White	52.54	52.22	50.84 (50.67, 51.02)	-0.32	-1.38 (-1.55, -1.20)
LIFE EXPECTANCY AT AGE 65 YEARS					
Total					
Hispanic	20.80	21.44	18.85 (18.68, 19.04)	0.64	-2.58 (-2.76, -2.40)
Non-Hispanic Black	17.72	18.09	16.22 (16.03, 16.42)	0.37	-1.87 (-2.06,-1.67)
Non-Hispanic White	19.12	19.32	18.53 (18.35, 18.71)	0.20	-0.79 (-0.97, -0.61)
Female					
Hispanic	22.08	22.69	20.53 (20.36, 20.70)	0.61	-2.16 (-2.33, -1.99)
Non-Hispanic Black	19.14	19.55	17.80 (17.62, 17.99)	0.41	-1.75 (-1.93, -1.56)
Non-Hispanic White	20.30	20.49	19.77 (19.60, 19.95)	0.19	-0.72 (-0.89, -0.54)
Male					
Hispanic	19.06	19.73	16.88 (16.70, 17.07)	0.67	-2.85 (-3.03, -2.66)
Non-Hispanic Black	15.82	16.21	14.33 (14.13, 14.53)	0.39	-1.88 (-2.08, -1.68)
Non-Hispanic White	17.73	18.01	17.20 (17.02, 17.38)	0.28	-0.81 (-0.99, -0.63)

Authors' analysis of data from the National Center for Health Statistics-U.S. Census Bureau and Human Mortality Database. P_5, P_{95}: 5th and 95th percentiles of 50,000 simulated life expectancies using 10% random uncertainty around the 2020 q_x estimates.

Table 3. Peer Country Average for Life Expectancy at Birth, Age 25 Years, and Age 65 Years: 2010, 2017, and 2020					
				Change in life expectancy (P_5, P_{95})	
	2010	**2017**	**2020 (P_5, P_{95})**	**2017 vs 2010**	**2020 vs. 2017**
Life expectancy at birth					
Total	80.60	81.74	81.55 (81.40, 81.70)	1.14	-0.19 (-0.34, 0.04)
Females	83.06	83.96	83.86 (83.71, 84.01)	0.90	-0.10 (-0.25, 0.05)
Males	78.14	79.53	79.31 (79.15, 79.47)	1.39	-0.22 (-0.38, -0.06)
Life expectancy at age 25					
Total	56.26	57.30	57.06 (56.91, 57.22)	1.04	-0.24 (-0.39, -0.08)
Females	58.61	59.42	59.27 (59.12, 59.42)	0.81	-0.15 (-0.30, 0.00)
Males	53.89	55.17	54.90 (54.74, 55.06)	1.28	-0.27 (-0.43, -0.11)
Life expectancy at age 65					
Total	19.54	20.26	20.00 (19.84, 20.16)	0.72	-0.26 (-0.42, -0.10)
Females	21.03	21.61	21.45 (21.30, 21.60)	0.58	-0.16 (-0.31, 0.01)
Males	17.87	18.72	18.47 (18.31, 18.64)	0.85	-0.25 (-0.41, -0.08)

Authors' analysis of data from the National Center for Health Statistics-U.S. Census Bureau and Human Mortality Database.
P_5, P_{95}: 5th and 95th percentiles of 50,000 simulated life expectancies using 10% random uncertainty around the 2020 q_x estimates.

References

[1] Woolf SH, Chapman DA, Lee JH. COVID-19 as the leading cause of death in the United States. JAMA. 2021;325(2):123-124.
[2] Dong E, Du H, Gardner L. An interactive web-based dashboard to track COVID-19 in real time. Lancet Infect Dis; published online Feb 19. https://doi.org/10.1016/S1473-3099(20)30120-1.
[3] Woolf SH, Aron L, eds. *U.S. Health in International Perspective: Shorter Lives, Poorer Health. Panel on Understanding Cross-National Health Differences Among High-Income Countries*. National Research Council, Committee on Population, Division of Behavioral and Social Sciences and Education, and Board on Population Health and Public Health Practice, Institute of Medicine. Washington, DC: The National Academies Press, 2013.
[4] Woolf SH, Schoomaker H. Life expectancy and mortality rates in the United States, 1959-2017. *JAMA*. 2019;322(20):1996-2016.
[5] Matthay EC, Duchowny KA, Riley AR, Galea S. Projected all-cause deaths attributable to COVID-19-related unemployment in the United States. *Am J Public Health*. 2021 Feb 18:e1-e4. doi: 10.2105/AJPH.2020.306095.
[6] Woolf SH, Chapman DA, Sabo RT, Weinberger DM, Hill L. Excess deaths from COVID-19 and other causes, March-April 2020. *JAMA*. 2020;324(5):510-3.
[7] Weinberger DM, Chen J, Cohen T, et al. Estimation of excess deaths associated with the COVID-19 pandemic in the United States, March to May 2020. *JAMA Intern Med*. 2020;180(10):1336-1344.
[8] Woolf SH, Chapman DA, Sabo RT, Weinberger DM, Hill L, Taylor DDH. Excess deaths from COVID-19 and other causes, March-July 2020. *JAMA* 2020;324(15):1562-1564.
[9] Rossen LM, Branum AM, Ahmad FB, Sutton P, Anderson RN. Excess deaths associated with COVID-19, by age and race and ethnicity - United States, January 26-October 3, 2020. *MMWR Morb Mortal Wkly Rep*. 2020;69(42):1522-1527.
[10] Jacobson SH, Jokela JA. Non-COVID-19 excess deaths by age and gender in the United States during the first three months of the COVID-19 pandemic. *Public Health*. 2020;189:101-103.
[11] Centers for Disease Control and Prevention. Risk for COVID-19 Infection, Hospitalization, and Death By Race/Ethnicity (website). Accessed March 4, 2021 at https://www.cdc.gov/coronavirus/2019-ncov/covid-data/investigations-discovery/hospitalization-death-by-race-ethnicity.html
[12] Andrasfay T, Goldman N. Reductions in 2020 U.S. life expectancy due to COVID-19 and the disproportionate impact on the Black and Latino populations. *Proc Natl Acad Sci U S A*. 2021;118(5):e2014746118.
[13] Arias E, Tejada-Vera B, Ahmad F. Provisional life expectancy estimates for January through June, 2020. Vital Statistics Rapid Release; no 10. Hyattsville, MD: National Center for Health Statistics. February 2021. DOI: https://dx.doi.org/10.15620/cdc:100392.
[14] Flanagin A, Frey T, Christiansen SL, Bauchner H. The reporting of race and ethnicity in medical and science journals. *JAMA*. 2021 Feb 22. doi: 10.1001/jama.2021.2104. Epub ahead of print. PMID: 33616604.
[15] Arias E. United States life tables, 2010. *National Vital Statistics Reports*; vol 63 no 7. Hyattsville, MD: National Center for Health Statistics. 2014.
[16] Arias E, Xu JQ. United States life tables, 2017. *National Vital Statistics Reports*; vol 68 no 7. Hyattsville, MD: National Center for Health Statistics. 2019.
[17] HealthData.gov. AH Excess Deaths by Sex, Age, and Race (website). Updated March 7, 2021. Accessed March 11, 2021 at https://healthdata.gov/dataset/ah-excess-deaths-sex-age-and-race
[18] U.S. Census Bureau. Population and Housing Unit Estimate (website). Accessed February 16, 2021 at https://www.census.gov/programs-surveys/popest/data.html

[19] University of California, Berkeley and Max Planck Institute for Demographic Research. Human Mortality Database (website). Updated March 5, 2021. Accessed March 7, 2021 at https://www.mortality.org/

[20] State of Israel. Complete Life Tables of Israel, 2013-2017 (website). Accessed February 23, 2021 at https://www.cbs.gov.il/en/publications/Pages/2019/Complete-Life-Tables-Of-Israel%20-%202013-2017.aspx#losExcelos

[21] New Zealand Government. New Zealand abridged period life table: 2016–18 (website). Accessed February 23, 2021 at https://www.stats.govt.nz/information-releases/new-zealand-abridged-period-life-table-201618-final

[22] Preston S, Heuveline P, Guillot M. *Demography: Measuring and Modeling Population Processes*. Oxford: Blackwell Publishers. 2001.

[23] Ruiz JM, Steffen P, Smith TB. Hispanic mortality paradox: a systematic review and meta-analysis of the longitudinal literature. *Am J Public Health*. 2013;103(3):e52-e60

[24] Chen Y, Freedman ND, Rodriquez EJ, et al. Trends in premature deaths among adults in the United States and Latin America. *JAMA Netw Open*. 2020;3(2):e1921085.

[25] Crimmins EM, Preston SH, Cohen B. *Explaining Divergent Levels of Longevity in High-Income Countries*. National Research Council. Washington, DC: The National Academies Press, 2011.

[26] Ho JY. Mortality under age 50 accounts for much of the fact that U.S. life expectancy lags that of other high-income countries. *Health Aff (Millwood)*. 2013;32(3):459-67.

[27] Ho JY, Hendi AS. Recent trends in life expectancy across high income countries: retrospective observational study. *BMJ*. 2018;362:k2562. doi: 10.1136/bmj.k2562. Erratum in: *BMJ*. 2018;362:k3622.

[28] Emanuel EJ, Gudbranson E, Van Parys J, Gørtz M, Helgeland J, Skinner J. Comparing health outcomes of privileged U.S. citizens with those of average residents of other developed countries. *JAMA Intern Med*. 2020:e207484. doi: 10.1001/jamainternmed.2020.7484. Epub ahead of print.

[29] National Academies of Sciences, Engineering, and Medicine 2021. *High and Rising Mortality Rates Among Working-Age Adults*. Washington, DC: The National Academies Press. https://doi.org/10.17226/25976.

[30] Bernstein L. Life expectancy declines again, a dismal trend not seen since World War I. *Washington Post*. November 21, 2018. https://www.washingtonpost.com/national/healthscience/us-life-expectancy-declines-again-adismal-trend-not-seen-since-world-war-i/2018/11/28/ae58bc8c-f28c-11e8-bc79-68604ed88993story.html. Accessed October 29, 2019.

[31] Avendano M, Kawachi I. Why do Americans have shorter life expectancy and worse health than do people in other high-income countries? *Annu Rev Public Health*. 2014;35:307-25.

[32] GBD 2017 Mortality Collaborators. Global, regional, and national age-sex-specific mortality and life expectancy, 1950-2017: a systematic analysis for the Global Burden of Disease Study 2017. *Lancet*. 2018;392(10159):1684-1735. Erratum in: *Lancet*. 2019;393(10190):e44.

[33] GBD 2017 DALYs and HALE Collaborators. Global, regional, and national disability-adjusted life-years (DALYs) for 359 diseases and injuries and healthy life expectancy (HALE) for 195 countries and territories, 1990-2017: a systematic analysis for the Global Burden of Disease Study 2017. *Lancet*. 2018;392(10159):1859-1922. Erratum in: Lancet. 2019;393(10190):e44. PMID: 30415748; PMCID: PMC6252083.

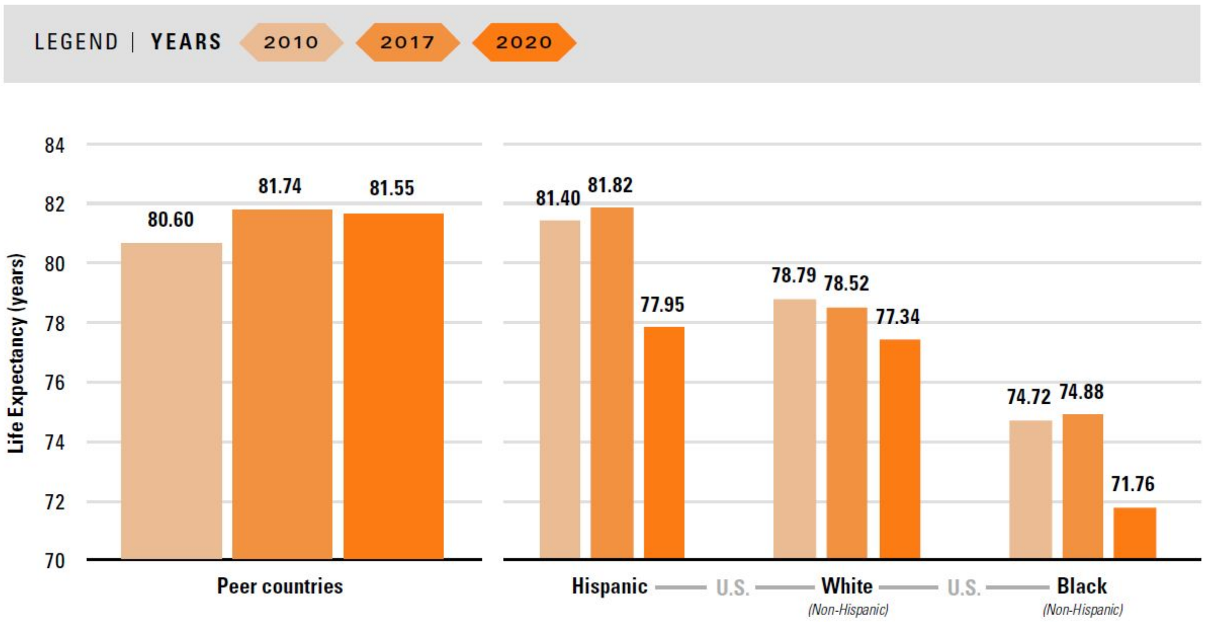
[34] Foreman KJ, Marquez N, Dolgert A, et al. Forecasting life expectancy, years of life lost, and all-cause and cause-specific mortality for 250 causes of death: reference and alternative scenarios for 2016-40 for 195 countries and territories. *Lancet*. 2018;392(10159):2052-2090.

[35] OECD Family Database. CO1.2: Life expectancy at birth. Accessed March 4, 2021 at https://www.google.com/search?client=firefox-b-1-e&q=oecd+36+life+expectancy

[36] OECD.Stat. Health status (website). Accessed March 4, 2021 at https://stats.oecd.org/Index.aspx?DataSetCode=HEALTH_STAT
[37] National Center for Health Statistics. *Life Tables. Vital Statistics of the United States*, 1970; vol. 11; section 5. Accessed March 8, 2021 at https://www.cdc.gov/nchs/data/lifetables/life70.pdf.
[38] Kiang MV, Irizarry RA, Buckee CO, Balsari S. Every body counts: measuring mortality from the COVID-19 pandemic*. Ann Intern Med*. 2020;173(12):1004-1007
[39] Hanage WP, Testa C, Chen JT, et al. COVID-19: U.S. federal accountability for entry, spread, and inequities-lessons for the future. *Eur J Epidemiol*. 2020;35(11):995-1006.
[40] WHO Regional Office for Europe, European Commission, European Observatory on Health Systems and Policies. COVID-19 Health System Response Monitor (website). Accessed March 4, 2021 at https://www.covid19healthsystem.org/mainpage.aspx
[41] University of Toronto. North American COVID-19 Policy Response Monitor (website). Accessed March 4, 2021 at https://ihpme.utoronto.ca/research/research-centres-initiatives/nao/covid19/
[42] Multistate. COVID-19 Policy Tracker (website). Accessed March 4, 2021 at https://www.multistate.us/issues/covid-19-policy-tracker
[43] OECD. Tackling Coronavirus (COVID-19): Contributing to a Global Effort (website). Accessed March 4, 2021 at https://www.oecd.org/coronavirus/en/
[44] Altman D. Understanding the U.S. failure on coronavirus—an essay by Drew Altman *BMJ* 2020; 370 :m3417
[45] Yong E. How the pandemic defeated America. *The Atlantic*. 2020 Aug 4;4.
[46] Parker R. *Why America's Response to the Covid-19 Pandemic Failed: Lessons From New Zealand's Success*. Faculty Articles and Papers. 528, 2021. Accessed 2-27-21 at https://opencommons.uconn.edu/law_papers/528
[47] Beckfield J, Bambra C. Shorter lives in stingier states: Social policy shortcomings help explain the U.S. mortality disadvantage. *Soc Sci Med*. 2016;171:30-38.
[48] Bassett MT, Chen JT, Krieger N. Variation in racial/ethnic disparities in COVID-19 mortality by age in the United States: A cross-sectional study. *PLoS Med*. 2020;17(10):e1003402. Erratum in: *PLoS Med*. 2021 Feb 4;18 Krieger N, Testa C, Hanage WP, Chen JT. (2):e1003541. PMID:
[49] Lopez L, Hart III, LH, Katz MH. Racial and ethnic disparities related to COVID-19. *JAMA*. 2021;325(8):719-720.
[50] Arias E. United States life tables, 2002. *National Vital Statistics Reports*; vol 53 no 6. Hyattsville, Maryland: National Center for Health Statistics. 2004.
[51] Delgado R, Stefancic J. *Critical Race Theory: The Cutting Edge*. Temple University Press; 2013.
[52] Jones CP. Systems of power, axes of inequity: parallels, intersections, braiding the strands. *Med Care*. 2014;52(10 Suppl 3):S71-5.
[53] Bailey ZD, Krieger N, Agénor M, Graves J, Linos N, Bassett MT. Structural racism and health inequities in the USA: evidence and interventions. *Lancet*. 2017;389(10077):1453-1463.
[54] Malat J, Mayorga-Gallo S, Williams DR. The effects of whiteness on the health of whites in the USA. *Soc Sci Med*. 2018;199:148-156.
[55] Williams DR, Lawrence JA, Davis BA. Racism and health: evidence and needed research. *Annu Rev Public Health*. 2019;40:105-125.
[56] Benjamins MR, Silva A, Saiyed NS, De Maio FG. Comparison of all-cause mortality rates and inequities between Black and White populations across the 30 most populous U.S. cities. *JAMA Netw Open*. 2021;4(1):e2032086.
[57] Bailey ZD, Feldman JM, Bassett MT. How structural racism works—racist policies as a root cause of U.S. racial health inequities. *N Engl J Med* 2021;384:768-773

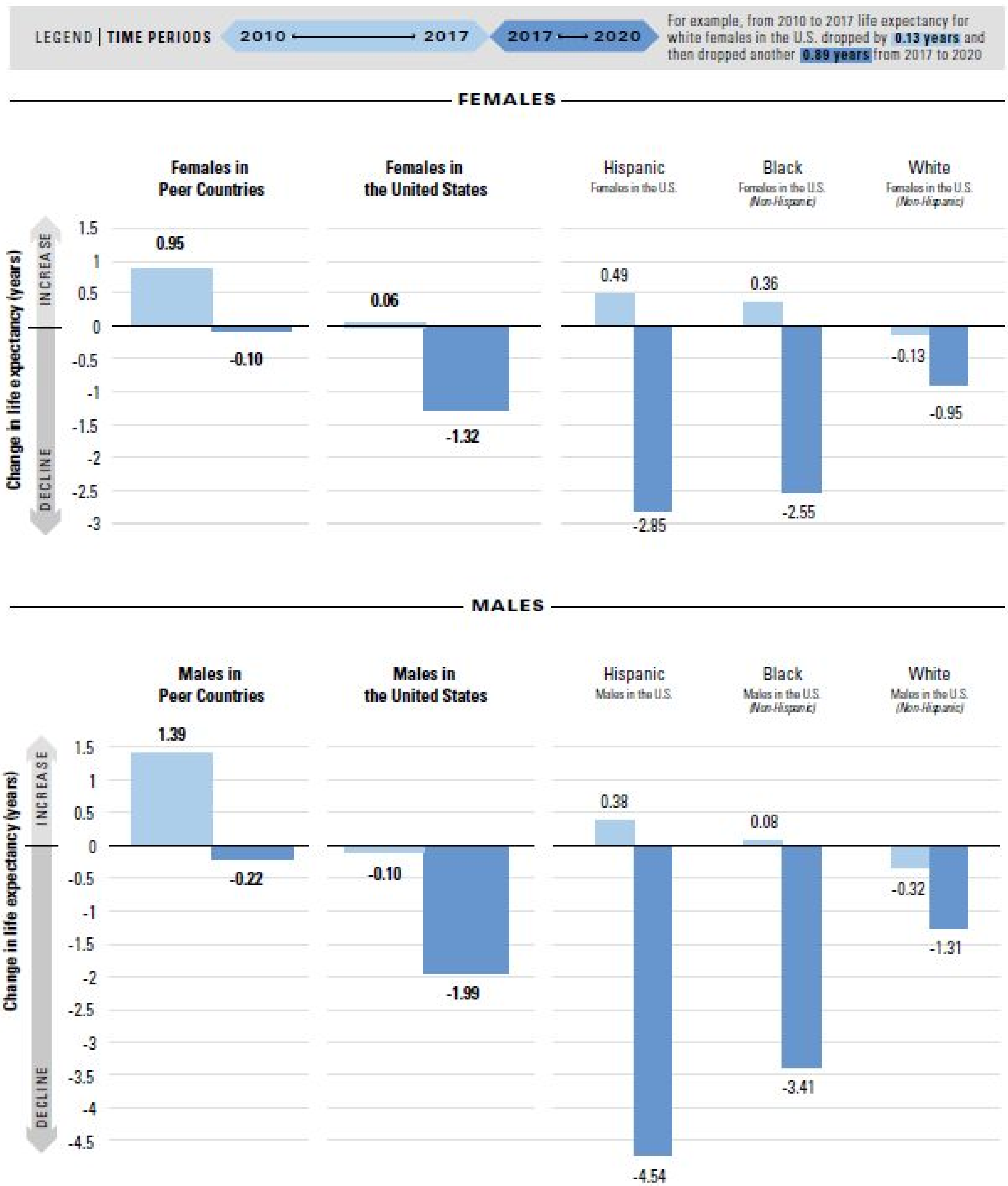
[58] Yancy CW. COVID-19 and African Americans. *JAMA*. 2020;323(19):1891–1892.
[59] Egede LE, Walker RJ. Structural racism, social risk factors, and Covid-19 - a dangerous convergence for Black Americans. *N Engl J Med*. 2020;383(12):e77. doi: 10.1056/NEJMp2023616. Epub 2020 Jul 22.
[60] Tan SB, deSouza P, Raifman M. Structural racism and COVID-19 in the USA: a county-level empirical analysis. *J Racial Ethn Health Disparities*. 2021 Jan 19:1–11.
[61] Tipirneni R. A data-informed approach to targeting social determinants of health as the root causes of COVID-19 disparities. *Am J Public Health*. 2021:e1-e3. doi: 10.2105/AJPH.2020.306085. Epub ahead of print.
[62] Krieger N, Waterman PD, Chen JT. COVID-19 and overall mortality inequities in the surge in death rates by Zip code characteristics: Massachusetts, January 1 to May 19, 2020. *Am J Public Health*. 2020;110(12):1850-1852.
[63] Allen S, Julian Z, Coyne-Beasley T, Erwin PC, Fletcher FE. COVID-19's impact on women: a stakeholder-engagement approach to increase public awareness through virtual town halls. *J Public Health Manag Pract*. 2020;26(6):534-538.
[64] U.S. racial and ethnic data for COVID-19 cases: still missing in action. *Lancet*. 2020;396(10261):e81.
[65] APM Research Lab. The Color of Coronavirus: COVID-19 Deaths by Race and Ethnicity in the U.S. (website). Accessed March 4, 2021 at https://www.apmresearchlab.org/covid/deaths-by-race
[66] Rubin R. As their numbers grow, COVID-19 "long haulers" stump experts. *JAMA*. 2020;324(14):1381-1383.
[67] Verdery AM, Smith-Greenaway E, Margolis R, Daw J. Tracking the reach of COVID-19 kin loss with a bereavement multiplier applied to the United States. *Proc Natl Acad Sci U S A*. 2020;117(30):17695-17701.

Figure 1. Life expectancy at Birth in the United States, by Race-Ethnicity, and in Peer Countries: 2010, 2017, 2020



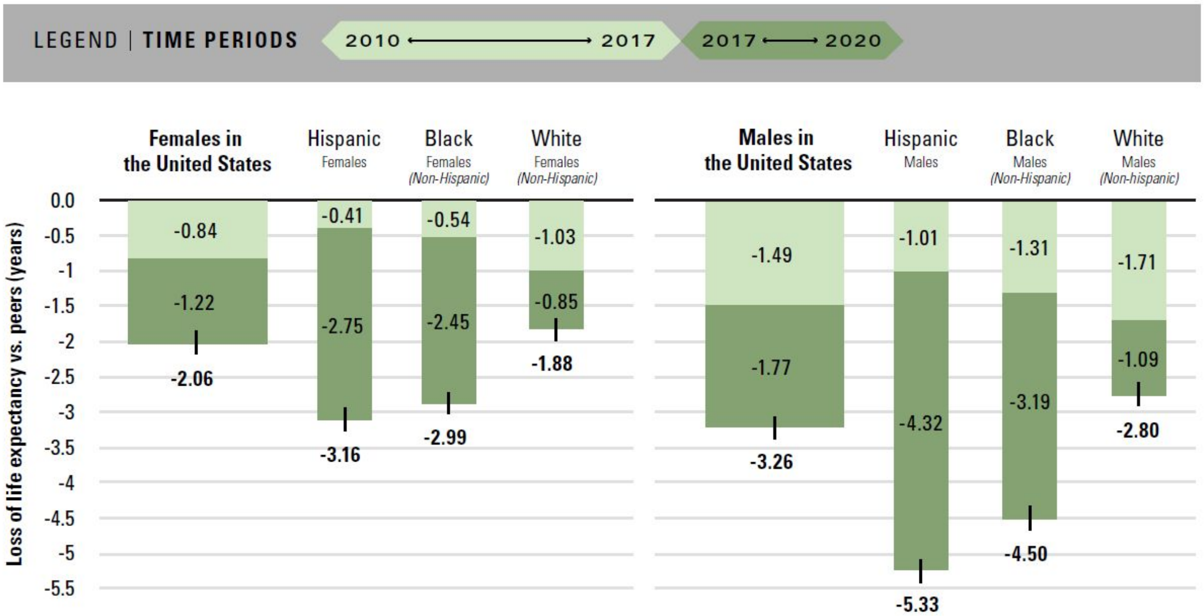
Authors' analysis of data from the National Center for Health Statistics-U.S. Census Bureau and Human Mortality Database.

Figure 2. Changes in Life Expectancy at Birth, U.S. Populations and Peer Country Average: 2010 to 2017 and 2017 to 2020



Authors' analysis of data from the National Center for Health Statistics-U.S. Census Bureau and Human Mortality Database.

Figure 3. Loss of Life Expectancy at Birth in U.S. Populations, Relative to Peer Country Average, 2010-2017 and 2017-2020



Authors' analysis of data from the National Center for Health Statistics-U.S. Census Bureau and Human Mortality Database.

DECLINES IN U.S. LIFE EXPECTANCY IN THE WAKE OF COVID-19: ONLINE SUPPLEMENT

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Life expectancies for 12 U.S. populations in 2010 were recorded from *National Vital Statistics Reports* Volume 63, Number 7, "United States Life Tables, 2010"[1] and 2017 life expectancies for these 12 US populations were recorded from *National Vital Statistics Reports* Volume 68, Number 7, "United States Life Tables, 2017."[2]

Comparison Group Populations for 18 Peer Countries

Countries comprising the peer country comparison group were: Austria, Belgium, Denmark, Finland, France, Germany, Israel, Italy, Netherlands, New Zealand, Norway, Portugal, South Korea, Spain, Sweden, Switzerland, Taiwan, United Kingdom (England and Wales, Northern Ireland, Scotland reported separately).

Criteria for inclusion in the peer country comparison group were: (1) high-income, (2) advanced democracy, and (3) data availability in both the Human Mortality Database (HMDB) 5 x 1 period life tables and the HMDB-Short Term Mortality Fluctuations (STMF) reports of weekly deaths in 2020. Data for each country's total population, female population, and male population in 2010 and 2017 were obtained from 5-year age x 1-year time period abridged period life tables taken from the Human Mortality Database. (Direct sources[3,4] were used for Israel and New Zealand 2017 life tables.) In total, 60 separate data sets were downloaded and analyzed.

2. Average 2010 and 2017 Life Expectancies among Peer Populations

Life expectancy for each peer country's total population, female population, and male population were saved separately as well as appended together. The ***average life expectancy*** at birth (e_0), at age 25 (e_{25}), at age 65 (e_{65}), the *average* ***age-specific probability of death*** (q_x), and the average ***age-specific person-years lived by the deceased*** (a_x) were calculated. The individual countries and the averages were collapsed into 2010 and 2017 datasets for total populations among peer countries, female populations among peer countries, and male populations among peer countries.

3a. Estimated 2020 Life Expectancy for U.S. Populations

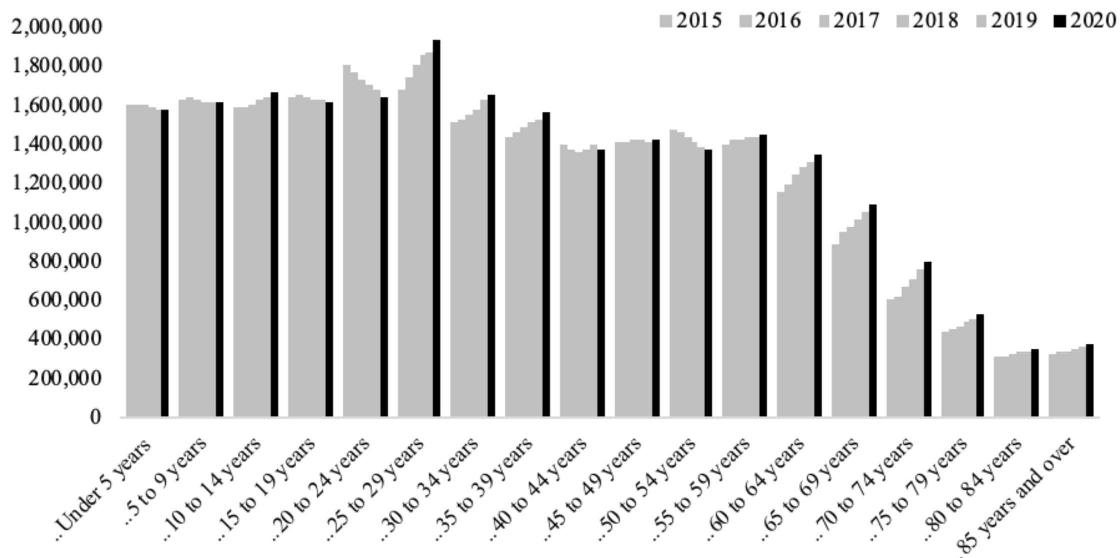
To calculate 2020 life tables for each U.S. population, we estimated 2020 age-specific death rates (m_x) for each U.S. population using (1) official life tables for 2017[2] (2) estimates of age-specific death counts among US populations in 2017, 2018, and 2020[5], and (3) estimates of age-specific population counts in 2017, 2018, and 2020.[6] The analytic steps are described below.

Estimated age-specific death rates in 2017, 2018, 2020 from NCHS-Census data

Age-specific death rates for US populations in 2017, 2018, and 2020 were calculated by merging estimates of age-specific counts of death with estimates of age-specific population counts. The counts of death were obtained from the February 17, 2021 release of the National Center for Health Statistics (NCHS), Center for Disease Control and Prevention, file, *AH Excess Deaths by Sex, Age, and Race*.[5] These NCHS data are composed of weekly death counts for ages 0-14; 15-

19; …; 80-84; and 85+ years. We summed the weekly counts for years 2017, 2018, and 2020 separately for each age group, separately for the twelve U.S. populations.

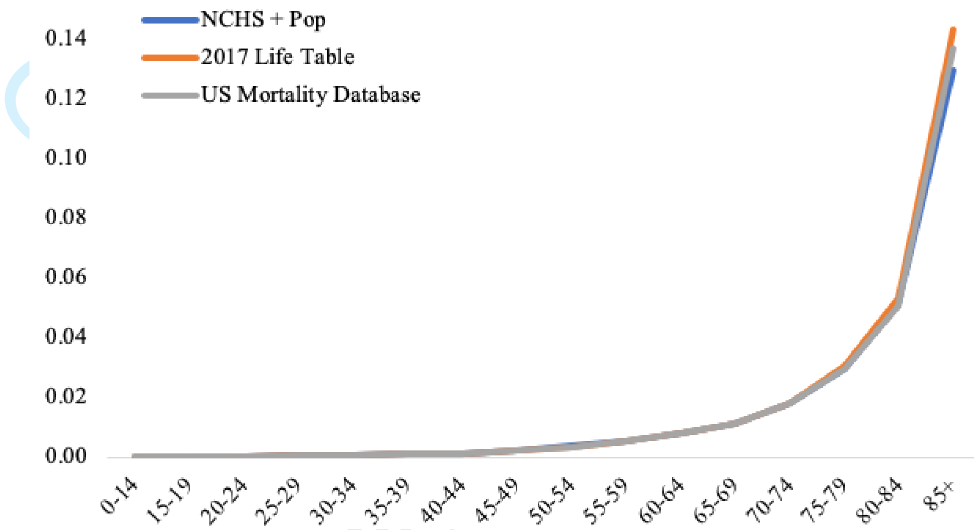
Mid-year population estimates were obtained from the U.S. Census Bureau file, *2019 Population Estimates by Age, Sex, Race, and Hispanic Origin*.[6] Tables *NC-EST2019-ASR5H* and *NC-EST2019-ASR6H* provide estimated annual counts of mid-year populations for ages 0-4; 5-9; …; 80-84; 85+ years for 2015-2019. Estimated population counts for ages 0-4; 5-9; and 10-14 are summed to approximate mid-year populations for ages 0-14 to match the age structure of the death counts in the NCHS data. For year 2020, the estimated population counts for ages 0-4; 5-9; …; 80-84; 85+ years are estimated from the linear trends of age-specific populations between years 2015 and 2019. For example, below are the estimated age-specific population counts for the U.S. non-Hispanic Black female population:



The yearly age-specific death counts were merged with the yearly age-specific population counts, separately by race/ethnicity and sex, to estimate 2017 age-specific mortality rates (m_x), 2018 m_x, and 2020 m_x for the 12 separate U.S. populations.

The 2017 m_x and 2018 m_x estimated in these NCHS-Census data were compared with the m_x derived from the 2017 and 2018 U.S. life tables to validate the accuracy of the data. This validation was performed to assess the validity of the 2020 m_x estimated in the NCHS-Census data. Specifically, we compared the 2017 m_x estimated in the NCHS-Census data with the 2017 m_x derived from official 2017 U.S. life tables.[2] We also compared the 2018 m_x estimated in the NCHS-Census data with the 2018 m_x derived from official 2018 U.S. life tables.[7] To derive the m_x in the official life tables, we simply use the sum of d_x and the sum of L_x across age groups 0-14; 15-19; …; 80-84; 85+ years to match the age structure of the NCHS-Census data.

We contrast the 2017 m_x estimated from the NCHS-Census linked data with the 2017 m_x derived from official U.S. life tables to assess the validity of the m_x estimates in the NCHS-Census linked data. Below, for example, we contrast our estimated 2017 m_x for the U.S. total female population with the 2017 m_x derived from Arias et al. 2019[2] and the 2017 m_x reported by the US Mortality Database, *5X1 Female Period Life Table*[8] (after combining d_x and L_x for age group 0-14 years and for ages 85+ years).



The rate ratios (RR) between the estimated 2017 m_x using the NCHS-Census linked data and the 2017 m_x derived from Arias et al. 2019 are reported below, separately by U.S. male and female populations.

Rate Ratios: Estimated 2017 mx from NCHS-Census Linked Data vs. 2017 mx Reported by Arias et al. 2019

	US Female Population				US Male Population			
	Total	NHB	Latina	NHW	Total	NHB	Latino	NHW
0-14	0.90	0.83	0.86	0.87	0.90	0.86	0.89	0.81
15-19	1.01	0.89	0.96	0.97	1.01	0.92	1.09	0.96
20-24	1.01	0.90	0.95	0.98	1.01	0.93	1.10	0.97
25-29	1.00	0.95	0.98	0.97	1.01	0.99	0.98	0.97
30-34	1.00	0.97	0.99	0.98	1.00	0.99	0.98	0.98
35-39	1.00	0.97	1.00	0.98	1.00	0.97	0.96	0.99
40-44	1.00	0.98	1.00	0.99	1.01	0.98	0.96	0.99
45-49	1.01	0.99	0.92	0.99	1.01	0.99	0.98	1.00
50-54	1.00	0.99	0.92	1.00	1.01	1.00	0.98	1.00
55-59	1.00	0.98	0.94	0.99	1.00	1.00	0.96	1.00
60-64	1.00	0.98	0.95	0.99	1.00	0.99	0.96	0.99
65-69	0.99	0.98	1.00	0.99	1.00	0.99	0.96	0.99
70-74	0.98	0.97	1.00	0.99	0.99	0.98	0.96	0.99
75-79	0.97	0.96	0.98	0.98	0.97	0.96	0.97	0.98
80-84	0.96	0.93	0.95	0.97	0.96	0.92	0.92	0.97
85+	0.90	0.85	0.76	0.93	0.87	0.80	0.72	0.90

Although the estimated m_x from the NCHS-Census linked data are quite close to the reported m_x in Arias et al. 2019[2], two concerns are apparent. First, the m_x estimates are smaller than the reported m_x for the two pooled age groups at the youngest ages and the oldest ages (i.e., ages

0-14 and ages 85+ years). Second, m_x estimates smaller than the reported m_x are more common for non-Hispanic Black and Hispanic populations than for the non-Hispanic white and total populations. Both of these concerns about the m_x estimates are also evident in the 2018 data:

Rate Ratios: Estimated 2018 mx from NCHS-Census Linked Data vs. 2018 mx Reported by Arias 2020

	US Female Population				US Male Population			
	Total	NHB	Latina	NHW	Total	NHB	Latino	NHW
0-14	0.89	0.81	0.80	0.86	0.89	0.81	0.87	0.81
15-19	1.00	0.85	0.95	0.96	1.01	0.87	1.08	0.95
20-24	1.01	0.88	0.95	0.97	1.01	0.89	1.10	0.96
25-29	1.01	0.93	0.99	0.97	1.01	0.96	0.98	0.96
30-34	1.00	0.94	0.99	0.97	1.01	0.97	0.99	0.97
35-39	1.00	0.95	1.00	0.98	1.01	0.95	0.96	0.98
40-44	1.00	0.96	1.00	0.98	1.00	0.96	0.95	0.98
45-49	1.00	0.97	0.91	0.99	1.01	0.97	0.98	0.99
50-54	1.00	0.98	0.92	0.99	1.01	0.98	0.97	1.00
55-59	1.00	0.97	0.94	0.99	1.00	0.98	0.95	0.99
60-64	1.00	0.97	0.94	0.99	1.00	0.98	0.96	0.99
65-69	0.99	0.97	1.00	0.99	1.00	0.97	0.96	0.99
70-74	0.98	0.96	1.00	0.98	0.99	0.97	0.96	0.98
75-79	0.97	0.95	0.97	0.97	0.97	0.95	0.97	0.97
80-84	0.95	0.92	0.94	0.97	0.96	0.92	0.92	0.97
85+	0.90	0.84	0.75	0.94	0.86	0.80	0.71	0.89

Because concerns about bias in m_x estimates are evident in both the 2017 and 2018 NCHS-Census linked data, we assume the 2020 estimates are biased as well. Further, we assume that the degree of bias remains unchanged across 2017, 2018, and 2020 by age, sex, and race/ethnicity. That is, we assume the degree of bias is consistent across the years, such that rate ratios in the estimated 2017, 2018, and 2020 NCHS-Census linked data are due to *actual* changes in the m_x and not changes in bias across the years. This assumption is validated in the table below, which shows the absolute differences between the rate ratios reported in the two tables above:

Difference in Difference in Rate Ratios: 2018 Difference - 2017 Difference								
	US Female Population				US Male Population			
	Total	NHB	Latina	NHW	Total	NHB	Latino	NHW
0-14	-0.01	-0.02	-0.06	0.00	-0.01	-0.05	-0.03	0.00
15-19	0.00	-0.04	-0.01	-0.02	0.00	-0.06	-0.01	-0.01
20-24	0.00	-0.02	0.00	-0.01	0.00	-0.04	0.00	-0.01
25-29	0.00	-0.02	0.01	-0.01	0.00	-0.03	0.00	-0.01
30-34	0.00	-0.03	0.00	0.00	0.00	-0.02	0.01	-0.01
35-39	0.00	-0.02	0.00	-0.01	0.00	-0.02	0.00	-0.01
40-44	0.00	-0.02	0.00	-0.01	0.00	-0.02	0.00	-0.01
45-49	0.00	-0.02	-0.01	-0.01	0.00	-0.02	0.00	-0.01
50-54	0.00	-0.01	0.00	0.00	0.00	-0.02	0.00	0.00
55-59	0.00	-0.01	0.00	0.00	0.00	-0.01	0.00	0.00
60-64	0.00	-0.01	0.00	0.00	0.00	-0.01	-0.01	0.00
65-69	0.00	-0.01	0.00	0.00	0.00	-0.01	-0.01	0.00
70-74	0.00	-0.01	0.00	0.00	0.00	-0.01	0.00	0.00
75-79	0.00	-0.01	0.00	0.00	0.00	-0.01	-0.01	0.00
80-84	0.00	-0.01	-0.01	0.00	0.00	-0.01	0.00	0.00
85+	0.00	-0.01	-0.01	0.00	-0.01	-0.01	-0.01	0.00

The degree of bias in m_x estimates in the NCHS-Census data are consistent between 2017 and 2018, although some differences exist for m_x estimates at the youngest ages (0-14; 15-19; and 20-24 years) for the non-Hispanic Black population and the youngest age group (0-14 years) for the Latina population. Because deaths at these ages minimally affect changes in disparities in life expectancy at birth across the years, these differences in rate ratios are less concerning for estimates of life expectancy overall. At all other ages for all other U.S. populations, the differences between the rate ratios are minimal, suggesting that any difference in the rate ratios for year 2020 should overwhelmingly reflect actual changes in mortality rates, not discrepancies due to errors in reporting.

Because of the slight differences between the NCHS-Census estimated m_x and the m_x derived in the official US life tables,[2,7] we do not use the 2020 m_x estimated in the NCHS-Census linked data to calculate 2020 U.S. life tables. Rather, we instead use the estimated rate ratios between the 2020 m_x estimates in the NCHS-Census data and the 2017 m_x estimates in the NCHS-Census data (below), and multiply these rate ratios by the 2017 m_x derived in the official 2017 US life tables.[7]

Rate Ratios: 2020 mx vs. 2017 mx Estimated from NCHS-Census Linked Data								
	US Female Population				US Male Population			
	Total	NHB	Latina	NHW	Total	NHB	Latino	NHW
0-14	0.88	0.87	0.88	0.88	0.87	0.87	0.88	0.87
15-19	1.07	1.40	1.07	0.94	1.12	1.28	1.26	1.00
20-24	1.11	1.41	1.24	0.98	1.14	1.38	1.33	0.97
25-29	1.11	1.22	1.30	1.02	1.10	1.18	1.32	0.97
30-34	1.18	1.33	1.40	1.07	1.23	1.38	1.48	1.12
35-39	1.17	1.25	1.34	1.11	1.25	1.29	1.51	1.16
40-44	1.21	1.33	1.39	1.14	1.33	1.40	1.63	1.23
45-49	1.11	1.21	1.32	1.06	1.20	1.31	1.55	1.11
50-54	1.11	1.16	1.33	1.07	1.18	1.26	1.44	1.11
55-59	1.08	1.13	1.36	1.04	1.14	1.19	1.53	1.07
60-64	1.13	1.17	1.37	1.09	1.16	1.20	1.48	1.10
65-69	1.12	1.21	1.38	1.08	1.18	1.23	1.56	1.13
70-74	1.10	1.24	1.37	1.05	1.13	1.28	1.50	1.08
75-79	1.10	1.19	1.34	1.07	1.13	1.23	1.42	1.10
80-84	1.11	1.20	1.29	1.09	1.12	1.20	1.33	1.10
85+	1.11	1.19	1.21	1.11	1.11	1.20	1.26	1.09

Thus, the 2020 m_x used to calculate 2020 life tables for US populations are the official 2017 NCHS m_x[7] inflated by the 2020:2017 mortality rate ratios estimated from the NCHS-Census data. These calculations assume a constant rate ratio for ages 0, 1-4, 5-9, and 10-14 years (i.e., 0-14 year rate ratios in the NCHS-Census data are used to inflate the 2017 m_x at these ages) and a constant rate ratio for ages 85-89, 90-94, 95-99, and 100+ years (i.e., the 85+ rate ratio in the NCHS-Census data are used to inflate the 2017 m_x at these ages).

To calculate 2020 five-year q_x, we use the standard equation of Preston et al.[9]

$$q_x = (m_x*n)/(1+(a_x*m_x))$$

where *n* is the width of the age interval (i.e., 1 year, 4 years, or 5 years) and a_x is derived from the official 2017 US life tables for each US population.

Estimates of 2017 life expectancy at birth from five-year abridged life tables using q_x from this equation approximate the official reported 2017 life expectancy at birth with remarkable accuracy (see table below). Thus, using five-year q_x should not seriously bias estimates of 2020 life expectancy.

2017 Life Expectancy at Birth by U.S. Population

	Official	Abridged q_x
Total	78.61	78.59
Female	81.10	81.08
Male	76.10	76.10
Hispanic	81.82	81.85
Non-Hispanic Black	74.88	74.85
Non-Hispanic White	78.52	78.51
Hispanic female	84.31	84.33
Non-Hispanic Black female	78.08	78.04
Non-Hispanic White female	80.98	80.96
Hispanic male	79.10	79.08
Non-Hispanic Black male	71.51	71.50
Non-Hispanic White male	76.09	76.08

To account for possible error in 2020 death counts, possible error in 2020 population estimates, and possible error in estimated mortality rate ratios between 2020 m_x and 2017 m_x, we simulated 50,000 life tables with 10% uncertainty added to the 2020 estimated q_x. Specifically, we simulated life tables using random (i.e., uniform) draws of q_x ranging from $0.95*q_x$ to $1.05*q_x$ and a_x from official 2017 life tables.[2] We report the 5th percentiles, medians, and 95th percentiles of 2020 life expectancies at birth, at age 25, and at age 65 for all US populations.

3b. Estimated Average 2020 Life Expectancy for Peer Populations

To calculate average 2020 life expectancies among peer populations, we separately estimate 2020 q_x among each peer country's total population, male population, and female population using (a) the country's reported q_x in the 2017 life tables in the Human Mortality Database (and CBS-reported 2017 life table for Israel and StatsNZ-reported 2016-2018 life table for New Zealand) and (b) the mortality rate ratio between the country's reported m_x in the 2017 life tables and the country's reported 2020 m_x for ages 0-14; 15-64; 65-74; 75-84; and 85+ years in the *Human Mortality Database-Short Term Mortality Fluctuation* data. Weekly estimates of peer countries' mortality rates at ages 0-14; 15-64; 65-74; 75-84; and 85+ (m_x) were obtained from the *Human Mortality Database-Short Term Mortality Fluctuations* files. The rate ratios (RR) between the 2020 m_x and the 2017 m_x were calculated for each country.

To calculate 2020 five-year q_x among each peer country's total population and by sex, we use each country's 2017 q_x, each country's 2017 a_x, and each country's 2020:2017 RR. Generally, m_x

ratios are slightly different from q_x ratios at older ages, but the differences are minimal and do not substantively affect e_x estimates. As an illustration of the strong correspondence between countries' m_x ratios and q_x ratios, below is a table showing the differences between the q_x ratios between 2017 and 2014 and the mx ratios between 2017 and 2014 for Switzerland's and Norway's female population. We compare the ratios between 2017 and 2014 because it is the same time difference as between 2020 and 2017. The average differences between the ratios for all 18 peer country's female populations are also included, as well as the differences between the 2017 qx and the estimated 2017 q_x using a) 2014 q_x and b) the 2017:2014 m_x ratio.

	Switzerland			Norway			Average	
Age	2017:2014 m_x	2017:2014 q_x	Ratio	2017:2014 m_x	2017:2014 q_x	Ratio	Ratio	q_x est - q_x
0	0.890	0.890	1.000	1.014	1.018	1.005	1.000	0.000
1-4	0.917	0.878	0.957	1.500	1.424	0.949	0.999	0.000
5-9	1.250	1.286	1.029	1.800	1.731	0.962	1.001	0.000
10-14	0.889	0.870	0.978	2.750	2.650	0.964	0.980	0.000
15-19	1.083	1.082	0.999	1.000	1.000	1.000	0.995	0.000
20-24	0.765	0.724	0.947	0.750	0.752	1.003	0.997	0.000
25-29	1.000	1.010	1.010	1.368	1.419	1.037	0.998	0.000
30-34	0.759	0.767	1.011	0.829	0.828	0.999	1.000	0.000
35-39	1.158	1.160	1.002	1.071	1.087	1.014	1.002	0.000
40-44	0.841	0.853	1.014	1.015	1.009	0.994	1.001	0.000
45-49	0.990	0.990	1.000	0.906	0.907	1.001	0.999	0.000
50-54	0.903	0.906	1.003	0.830	0.833	1.003	1.001	0.000
55-59	0.935	0.938	1.003	0.892	0.893	1.001	1.001	0.000
60-64	0.919	0.919	1.000	0.920	0.920	1.001	1.000	0.000
65-69	0.972	0.971	0.999	0.959	0.960	1.001	1.000	0.000
70-74	0.982	0.983	1.001	1.092	1.090	0.998	1.000	0.000
75-79	0.982	0.983	1.001	0.974	0.974	1.000	1.001	0.000
80-84	0.991	0.992	1.000	0.952	0.955	1.003	1.002	0.000
85-89	0.983	0.985	1.002	0.999	1.002	1.004	1.000	0.000
90-94	1.005	1.008	1.004	1.003	1.005	1.002	1.013	0.005
95-99	0.997	0.999	1.002	1.019	1.009	0.990	0.983	0.014
100-104	0.999	1.000	1.001	1.025	1.006	0.981	0.973	0.026
105-109	1.001	1.000	1.000	1.024	1.003	0.979	0.970	0.019
110+	1.001	1.000	0.999	1.020	1.000	0.980	0.970	0.000

Sizable differences between the estimated 2017 q_x and the actual 2017 q_x are observed only at ages 95-99, 100-104, and 105-109, which have little effect on life expectancy estimates. Indeed, the average difference between the estimated 2017 life expectancies using the estimated 2017 q_x and the actual 2017 life expectancies is -.0177 years. This exercise shows that combining each country's 2017 q_x with the countries' mortality rate ratios between 2020 and 2017 likely approximates each country's 2020 q_x.

To account for possible error in 2020 m_x reported in the STMF data, possible error in estimated mortality rate ratios between 2020 m_x and 2016/2017/2018 m_x, we simulated 50,000 life tables with 10% uncertainty added to the 2020 estimated q_x. Specifically, we simulated life tables using random (i.e., uniform) draws of q_x ranging from .95* q_x to 1.05* q_x and average ax in the aggregate 2017 HMDB life tables. We report the 5th percentiles, medians, and 95th percentiles of life expectancies at birth, at age 25, and at age 65 for total peer populations and by sex.

4. Analytic Scripts

a. Stata files merging death counts in NCHS data and population counts from Census estimates

```
********* All US Pop ************
*** 2020 NCHS Mortality Data, by Week ***

import delimited "/…/NCHS
Data/AH_Excess_Deaths_by_Sex__Age__and_Race_3_7.csv",
encoding(ISO-8859-1)

drop footnote geography numberaboveaverageweighted
percentaboveaverageweighted numberaboveaverageunweighted
percentaboveaverageunweighted timeperiod analysisdate weekending
covid19weighted covid19unweighted averagenumberofdeathsweighted
averagenumberofdeathsunweighted

keep if mmwryear == 2020
keep if raceethnicity == "All Race/Ethnicity Groups"

keep if sex == "All Sexes"
encode agegroup, gen(age)
drop if age == 17 | age == 18


*** Sum Deaths for Entire 2020 by Age ***

sort age
collapse (sum) mort = deathsunweighted, by(age)

save "/…/total pop_age specific death counts_2020.dta", replace


****** Import 2020 Pop Estimates ******

* Linear Trend Approximations from Age-specific Populations
2015-2019
* All US Pop, 0-14, 15-19, 80-84, 85+

import excel "/…/total pop_age.xlsx", sheet("2020 pop") firstrow
clear

encode age, gen(agecat)
drop age
```

```
rename agecat age

merge using "/…/total pop_age specific death counts_2020.dta"

gen mx = mort/pop

save "/…/total pop_2020 mx.dta", replace
```

b. Stata files appending peer country data. Female HMDB as Example

```
*******************
****  Austria ****
*******************

import delimited "/.../HMDB data/women/Austria_Women.txt",
delimiter(space, collapse) varnames(1) encoding(ISO-8859-1)
clear

keep if   year == 2010 | year == 2017

gen country = "Austria"

save "/.../HMDB data/women/austria_paper1.dta", replace


*******************
****  Belgium ****
*******************

import delimited "/.../HMDB data/women/Belgium_Women.txt",
delimiter(space, collapse) varnames(1) encoding(ISO-8859-1)
clear

keep if   year == 2010 | year == 2017

gen country = "Belgium"

save "/.../HMDB data/women/belgium_paper1.dta", replace


****************
****  Israel ****
****************
```

```
import delimited "/.../HMDB data/women/Israel_Women.txt",
delimiter(space, collapse) varnames(1) encoding(ISO-8859-1)
clear

keep if   year == 2010

gen country = "Israel"

save "/.../HMDB data/women/israel_paper1.dta", replace


* Data from Central Bureau of Statistics, State of Israel 2017
Life Table
import excel "/…/HMDB data/Israel/Israel_2017.xlsx",
sheet("female") firstrow clear

append using "/.../HMDB data/women/israel_paper1.dta"

replace country = "Israel" if country == ""

* USE Data Editor to change String Variable Coding of Age
* *(1 variable, 24 observations pasted into data editor)

* save "/.../HMDB data/women/israel_paper1.dta", replace

save "/.../HMDB data/women/israel_paper1.dta", replace


*****************
****  S Korea ****
*****************

import delimited "/.../HMDB data/women/Korea_Women.txt",
delimiter(space, collapse) varnames(1) encoding(ISO-8859-1)
clear

keep if   year == 2010 | year == 2017

gen country = "S Korea"

save "/.../HMDB data/women/korea_paper1.dta", replace


*****************
****  Denmark ****
*****************
```

```
import delimited “/.../HMDB data/women/Denmark_Women.txt",
delimiter(space, collapse) varnames(1) encoding(ISO-8859-1)
clear

keep if   year == 2010 | year == 2017

gen country = "Denmark"

save “/.../HMDB data/women/denmark_paper1.dta", replace

*****************
****  Finland ****
*****************

import delimited “/.../HMDB data/women/Finland_Women.txt",
delimiter(space, collapse) varnames(1) encoding(ISO-8859-1)
clear

keep if   year == 2010 | year == 2017

gen country = "Finland"

save “/.../HMDB data/women/finland_paper1.dta", replace


****************
****  France ****
****************

import delimited “/.../HMDB data/women/France_Women.txt",
delimiter(space, collapse) varnames(1) encoding(ISO-8859-1)
clear

keep if   year == 2010 | year == 2017

gen country = "France"

save “/.../HMDB data/women/france_paper1.dta", replace


****************
****  Italy ****
****************
```

```
import delimited "/.../HMDB data/women/Italy_Women.txt",
delimiter(space, collapse) varnames(1) encoding(ISO-8859-1)
clear

keep if   year == 2010 | year == 2017

gen country = "Italy"

save "/.../HMDB data/women/italy_paper1.dta", replace



*********************
****  Netherlands ****
*********************

import delimited "/.../HMDB data/women/Netherlands_Women.txt",
delimiter(space, collapse) varnames(1) encoding(ISO-8859-1)
clear

keep if   year == 2010 | year == 2017

gen country = "Netherlands"

save "/.../HMDB data/women/netherlands_paper1.dta", replace


*********************
****  New Zealand ****
*********************

import delimited "/.../HMDB data/women/New Zealand_Women.txt",
delimiter(space, collapse) varnames(1) encoding(ISO-8859-1)
clear

keep if   year == 2010

gen country = "New Zealand"

save "/.../HMDB data/women/nz_paper1.dta", replace

* Data from Stats NZ, 2016-2018 Life Table
import excel "/…/HMDB data/New Zealand/NZ_2017.xlsx",
sheet("female") firstrow clear

append using "/.../HMDB data/women/nz_paper1.dta"
```

```
replace country = "New Zealand" if country == ""

drop if year == .
replace age = "90-94" if age == "90-95"
* Change ax

save “/.../HMDB data/women/nz_paper1.dta", replace


*********************
****  Taiwan ****
*********************

import delimited “/.../HMDB data/women/Taiwan_Women.txt",
delimiter(space, collapse) varnames(1) encoding(ISO-8859-1)
clear

keep if   year == 2010 | year == 2017

gen country = "Taiwan"

save “/.../HMDB data/women/taiwan_paper1.dta", replace


****************
****  Norway ****
****************

import delimited “/.../HMDB data/women/Norway_Women.txt",
delimiter(space, collapse) varnames(1) encoding(ISO-8859-1)
clear

keep if   year == 2010 | year == 2017

gen country = "Norway"

save “/.../HMDB data/women/norway_paper1.dta", replace


******************
****  Portugal ****
******************

import delimited “/.../HMDB data/women/Portugal_Women.txt",
delimiter(space, collapse) varnames(1) encoding(ISO-8859-1)
clear
```

```
keep if   year == 2010 | year == 2017

gen country = "Portugal"

save "/.../HMDB data/women/portugal_paper1.dta", replace


****************
****  Spain ****
****************


import delimited "/.../HMDB data/women/Spain_Women.txt",
delimiter(space, collapse) varnames(1) encoding(ISO-8859-1)
clear

keep if   year == 2010 | year == 2017

gen country = "Spain"

save "/.../HMDB data/women/spain_paper1.dta", replace


*****************
****  Sweden ****
*****************

import delimited "/.../HMDB data/women/Sweden_Women.txt",
delimiter(space, collapse) varnames(1) encoding(ISO-8859-1)
clear

keep if   year == 2010 | year == 2017

gen country = "Sweden"

save "/.../HMDB data/women/sweden_paper1.dta", replace


**********************
****  Switzerland ****
**********************

import delimited "/.../HMDB data/women/Switzerland_Women.txt",
delimiter(space, collapse) varnames(1) encoding(ISO-8859-1)
clear

keep if   year == 2010 | year == 2017
```

```
gen country = "Switzerland"

save "/.../HMDB data/women/swiss_paper1.dta", replace


************************
****  United Kingdom ****
************************


import delimited "/.../HMDB data/women/England_Wales_Women.txt",
delimiter(space, collapse) varnames(1) encoding(ISO-8859-1)
clear

keep if   year == 2010 | year == 2017

gen country = "England & Wales"

save "/.../HMDB data/women/england_wales_paper1.dta", replace

import delimited "/.../HMDB data/women/Scotland_Women.txt",
delimiter(space, collapse) varnames(1) encoding(ISO-8859-1)
clear

keep if   year == 2010 | year == 2017

gen country = "Scotland"

save "/.../HMDB data/women/scotland_paper1.dta", replace


import delimited "/.../HMDB data/women/Northern
Ireland_Women.txt", delimiter(space, collapse) varnames(1)
encoding(ISO-8859-1) clear

keep if   year == 2010 | year == 2017

gen country = "Northern Ireland"

save "/.../HMDB data/women/northern ireland_paper1.dta", replace


**********************
****  Germany ****
**********************
```

```
import delimited "/.../HMDB data/women/Germany_Women.txt",
delimiter(space, collapse) varnames(1) encoding(ISO-8859-1)
clear

keep if   year == 2010 | year == 2017

gen country = "Germany"

save "/.../HMDB data/women/germany_paper1.dta", replace



*************************
* Append Peer Countries *
*************************

* 18 Country Comparison Group

use "/.../HMDB data/women/germany_paper1.dta", clear

append using "/.../HMDB data/women/swiss_paper1.dta"
append using "/.../HMDB data/women/sweden_paper1.dta"
append using "/.../HMDB data/women/spain_paper1.dta"
append using "/.../HMDB data/women/portugal_paper1.dta"
append using "/.../HMDB data/women/norway_paper1.dta"
append using "/.../HMDB data/women/netherlands_paper1.dta"
append using "/.../HMDB data/women/italy_paper1.dta"
append using "/.../HMDB data/women/france_paper1.dta"
append using "/.../HMDB data/women/finland_paper1.dta"
append using "/.../HMDB data/women/denmark_paper1.dta"
append using "/.../HMDB data/women/austria_paper1.dta"
append using "/.../HMDB data/women/belgium_paper1.dta"
append using "/.../HMDB data/women/nz_paper1.dta"
append using "/.../HMDB data/women/korea_paper1.dta"
append using "/.../HMDB data/women/israel_paper1.dta"
append using "/.../HMDB data/women/taiwan_paper1.dta"
append using "/.../HMDB data/women/england_wales_paper1.dta"
append using "/.../HMDB data/women/scotland_paper1.dta"
append using "/.../HMDB data/women/northern ireland_paper1.dta"


save "/…/peer18_paper1sep.dta", replace


* Variation in LE at Birth
```

```
set scheme s1manual

kdensity ex if nage==1 & year==2010
kdensity ex if nage==1 & year==2017

sum ex if nage==1 & year==2010, detail
sum ex if nage==1 & year==2017, detail


* Individual LT Kept for Merging with STMF RR

gen id = .
replace id = 1 if country == "Austria"
replace id = 2 if country == "Belgium"
replace id = 3 if country == "Denmark"
replace id = 4 if country == "Finland"
replace id = 5 if country == "France"
replace id = 6 if country == "Germany"
replace id = 7 if country == "Israel"
replace id = 8 if country == "Italy"
replace id = 9 if country == "Netherlands"
replace id = 10 if country == "New Zealand"
replace id = 11 if country == "Norway"
replace id = 12 if country == "Portugal"
replace id = 13 if country == "Spain"
replace id = 14 if country == "Sweden"
replace id = 15 if country == "Switzerland"
replace id = 16 if country == "Taiwan"
replace id = 17 if country == "England & Wales"
replace id = 18 if country == "Scotland"
replace id = 19 if country == "Northern Ireland"
replace id = 20 if country == "S Korea"

sort id year

save "/…/peer18_paper1_sepLT.dta", replace

merge id using "/…/paper3_rr_female.dta"

sort id year nage

drop lx dx Lx Tx countrycode sex _merge

bysort nage: gen mx20 = mx*rr_0 if year == 2017
bysort nage: replace mx20 = mx*rr_15 if nage >= 5 & nage < 15 &
year == 2017
```

```
bysort nage: replace mx20 = mx*rr_65 if nage >= 15 & nage < 17 &
year == 2017
bysort nage: replace mx20 = mx*rr_75 if nage >= 17 & nage < 19 &
year == 2017
bysort nage: replace mx20 = mx*rr_85 if nage >= 19 & year ==
2017

bysort nage: gen qx20 = qx*rr_0 if year == 2017
bysort nage: replace qx20 = qx*rr_15 if nage >= 5 & nage < 15 &
year == 2017
bysort nage: replace qx20 = qx*rr_65 if nage >= 15 & nage < 17 &
year == 2017
bysort nage: replace qx20 = qx*rr_75 if nage >= 17 & nage < 19 &
year == 2017
bysort nage: replace qx20 = qx*rr_85 if nage >= 19 & year ==
2017

save "/…/peer18_paper1_sepLT.dta", replace

sort id year nage

export excel using "/…/peer_sepLT_female.xls",
firstrow(variables) nolabel replace
```

c. Stata files estimating 2017 and 2020 death rates in peer country data.

```
*** Import HMDB Raw .txt Data ***

import delimited "/…/peer_STMF/pooled_stmf_2_14_21.csv", encoding(ISO-
8859-1)

drop split splitsex forecast rtotal dtotal d85p d75_84 d65_74 d15_64
d0_14

keep if sex == "b"

drop if inlist(country,"AUS2","BGR","CAN",
"CHL","CZE","EST","GRC","HRV","HUN")
drop if inlist(country,"ISL","LTU","LUX","LVA","POL","RUS")
drop if inlist(country,"SVK","SVN","USA")

keep if year >= 2016

* Estimate Yearly Average ASRD - Mean across the 52 weeks

sort countrycode year

collapse (mean) r0=r0_14 r15=r15_64 r65=r65_74 r75=r75_84 r85=r85p,
by(countrycode year)

* RR b/w 2020 and average of (2016,2017,2018)
* Compute Average of 2016/2017/2018

tempfile a b c

sort countrycode

save `a'

keep if year >=2016 & year <= 2018

collapse (mean) r017=r0 r1517=r15 r6517=r65 r7517=r75 r8517=r85,
by(countrycode)

sort countrycode

save `b'

use `a', clear

sort countrycode

keep if year == 2020
```

```
sort countrycode

save `c'

merge using `b'

drop _merge

* Data are now Country-specific ASDRs in 2020 and average ASDRs in
2016/2017/2018

* Estimate RR
* Take Average for peers
* Combine with the 2017 Peer Life Table to Estimate ASDRs for 2020
Life Table

gen rr_0 = r0/r017
gen rr_15 = r15/r1517
gen rr_65 = r65/r6517
gen rr_75 = r75/r7517
gen rr_85 = r85/r8517

* Heterogeneity in countries RR

set scheme s1manual

kdensity rr_0
kdensity rr_15
kdensity rr_65
kdensity rr_75
kdensity rr_85

sum rr_0 rr_15 rr_65 rr_75 rr_85

collapse (mean) rr_0=rr_0 rr_15=rr_15 rr_65=rr_65 rr_75=rr_75
rr85=rr_85
```

d. Python files simulating life tables. Norway female population as example.

```
"""
Peer 2020 Life Tables from 2017 qx*2020:2017RR and 2017 ax

@author: …

"""
#import packages
import random

# importing in the qx and error and ax
nor_f = r"/…/nor_f.txt"
# change as needed for input files

# read in the file
textFile = open(nor_f,'r')
text = textFile.readlines()
# split into different age categories
a0=text[1]
a1=text[2]
a5=text[3]
a10=text[4]
a15=text[5]
a20=text[6]

a25=text[7]
a30=text[8]
a35=text[9]
a40=text[10]
a45=text[11]
a50=text[12]
a55=text[13]
a60=text[14]
a65=text[15]
a70=text[16]
a75=text[17]
a80=text[18]
a85=text[19]
a90=text[20]
a95=text[21]
a100=text[22]
a105=text[23]
a110=text[24]
```

```
a0_sp = a0.split(",")
a1_sp = a1.split(",")
a5_sp = a5.split(",")
a10_sp = a10.split(",")
a15_sp = a15.split(",")
a20_sp = a20.split(",")
a25_sp = a25.split(",")
a30_sp = a30.split(",")
a35_sp = a35.split(",")
a40_sp = a40.split(",")
a45_sp = a45.split(",")
a50_sp = a50.split(",")
a55_sp = a55.split(",")
a60_sp = a60.split(",")
a65_sp = a65.split(",")
a70_sp = a70.split(",")
a75_sp = a75.split(",")
a80_sp = a80.split(",")
a85_sp = a85.split(",")
a90_sp = a90.split(",")
a95_sp = a95.split(",")
a100_sp = a100.split(",")
a105_sp = a105.split(",")
a110_sp = a110.split(",")

# qx
a0_qx = float(a0_sp[1])
a1_qx = float(a1_sp[1])
a5_qx = float(a5_sp[1])
a10_qx = float(a10_sp[1])
a15_qx = float(a15_sp[1])
a20_qx = float(a20_sp[1])
a25_qx = float(a25_sp[1])
a30_qx = float(a30_sp[1])
a35_qx = float(a35_sp[1])
a40_qx = float(a40_sp[1])
a45_qx = float(a45_sp[1])
a50_qx = float(a50_sp[1])
a55_qx = float(a55_sp[1])
a60_qx = float(a60_sp[1])
a65_qx = float(a65_sp[1])
a70_qx = float(a70_sp[1])
a75_qx = float(a75_sp[1])
```

```
a80_qx = float(a80_sp[1])
a85_qx = float(a85_sp[1])
a90_qx = float(a90_sp[1])
a95_qx = float(a95_sp[1])
a100_qx = float(a100_sp[1])
a105_qx = float(a105_sp[1])
a110_qx = float(a110_sp[1])

# qx - lower bound
a0_qxl = float(a0_sp[2])
a1_qxl = float(a1_sp[2])
a5_qxl = float(a5_sp[2])
a10_qxl = float(a10_sp[2])
a15_qxl = float(a15_sp[2])
a20_qxl = float(a20_sp[2])
a25_qxl = float(a25_sp[2])
a30_qxl = float(a30_sp[2])
a35_qxl = float(a35_sp[2])
a40_qxl = float(a40_sp[2])
a45_qxl = float(a45_sp[2])
a50_qxl = float(a50_sp[2])
a55_qxl = float(a55_sp[2])
a60_qxl = float(a60_sp[2])
a65_qxl = float(a65_sp[2])
a70_qxl = float(a70_sp[2])
a75_qxl = float(a75_sp[2])
a80_qxl = float(a80_sp[2])
a85_qxl = float(a85_sp[2])
a90_qxl = float(a90_sp[2])
a95_qxl = float(a95_sp[2])
a100_qxl = float(a100_sp[2])
a105_qxl = float(a105_sp[2])
a110_qxl = float(a110_sp[2])
# qx - Upper bound
a0_qxu = float(a0_sp[3])
a1_qxu = float(a1_sp[3])
a5_qxu = float(a5_sp[3])
a10_qxu = float(a10_sp[3])
a15_qxu = float(a15_sp[3])
a20_qxu = float(a20_sp[3])
a25_qxu = float(a25_sp[3])
a30_qxu = float(a30_sp[3])
a35_qxu = float(a35_sp[3])
a40_qxu = float(a40_sp[3])
```

```
a45_qxu = float(a45_sp[3])
a50_qxu = float(a50_sp[3])
a55_qxu = float(a55_sp[3])
a60_qxu = float(a60_sp[3])
a65_qxu = float(a65_sp[3])
a70_qxu = float(a70_sp[3])
a75_qxu = float(a75_sp[3])
a80_qxu = float(a80_sp[3])
a85_qxu = float(a85_sp[3])
a90_qxu = float(a90_sp[3])
a95_qxu = float(a95_sp[3])
a100_qxu = float(a100_sp[3])
a105_qxu = float(a105_sp[3])
a110_qxu = float(a110_sp[3])

# ax
a0_ax = float(a0_sp[4])
a1_ax = float(a1_sp[4])
a5_ax = float(a5_sp[4])
a10_ax = float(a10_sp[4])
a15_ax = float(a15_sp[4])
a20_ax = float(a20_sp[4])
a25_ax = float(a25_sp[4])
a30_ax = float(a30_sp[4])
a35_ax = float(a35_sp[4])
a40_ax = float(a40_sp[4])
a45_ax = float(a45_sp[4])
a50_ax = float(a50_sp[4])
a55_ax = float(a55_sp[4])
a60_ax = float(a60_sp[4])
a65_ax = float(a65_sp[4])
a70_ax = float(a70_sp[4])
a75_ax = float(a75_sp[4])
a80_ax = float(a80_sp[4])
a85_ax = float(a85_sp[4])
a90_ax = float(a90_sp[4])
a95_ax = float(a95_sp[4])
a100_ax = float(a100_sp[4])
a105_ax = float(a105_sp[4])
a110_ax = float(a110_sp[4])



count = 0
```

```
while count < 50000: #5000: #50000

    a0_rand_qx = random.uniform(a0_qxl,a0_qxu)
    a1_rand_qx = random.uniform(a1_qxl,a1_qxu)
    a5_rand_qx = random.uniform(a5_qxl,a5_qxu)
    a10_rand_qx = random.uniform(a10_qxl,a10_qxu)
    a15_rand_qx = random.uniform(a15_qxl,a15_qxu)
    a20_rand_qx = random.uniform(a20_qxl,a20_qxu)
    a25_rand_qx = random.uniform(a25_qxl,a25_qxu)
    a30_rand_qx = random.uniform(a30_qxl,a30_qxu)
    a35_rand_qx = random.uniform(a35_qxl,a35_qxu)
    a40_rand_qx = random.uniform(a40_qxl,a40_qxu)
    a45_rand_qx = random.uniform(a45_qxl,a45_qxu)
    a50_rand_qx = random.uniform(a50_qxl,a50_qxu)
    a55_rand_qx = random.uniform(a55_qxl,a55_qxu)
    a60_rand_qx = random.uniform(a60_qxl,a60_qxu)
    a65_rand_qx = random.uniform(a65_qxl,a65_qxu)
    a70_rand_qx = random.uniform(a70_qxl,a70_qxu)
    a75_rand_qx = random.uniform(a75_qxl,a75_qxu)
    a80_rand_qx = random.uniform(a80_qxl,a80_qxu)
    a85_rand_qx = random.uniform(a85_qxl,a85_qxu)
    a90_rand_qx = random.uniform(a90_qxl,a90_qxu)
    a95_rand_qx = random.uniform(a95_qxl,a95_qxu)
    a100_rand_qx = random.uniform(a100_qxl,a100_qxu)
    a105_rand_qx = random.uniform(a105_qxl,a105_qxu)
    a110_rand_qx = 1

    # without randomization
#    a0_rand_qx = a0_qx
#    a1_rand_qx = a1_qx
#    a5_rand_qx = a5_qx
#    a10_rand_qx = a10_qx
#    a15_rand_qx = a15_qx
#    a20_rand_qx = a20_qx
#    a25_rand_qx = a25_qx
#    a30_rand_qx = a30_qx
#    a35_rand_qx = a35_qx
#    a40_rand_qx = a40_qx
#    a45_rand_qx = a45_qx
#    a50_rand_qx = a50_qx
#    a55_rand_qx = a55_qx
#    a60_rand_qx = a60_qx
#    a65_rand_qx = a65_qx
#    a70_rand_qx = a70_qx
```

```
#    a75_rand_qx = a75_qx
#    a80_rand_qx = a80_qx
#    a85_rand_qx = a85_qx
#    a90_rand_qx = a90_qx
#    a95_rand_qx = a95_qx
#    a100_rand_qx = a100_qx
#    a105_rand_qx = a105_qx
#    a110_rand_qx = 1
#


### calculate life table variables
    radix = 1000000.0000000

    # calculate the number of deaths age0
    a0_dx = a0_rand_qx*radix
    # calculate survivors
    a0_lx=radix
    a0_sx=a0_lx/radix # this is 1?
    a1_lx=(radix-a0_dx)
    a1_sx = a1_lx/radix

    # calculate the number of deaths age1
    a1_dx = a1_rand_qx*a1_lx
    # calculate survivors
    a5_lx=(a1_lx-a1_dx)
    a5_sx = a5_lx/radix

    # calculate the number of deaths age5
    a5_dx = a5_rand_qx*a5_lx
    # calculate survivors
    a10_lx=(a5_lx-a5_dx)
    a10_sx = a10_lx/radix

    # calculate the number of deaths age10
    a10_dx = a10_rand_qx*a10_lx
    # calculate survivors
    a15_lx=(a10_lx-a10_dx)
    a15_sx = a15_lx/radix

    # calculate the number of deaths age15
    a15_dx = a15_rand_qx*a15_lx
    # calculate survivors
    a20_lx=(a15_lx-a15_dx)
```

```
a20_sx = a20_lx/radix

# calculate the number of deaths age20
a20_dx = a20_rand_qx*a20_lx
# calculate survivors
a25_lx=(a20_lx-a20_dx)
a25_sx = a25_lx/radix

# calculate the number of deaths age25
a25_dx = a25_rand_qx*a25_lx
# calculate survivors
a30_lx=(a25_lx-a25_dx)
a30_sx = a30_lx/radix

# calculate the number of deaths age30
a30_dx = a30_rand_qx*a30_lx
# calculate survivors
a35_lx=(a30_lx-a30_dx)
a35_sx = a35_lx/radix

# calculate the number of deaths age35
a35_dx = a35_rand_qx*a35_lx
# calculate survivors
a40_lx=(a35_lx-a35_dx)
a40_sx = a40_lx/radix

# calculate the number of deaths age40
a40_dx = a40_rand_qx*a40_lx
# calculate survivors
a45_lx=(a40_lx-a40_dx)
a45_sx = a45_lx/radix

# calculate the number of deaths age45
a45_dx = a45_rand_qx*a45_lx
# calculate survivors
a50_lx=(a45_lx-a45_dx)
a50_sx = a50_lx/radix

# calculate the number of deaths age50
a50_dx = a50_rand_qx*a50_lx
# calculate survivors
a55_lx=(a50_lx-a50_dx)
a55_sx = a55_lx/radix
```

```
# calculate the number of deaths age55
a55_dx = a55_rand_qx*a55_lx
# calculate survivors
a60_lx=(a55_lx-a55_dx)
a60_sx = a60_lx/radix

# calculate the number of deaths age60
a60_dx = a60_rand_qx*a60_lx
# calculate survivors
a65_lx=(a60_lx-a60_dx)
a65_sx = a65_lx/radix

# calculate the number of deaths age65
a65_dx = a65_rand_qx*a65_lx
# calculate survivors
a70_lx=(a65_lx-a65_dx)
a70_sx = a70_lx/radix

# calculate the number of deaths age70
a70_dx = a70_rand_qx*a70_lx
# calculate survivors
a75_lx=(a70_lx-a70_dx)
a75_sx = a75_lx/radix

# calculate the number of deaths age75
a75_dx = a75_rand_qx*a75_lx
# calculate survivors
a80_lx=(a75_lx-a75_dx)
a80_sx = a80_lx/radix

# calculate the number of deaths age80
a80_dx = a80_rand_qx*a80_lx
# calculate survivors
a85_lx=(a80_lx-a80_dx)
a85_sx = a85_lx/radix

# calculate the number of deaths age85
a85_dx = a85_rand_qx*a85_lx
# calculate survivors
a90_lx=(a85_lx-a85_dx)
a90_sx = a90_lx/radix

# calculate the number of deaths age90
a90_dx = a90_rand_qx*a90_lx
```

```
# calculate survivors
a95_lx=(a90_lx-a90_dx)
a95_sx = a95_lx/radix

# calculate the number of deaths age95
a95_dx = a95_rand_qx*a95_lx
# calculate survivors
a100_lx=(a95_lx-a95_dx)
a100_sx = a100_lx/radix

# calculate the number of deaths age100
a100_dx = a100_rand_qx*a100_lx
# calculate survivors
a105_lx=(a100_lx-a100_dx)
a105_sx = a105_lx/radix

# calculate the number of deaths age105
a105_dx = a105_rand_qx*a105_lx
# calculate survivors
a110_lx=(a105_lx-a105_dx)
a110_sx = a110_lx/radix

# calculate the number of deaths age110
a110_dx = a110_rand_qx*a110_lx
# No Survivors - top-coded

#calculate Lx
a0_Lx = (a1_lx*1)+(a0_dx*a0_ax)
a1_Lx = (a5_lx*4)+(a1_dx*a1_ax)
a5_Lx = (a10_lx*5)+(a5_dx*a5_ax)
a10_Lx = (a15_lx*5)+(a10_dx*a10_ax)
a15_Lx = (a20_lx*5)+(a15_dx*a15_ax)
a20_Lx = (a25_lx*5)+(a20_dx*a20_ax)
a25_Lx = (a30_lx*5)+(a25_dx*a25_ax)
a30_Lx = (a35_lx*5)+(a30_dx*a30_ax)
a35_Lx = (a40_lx*5)+(a35_dx*a35_ax)
a40_Lx = (a45_lx*5)+(a40_dx*a40_ax)
a45_Lx = (a50_lx*5)+(a45_dx*a45_ax)
a50_Lx = (a55_lx*5)+(a50_dx*a50_ax)
a55_Lx = (a60_lx*5)+(a55_dx*a55_ax)
a60_Lx = (a65_lx*5)+(a60_dx*a60_ax)
a65_Lx = (a70_lx*5)+(a65_dx*a65_ax)
a70_Lx = (a75_lx*5)+(a70_dx*a70_ax)
a75_Lx = (a80_lx*5)+(a75_dx*a75_ax)
```

```
a80_Lx = (a85_lx*5)+(a80_dx*a80_ax)
a85_Lx = (a90_lx*5)+(a85_dx*a85_ax)
a90_Lx = (a95_lx*5)+(a90_dx*a90_ax)
a95_Lx = (a100_lx*5)+(a95_dx*a95_ax)
a100_Lx = (a105_lx*5)+(a100_dx*a100_ax)
a105_Lx = (a110_lx*5)+(a105_dx*a105_ax)
a110_Lx = (a110_dx*a110_ax)

####
# calculate Tx
a0_Tx =
a0_Lx+a1_Lx+a5_Lx+a10_Lx+a15_Lx+a20_Lx+a25_Lx+a30_Lx+a35_Lx+a40_Lx+a45_Lx+a50_Lx+
a55_Lx+a60_Lx+a65_Lx+a70_Lx+a75_Lx+a80_Lx+a85_Lx+a90_Lx+a95_Lx+a100_Lx+a105_Lx+a1
10_Lx
a1_Tx =
a1_Lx+a5_Lx+a10_Lx+a15_Lx+a20_Lx+a25_Lx+a30_Lx+a35_Lx+a40_Lx+a45_Lx+a50_Lx+a55_Lx
+a60_Lx+a65_Lx+a70_Lx+a75_Lx+a80_Lx+a85_Lx+a90_Lx+a95_Lx+a100_Lx+a105_Lx+a110_Lx
a5_Tx =
a5_Lx+a10_Lx+a15_Lx+a20_Lx+a25_Lx+a30_Lx+a35_Lx+a40_Lx+a45_Lx+a50_Lx+a55_Lx+a60_L
x+a65_Lx+a70_Lx+a75_Lx+a80_Lx+a85_Lx+a90_Lx+a95_Lx+a100_Lx+a105_Lx+a110_Lx
a10_Tx =
a10_Lx+a15_Lx+a20_Lx+a25_Lx+a30_Lx+a35_Lx+a40_Lx+a45_Lx+a50_Lx+a55_Lx+a60_Lx+a65_
Lx+a70_Lx+a75_Lx+a80_Lx+a85_Lx+a90_Lx+a95_Lx+a100_Lx+a105_Lx+a110_Lx
a15_Tx =
a15_Lx+a20_Lx+a25_Lx+a30_Lx+a35_Lx+a40_Lx+a45_Lx+a50_Lx+a55_Lx+a60_Lx+a65_Lx+a70_
Lx+a75_Lx+a80_Lx+a85_Lx+a90_Lx+a95_Lx+a100_Lx+a105_Lx+a110_Lx
a20_Tx =
a20_Lx+a25_Lx+a30_Lx+a35_Lx+a40_Lx+a45_Lx+a50_Lx+a55_Lx+a60_Lx+a65_Lx+a70_Lx+a75_
Lx+a80_Lx+a85_Lx+a90_Lx+a95_Lx+a100_Lx+a105_Lx+a110_Lx
a25_Tx =
a25_Lx+a30_Lx+a35_Lx+a40_Lx+a45_Lx+a50_Lx+a55_Lx+a60_Lx+a65_Lx+a70_Lx+a75_Lx+a80_
Lx+a85_Lx+a90_Lx+a95_Lx+a100_Lx+a105_Lx+a110_Lx
a30_Tx =
a30_Lx+a35_Lx+a40_Lx+a45_Lx+a50_Lx+a55_Lx+a60_Lx+a65_Lx+a70_Lx+a75_Lx+a80_Lx+a85_
Lx+a90_Lx+a95_Lx+a100_Lx+a105_Lx+a110_Lx
a35_Tx =
a35_Lx+a40_Lx+a45_Lx+a50_Lx+a55_Lx+a60_Lx+a65_Lx+a70_Lx+a75_Lx+a80_Lx+a85_Lx+a90_
Lx+a95_Lx+a100_Lx+a105_Lx+a110_Lx
a40_Tx =
a40_Lx+a45_Lx+a50_Lx+a55_Lx+a60_Lx+a65_Lx+a70_Lx+a75_Lx+a80_Lx+a85_Lx+a90_Lx+a95_
Lx+a100_Lx+a105_Lx+a110_Lx
a45_Tx =
a45_Lx+a50_Lx+a55_Lx+a60_Lx+a65_Lx+a70_Lx+a75_Lx+a80_Lx+a85_Lx+a90_Lx+a95_Lx+a100
_Lx+a105_Lx+a110_Lx
```

```
a50_Tx =
a50_Lx+a55_Lx+a60_Lx+a65_Lx+a70_Lx+a75_Lx+a80_Lx+a85_Lx+a90_Lx+a95_Lx+a100_Lx+a10
5_Lx+a110_Lx
  a55_Tx =
a55_Lx+a60_Lx+a65_Lx+a70_Lx+a75_Lx+a80_Lx+a85_Lx+a90_Lx+a95_Lx+a100_Lx+a105_Lx+a1
10_Lx
  a60_Tx =
a60_Lx+a65_Lx+a70_Lx+a75_Lx+a80_Lx+a85_Lx+a90_Lx+a95_Lx+a100_Lx+a105_Lx+a110_Lx
  a65_Tx =
a65_Lx+a70_Lx+a75_Lx+a80_Lx+a85_Lx+a90_Lx+a95_Lx+a100_Lx+a105_Lx+a110_Lx
  a70_Tx = a70_Lx+a75_Lx+a80_Lx+a85_Lx+a90_Lx+a95_Lx+a100_Lx+a105_Lx+a110_Lx
  a75_Tx = a75_Lx+a80_Lx+a85_Lx+a90_Lx+a95_Lx+a100_Lx+a105_Lx+a110_Lx
  a80_Tx = a80_Lx+a85_Lx+a90_Lx+a95_Lx+a100_Lx+a105_Lx+a110_Lx
  a85_Tx = a85_Lx+a90_Lx+a95_Lx+a100_Lx+a105_Lx+a110_Lx
  a90_Tx = a90_Lx+a95_Lx+a100_Lx+a105_Lx+a110_Lx
  a95_Tx = a95_Lx+a100_Lx+a105_Lx+a110_Lx
  a100_Tx = a100_Lx+a105_Lx+a110_Lx
  a105_Tx = a105_Lx+a110_Lx
  a110_Tx = a110_Lx

  ###### estimate qx: 15-64, 65-84, 85-99

  a1564_qx =
(a15_dx+a20_dx+a25_dx+a30_dx+a35_dx+a40_dx+a45_dx+a50_dx+a55_dx+a60_dx)/a15_lx
  a6584_qx = (a65_dx+a70_dx+a75_dx+a80_dx)/a65_lx
  a8599_qx = (a85_dx+a90_dx+a95_dx)/a85_lx


  ###### estimate life expectancy

  a0_ex = a0_Tx/radix
  a1_ex = a1_Tx/a1_lx
  a5_ex = a5_Tx/a5_lx
  a10_ex = a10_Tx/a10_lx
  a15_ex = a15_Tx/a15_lx
  a20_ex = a20_Tx/a20_lx
  a25_ex = a25_Tx/a25_lx
  a30_ex = a30_Tx/a30_lx
  a35_ex = a35_Tx/a35_lx
  a40_ex = a40_Tx/a40_lx
  a45_ex = a45_Tx/a45_lx
  a50_ex = a50_Tx/a50_lx
  a55_ex = a55_Tx/a55_lx
  a60_ex = a60_Tx/a60_lx
```

```
    a65_ex = a65_Tx/a65_lx
    a70_ex = a70_Tx/a70_lx
    a75_ex = a75_Tx/a75_lx
    a80_ex = a80_Tx/a80_lx
    a85_ex = a85_Tx/a85_lx
    a90_ex = a90_Tx/a90_lx
    a95_ex = a95_Tx/a95_lx
    a100_ex = a100_Tx/a100_lx
    a105_ex = a105_Tx/a105_lx
    a110_ex = a110_Tx/a110_lx

# this outputs the probabilities of each estimate as a check
    nor_f_filenm = r"/…/nor_f_qx.txt"
    opened_file = open(nor_f_filenm, 'a')

    if count==0:
        opened_file.write('{0} {1} {2} {3}\n'.format("sim_num","qx1564","qx6584","qx8599"))

    else:
        opened_file.write('{0} {1} {2} {3}\n'.format(count,a1564_qx,a6584_qx,a8599_qx))

    # save data

    tot_file_name = r"/…/nor_f_ex.txt"
#   file_name = r"C:\… .txt"
    tot_opened_file = open(tot_file_name, 'a')
    #opened_file.write("%r\n" %age45_ex_total)
    if count==0:
        tot_opened_file.write('{0} {1} {2} {3}\n'.format("sim_num","age","sx", "ex"))
        tot_opened_file.write('{0} {1} {2} {3}\n'.format(count,"0",a0_sx,a0_ex))
        tot_opened_file.write('{0} {1} {2} {3}\n'.format(count,"1",a1_sx,a1_ex))
        tot_opened_file.write('{0} {1} {2} {3}\n'.format(count,"5",a5_sx,a5_ex))
        tot_opened_file.write('{0} {1} {2} {3}\n'.format(count,"10",a10_sx,a10_ex))
        tot_opened_file.write('{0} {1} {2} {3}\n'.format(count,"15",a15_sx,a15_ex))
        tot_opened_file.write('{0} {1} {2} {3}\n'.format(count,"20",a20_sx,a20_ex))
        tot_opened_file.write('{0} {1} {2} {3}\n'.format(count,"25",a25_sx,a25_ex))
        tot_opened_file.write('{0} {1} {2} {3}\n'.format(count,"30",a30_sx,a30_ex))
        tot_opened_file.write('{0} {1} {2} {3}\n'.format(count,"35",a35_sx,a35_ex))
        tot_opened_file.write('{0} {1} {2} {3}\n'.format(count,"40",a40_sx,a40_ex))
        tot_opened_file.write('{0} {1} {2} {3}\n'.format(count,"45",a45_sx,a45_ex))
        tot_opened_file.write('{0} {1} {2} {3}\n'.format(count,"50",a50_sx,a50_ex))
        tot_opened_file.write('{0} {1} {2} {3}\n'.format(count,"55",a55_sx,a55_ex))
        tot_opened_file.write('{0} {1} {2} {3}\n'.format(count,"60",a60_sx,a60_ex))
        tot_opened_file.write('{0} {1} {2} {3}\n'.format(count,"65",a65_sx,a65_ex))
```

```
            tot_opened_file.write('{0} {1} {2} {3}\n'.format(count,"70",a70_sx,a70_ex))
            tot_opened_file.write('{0} {1} {2} {3}\n'.format(count,"75",a75_sx,a75_ex))
            tot_opened_file.write('{0} {1} {2} {3}\n'.format(count,"80",a80_sx,a80_ex))
            tot_opened_file.write('{0} {1} {2} {3}\n'.format(count,"85",a85_sx,a85_ex))
            tot_opened_file.write('{0} {1} {2} {3}\n'.format(count,"90",a90_sx,a90_ex))
            tot_opened_file.write('{0} {1} {2} {3}\n'.format(count,"95",a95_sx,a95_ex))
            tot_opened_file.write('{0} {1} {2} {3}\n'.format(count,"100",a100_sx,a100_ex))
            tot_opened_file.write('{0} {1} {2} {3}\n'.format(count,"105",a105_sx,a105_ex))
            tot_opened_file.write('{0} {1} {2} {3}\n'.format(count,"110",a110_sx,a110_ex))

        else:
            tot_opened_file.write('{0} {1} {2} {3}\n'.format(count,"0",a0_sx,a0_ex))
            tot_opened_file.write('{0} {1} {2} {3}\n'.format(count,"1",a1_sx,a1_ex))
            tot_opened_file.write('{0} {1} {2} {3}\n'.format(count,"5",a5_sx,a5_ex))
            tot_opened_file.write('{0} {1} {2} {3}\n'.format(count,"10",a10_sx,a10_ex))
            tot_opened_file.write('{0} {1} {2} {3}\n'.format(count,"15",a15_sx,a15_ex))
            tot_opened_file.write('{0} {1} {2} {3}\n'.format(count,"20",a20_sx,a20_ex))
            tot_opened_file.write('{0} {1} {2} {3}\n'.format(count,"25",a25_sx,a25_ex))
            tot_opened_file.write('{0} {1} {2} {3}\n'.format(count,"30",a30_sx,a30_ex))
            tot_opened_file.write('{0} {1} {2} {3}\n'.format(count,"35",a35_sx,a35_ex))
            tot_opened_file.write('{0} {1} {2} {3}\n'.format(count,"40",a40_sx,a40_ex))
            tot_opened_file.write('{0} {1} {2} {3}\n'.format(count,"45",a45_sx,a45_ex))
            tot_opened_file.write('{0} {1} {2} {3}\n'.format(count,"50",a50_sx,a50_ex))
            tot_opened_file.write('{0} {1} {2} {3}\n'.format(count,"55",a55_sx,a55_ex))
            tot_opened_file.write('{0} {1} {2} {3}\n'.format(count,"60",a60_sx,a60_ex))
            tot_opened_file.write('{0} {1} {2} {3}\n'.format(count,"65",a65_sx,a65_ex))
            tot_opened_file.write('{0} {1} {2} {3}\n'.format(count,"70",a70_sx,a70_ex))
            tot_opened_file.write('{0} {1} {2} {3}\n'.format(count,"75",a75_sx,a75_ex))
            tot_opened_file.write('{0} {1} {2} {3}\n'.format(count,"80",a80_sx,a80_ex))
            tot_opened_file.write('{0} {1} {2} {3}\n'.format(count,"85",a85_sx,a85_ex))
            tot_opened_file.write('{0} {1} {2} {3}\n'.format(count,"90",a90_sx,a90_ex))
            tot_opened_file.write('{0} {1} {2} {3}\n'.format(count,"95",a95_sx,a95_ex))
            tot_opened_file.write('{0} {1} {2} {3}\n'.format(count,"100",a100_sx,a100_ex))
            tot_opened_file.write('{0} {1} {2} {3}\n'.format(count,"105",a105_sx,a105_ex))
            tot_opened_file.write('{0} {1} {2} {3}\n'.format(count,"110",a110_sx,a110_ex))

        print(count)
        count += 1  # This is the same as count = count + 1

    tot_opened_file.close()
    opened_file.close()
    print("simulation completed")
```

e. Stata files estimating life expectancy distributions from simulated life tables. Peer female populations as examples.

```
* Input Simulation Results into Stata

* Austria, Female

import delimited "/.../aut_f_ex.txt", delimiter(space) encoding(ISO-8859-1) clear

gen country="Austria"

keep if age==0 | age==25 | age==65
drop sx

save "/.../aut_f.dta", replace



* Belgium, Female

import delimited "/.../bel_f_ex.txt", delimiter(space) encoding(ISO-8859-1) clear

gen country="Belgium"

keep if age==0 | age==25 | age==65
drop sx

save "/.../bel_f.dta", replace


* Denmark, Female

import delimited "/.../den_f_ex.txt", delimiter(space) encoding(ISO-8859-1) clear

gen country="Denmark"

keep if age==0 | age==25 | age==65
drop sx

save "/.../den_f.dta", replace


* Finland, Female

import delimited "/.../fin_f_ex.txt", delimiter(space) encoding(ISO-8859-1) clear
```

```
gen country="Finland"

keep if age==0 | age==25 | age==65
drop sx

save "/.../fin_f.dta", replace


* England, Female

import delimited "/.../engw_f_ex.txt", delimiter(space) encoding(ISO-
8859-1) clear

gen country="England & Wales"

keep if age==0 | age==25 | age==65
drop sx

save "/.../engw_f.dta", replace


* Spain, Female

import delimited "/.../esp_f_ex.txt", delimiter(space) encoding(ISO-
8859-1) clear

gen country="Spain"

keep if age==0 | age==25 | age==65
drop sx

save "/.../esp_f.dta", replace


* France, Female

import delimited "/.../fra_f_ex.txt", delimiter(space) encoding(ISO-
8859-1) clear

gen country="France"

keep if age==0 | age==25 | age==65
drop sx

save "/.../fra_f.dta", replace


* Germany, Female

import delimited "/.../ger_f_ex.txt", delimiter(space) encoding(ISO-
8859-1) clear
```

```
gen country="Germany"

keep if age==0 | age==25 | age==65
drop sx

save "/.../ger_f.dta", replace


* Israel, Female

import delimited "/.../isr_f_ex.txt", delimiter(space) encoding(ISO-
8859-1) clear

gen country="Israel"

keep if age==0 | age==25 | age==65
drop sx

save "/.../isr_f.dta", replace


* Italy, Female

import delimited "/.../ita_f_ex.txt", delimiter(space) encoding(ISO-
8859-1) clear

gen country="Italy"

keep if age==0 | age==25 | age==65
drop sx

save "/.../ita_f.dta", replace


* S Korea, Female

import delimited "/.../kor_f_ex.txt", delimiter(space) encoding(ISO-
8859-1) clear

gen country="Korea"

keep if age==0 | age==25 | age==65
drop sx

save "/.../kor_f.dta", replace


* Northern Ireland, Female

import delimited "/.../nir_f_ex.txt", delimiter(space) encoding(ISO-
8859-1) clear
```

```
gen country="Northern Ireland"

keep if age==0 | age==25 | age==65
drop sx

save "/.../nir_f.dta", replace


* Netherlands, Female

import delimited "/.../nld_f_ex.txt", delimiter(space) encoding(ISO-
8859-1) clear

gen country="Netherlands"

keep if age==0 | age==25 | age==65
drop sx

save "/.../nld_f.dta", replace


* Norway, Female

import delimited "/.../nor_f_ex.txt", delimiter(space) encoding(ISO-
8859-1) clear

gen country="Norway"

keep if age==0 | age==25 | age==65
drop sx

save "/.../nor_f.dta", replace


* Portugal, Female

import delimited "/.../por_f_ex.txt", delimiter(space) encoding(ISO-
8859-1) clear

gen country="Portugal"

keep if age==0 | age==25 | age==65
drop sx

save "/.../por_f.dta", replace


* Scotland, Female

import delimited "/.../sco_f_ex.txt", delimiter(space) encoding(ISO-
8859-1) clear
```

```
gen country="Scotland"

keep if age==0 | age==25 | age==65
drop sx

save "/.../sco_f.dta", replace


* Sweden, Female

import delimited "/.../swe_f_ex.txt", delimiter(space) encoding(ISO-
8859-1) clear

gen country="Sweden"

keep if age==0 | age==25 | age==65
drop sx

save "/.../swe_f.dta", replace


* Switzerland, Female

import delimited "/.../swz_f_ex.txt", delimiter(space) encoding(ISO-
8859-1) clear

gen country="Switzerland"

keep if age==0 | age==25 | age==65
drop sx

save "/.../swz_f.dta", replace


* Taiwan, Female

import delimited "/.../twn_f_ex.txt", delimiter(space) encoding(ISO-
8859-1) clear

gen country="Taiwan"

keep if age==0 | age==25 | age==65
drop sx

save "/.../twn_f.dta", replace


* New Zealand, Female

import delimited "/.../nz_f_ex.txt", delimiter(space) encoding(ISO-
8859-1) clear
```

```
gen country="New Zealand"

keep if age==0 | age==25 | age==65
drop sx

save "/.../nz_f.dta", replace



*******************************************************************
******************** Append all Countries *********************
***** Distributions of Sim LE at birth for 20 peer countries *****
*******************************************************************

use "/.../aut_f.dta", clear

append using "/.../bel_f.dta"

append using "/.../den_f.dta"

append using "/.../fin_f.dta"

append using "/.../engw_f.dta"

append using "/.../esp_f.dta"

append using "/.../fra_f.dta"

append using "/.../ger_f.dta"

append using "/.../isr_f.dta"

append using "/.../ita_f.dta"

append using "/.../kor_f.dta"

append using "/.../nir_f.dta"

append using "/.../nld_f.dta"

append using "/.../nor_f.dta"

append using "/.../por_f.dta"

append using "/.../sco_f.dta"

append using "/.../swe_f.dta"

append using "/.../swz_f.dta"

append using "/.../twn_f.dta"
```

```
append using "/.../nz_f.dta"

save "/.../female_2020ex_sim.dta", replace


tabstat ex if age==0, statistics( p5 p50 p95 ) by(country)
tabstat ex if age==25, statistics( p5 p50 p95 ) by(country)
tabstat ex if age==65, statistics( p5 p50 p95 ) by(country)


bysort country: egen med_ex = median(ex) if age==0
bysort country: egen med_ex25 = median(ex) if age==25
bysort country: egen med_ex65 = median(ex) if age==65
sum med_ex med_ex25 med_ex65
```

REFERENCES

[1] Arias E. United States life tables, 2010. *National Vital Statistics Reports*; vol 63 no 7. Hyattsville, MD: National Center for Health Statistics. 2014.

[2] Arias E, Xu JQ. United States life tables, 2017. *National Vital Statistics Reports*; vol 68 no 7. Hyattsville, MD: National Center for Health Statistics. 2019.

[3] State of Israel. Complete Life Tables of Israel, 2013-2017 (website). Accessed February 23, 2021 at https://www.cbs.gov.il/en/publications/Pages/2019/Complete-Life-Tables-Of-Israel%20-%202013-2017.aspx#losExcelos

[4] New Zealand Government. New Zealand abridged period life table: 2016–18 (website). Accessed February 23, 2021 at https://www.stats.govt.nz/information-releases/new-zealand-abridged-period-life-table-201618-final

[5] HealthData.gov. AH Excess Deaths by Sex, Age, and Race (website). Updated March 7, 2021. Accessed March 11, 2021 at https://healthdata.gov/dataset/ah-excess-deaths-sex-age-and-race

[6] U.S. Census Bureau. Population and Housing Unit Estimate (website). Accessed February 16, 2021 at https://www.census.gov/programs-surveys/popest/data.html

[7] Arias E, Xu JQ. United States life tables, 2018. *National Vital Statistics Reports*; vol 69, no 12. Hyattsville, MD: National Center for Health Statistics. 2020.

[8] University of California, Berkeley and Max Planck Institute for Demographic Research. Human Mortality Database (website). Updated March 5, 2021. Accessed March 7, 2021 at https://www.mortality.org/ and https://usa.mortality.org/national.php?national=USA

[9] Preston S, Heuveline P, and Guillot, M. *Demography: Measuring and Modeling Population Processes*. Oxford: Blackwell Publishers. 2001