THE GERONTOLOGICAL SOCIETY OF AMERICA®

Journals of Gerontology: Social Sciences
cite as: *J Gerontol B Psychol Sci Soc Sci*, 2021, Vol. 76, No. 2, 319–329
doi:10.1093/geronb/gbz145
Advance Access publication November 11, 2019

OXFORD

Research Article

Increasing Education-Based Disparities in Healthy Life Expectancy Among U.S. Non-Hispanic Whites, 2000–2010

Phillip A. Cantu, MA,[1,2,*] Connor M. Sheehan, PhD,[3] Isaac Sasson, PhD,[4] and Mark D. Hayward, PhD[1]

[1]Department of Sociology and Population Research Center, University of Texas at Austin [2]Preventative Medicine and Population Health, University of Texas Medical Branch, Galveston [3]School of Social and Family Dynamics, Arizona State University, Tempe [4]Department of Sociology and Anthropology and the Herczeg Institute on Aging, Tel Aviv University, Israel

*Address correspondence to: Phillip Cantu, Department of Sociology and Population Research Center, University of Texas at Austin. Population Research Center, G1800, University of Texas at Austin, Austin, TX 78712-0544. E-mail: cantuphillip@utexas.edu

Received: October 9, 2018; Editorial Decision Date: October 25, 2019

Decision Editor: Deborah Carr, PhD

Abstract

Objectives: To examine changes in Healthy Life Expectancy (HLE) against the backdrop of rising mortality among less-educated white Americans during the first decade of the twenty-first century.

Methods: This study documented changes in HLE by education among U.S. non-Hispanic whites, using data from the U.S. Multiple Cause of Death public-use files, the Integrated Public Use Microdata Sample (IPUMS) of the 2000 Census and the 2010 American Community Survey, and the Health and Retirement Study (HRS). Changes in HLE were decomposed into contributions from: (i) change in age-specific mortality rates; and (ii) change in disability prevalence, measured via Activities of Daily Living (ADL) and Instrumental Activities of Daily Living (IADL).

Results: Between 2000 and 2010, HLE significantly decreased for white men and women with less than 12 years of schooling. In contrast, HLE increased among college-educated white men and women. Declines or stagnation in HLE among less-educated whites reflected increases in disability prevalence over the study period, whereas improvements among the college educated reflected decreases in both age-specific mortality rates and disability prevalence at older ages.

Discussion: Differences in HLE between education groups increased among non-Hispanic whites from 2000 to 2010. In fact, education-based differences in HLE were larger than differences in total life expectancy. Thus, the lives of less-educated whites were not only shorter, on average, compared with their college-educated counterparts, but they were also more burdened with disability.

Keywords: disability, education, healthy life expectancy, mortality

Adult life expectancy has declined since 1990 among less-educated white Americans, particularly among women (Case & Deaton, 2015; Kochanek, Arias, & Anderson, 2013; Kochanek, Arias, & Bastian, 2016; Masters, Hummer, & Powers, 2012; Olshansky et al., 2012; Sasson, 2016a; Sasson, 2016b). Sasson (2016a) reported that the period-based Total Life Expectancy (TLE) at age 25, the average number of years a person can expect to live if age-specific mortality rates remain constant throughout her remaining lifetime, decreased for non-Hispanic white women (hereafter white) with less than a high school education from 54.0 to 50.9 years between 1990 and 2010. Decreasing life expectancy among individuals with low levels of education marks a possible reversal in the long-term improvement in TLE which characterized much of the twentieth century (Fogel & Costa, 1997; Omran, 1971). In contrast, life expectancy increased substantially among college-educated whites during the same period. For example, TLE at age

25 increased among college-educated white women by 3.6 years between 1990 and 2010 (Sasson 2016b). These diverging secular trends resulted in widening educational disparities in life expectancy among whites. Whereas in 1990 TLE for the least- and most-educated white women differed by 2.5 years, by 2010, the difference had increased more than threefold, to 9.3 years. Among white men, the gap almost doubled, from 6.1 to 11.9 years (Sasson, 2016b).

While the recent divergence in TLE by education among whites is well-documented, it remains less clear whether those trends were paralleled by a similar educational divergence in Healthy Life Expectancy (HLE), or the expected number of years lived without disability. HLE is more sensitive than TLE in measuring the quality of life in the population (Jagger & Robine, 2011). In this study, both TLE and HLE are period-based measures, combining data from multiple birth cohorts at a single point in time to create a synthetic cohort (Rowland 2003:140). As such, they should not be interpreted as a forecast of the average number of years that a real cohort or individual can expect to live. Instead, these are summary measures intended to compare changes in population health over time. Prior research has shown that increases in TLE across the globe have been greater than increases in HLE (Crimmins & Beltrán-Sánchez, 2011; Crimmins, Zhang, & Saito, 2016; Jagger et al., 2008; Martin, Freedman, Schoeni, & Andreski, 2009). In other words, the added years of life are, on average, increasingly spent with disability. Although most studies have generally been focused on contexts of increasing TLE, here, we analyze a population in which certain segments have recently seen their TLE decrease (Sasson 2016a; Sasson 2016b).

Indeed, previous research on HLE trends has primarily examined trends under conditions of improving TLE, both in the United States (Freedman et al., 2013; Martin et al., 2009; Martin, Freedman, Schoeni, & Andreski, 2010) and internationally (Jagger et al., 2008; Mathers, Sadana, Salomon, Murray, & Lopez, 2001; Salomon et al., 2012, Yong & Saito, 2009). This study focuses on change in HLE in a context of widening educational disparities in TLE and, perhaps more importantly, declining TLE among the less educated. Change in HLE can be driven by both changes in age-specific mortality and changes in disability prevalence. For example, increasing TLE combined with increasing disability prevalence may result in a greater number of years spent with disability. In contrast, rising mortality could reduce the number of years spent with disability, even if there is no change in disability prevalence, thus reducing TLE while HLE stays constant. Therefore, a thorough analysis of educational disparities in HLE must include a decomposition of both sources of change—age-specific disability prevalence and age-specific mortality rates—in each education group.

To conduct this analysis, we used data from the U.S. Multiple Cause of Death public use files (Centers for Disease Control and Prevention 2013), the Integrated Public Use Microdata Sample (IPUMS) from the 2000 Census and the 2010 American Community Survey (Ruggles et al., 2019), and the Health and Retirement Study (HRS). For the white U.S. population aged 50–89, we construct period life tables by gender and educational attainment for 2000 and 2010. We analyzed only whites both because educational inequality in mortality is especially pronounced for whites (Sasson, 2016a) and because cell sizes in our data sources precluded analysis of other racial/ethnic groups. We decomposed changes in HLE into change in mortality rate and change in disability prevalence, by age group (50–69 and 70–89) in order to examine which education groups gained or lost healthy life years between 2000 and 2010 and at what ages.

Educational attainment is one of the most important factors in explaining trends in disability in the United States (Freedman & Martin, 1999), Japan (Schoeni et al., 2006), and Europe (Mäki et al., 2013; Pérez-Hernández, Rubio-Valverde, Nusselder, & Mackenbach, 2019; Picavet & Hoeymans, 2002). This is not surprising given the epidemiological transition. As causes of death shifted from communicable to chronic diseases, researchers have stressed that education is increasingly shaping one's risk of disability (Case & Deaton, 2015; Solé-Auró et al., 2015; Zajacova & Montez, 2017) and mortality, since chronic conditions are largely associated with lifestyle factors and highly educated people are better able to live healthy lifestyles (Hayward, Hummer, & Sasson, 2015; Sasson, 2016a, 2016a; Tsai, 2017). Education is generally attained early in the life course and shapes subsequent socioeconomic status, which is associated with mortality (Hummer & Lariscy, 2011), beneficial health behaviors (Hummer & Hernandez, 2013), and avoidance of the unhealthy "default American lifestyle" (Mirowsky & Ross, 2015), which may increase one's risk of becoming disabled. Indeed, recent research finds that higher educational attainment is associated with lower risk of disability and fewer years lived with disability than is lower educational attainment (Solé-Auró, Beltrán-Sánchez, & Crimmins, 2015). Other work has argued that educational attainment is so important that declining levels of disability in the U.S. population from 1997 to 2010 have been attributed to the expansion of education in American society (Martin & Schoeni, 2014).

The decrease in TLE among the less educated between 1990 and 2010 sparked a national conversation, resulting in narratives focused on "deaths of despair" and the opioid epidemic (Case & Deaton, 2015, 2017; Rudd, 2016; Stone et al., 2018). This line of inquiry identified that rising mortality rates were concentrated among middle-aged white Americans. Sasson (2016a) further concluded that, while mortality rates for less-educated white women had increased in every age group over 25, the gains in life expectancy for highly educated whites also occurred across the entire age range and were concentrated at older ages. Thus, identifying the age range in which mortality change occurs is critically important to understanding changes in TLE for each education group. Yet, much of the scholarly conversation was directed at rising mortality and declining life expectancy among less-educated white Americans, with limited attention to how those changes had affected trends and group differences in HLE.

Equally important is the context and meaning of education in the early twenty-first century. The highly educated are increasingly maximizing their life chances while those with low education are at greater risk of poor health and early mortality (Hayward et al., 2015). Indeed, the association between education and adult mortality has progressively shifted toward a combined credentialist-human capital model in which mortality reductions accrue with each additional year of schooling, but greater reductions are associated with high-school and college graduation. Although education confers both material and nonmaterial benefits, the shift toward credentialism partly reflects better employment opportunities and higher income for the highly educated, which result in greater health returns (Hayward et al 2015, Sheehan et al. 2018). In addition to longer TLE, the college-educated whites also exhibit greater compression of mortality compared with their less-educated counterparts (Brown et al., 2012), suggesting greater ability to delay biological aging processes. Montez (2019) and colleagues found that, in the U.S. states where educational disparities grew in the early twenty-first century relative to the late twentieth century, this gap occurred through either a combination of decreased mortality for the high-educated and increased mortality for the low-educated, or declines in mortality for both (but more so for the high-educated). During the same period, education-based mortality inequalities increased across Europe (Mackenbach et al., 2018). In Western Europe, this increase was attributed to greater mortality decline among the highly educated. In Eastern Europe, mortality decreased for the highly educated but increased for the low educated. In sum, studies across multiple high-income countries have found that in the beginning of twenty-first century, mortality improvements were greater, and often limited to, highly educated individuals.

Research examining the relationship between changes in U.S. TLE and HLE by educational attainment and gender has a rich history. Crimmins and Saito (2001) reviewed the trends in HLE for 1970–1990 for persons aged 30 years and older, noting that educational differences in healthy (disability-free) life expectancy were even greater than differences in TLE. Over the 20-year period they analyzed, educational differences in HLE increased because of increasing educational disparities in both mortality and disability (Crimmins & Saito, 2001, p. 1631). Less-educated Americans generally experienced losses or relatively stagnant HLE over the 20-year period, and their TLE improvement was relatively small. Of course, Crimmins and Saito's seminal study was conducted in a period of increasing TLE, and given the recent findings of decreasing life expectancy for whites (e.g., Sasson, 2016b), it is critically important to update these trends.

As in other high-income countries, HLE at age 65 for the U.S. population as a whole increased in the last decade of the twentieth century, owing to decreases in disabled life expectancy and increases in disability-free life expectancy (Cai & Lubitz, 2007; Crimmins & Beltrán-Sánchez, 2011; Jeune & Brønnum-Hansen, 2008; Mathers et al., 2001). Solé-Auró and colleagues (2015) evaluated educational differences in HLE between 1990 and 2000, expanding the evidence on trends in educational inequality in HLE in the latter part of the twentieth century. Their results showed that white men with less than a high school education had decreases in HLE, whereas those with at least a high school education had increases, widening the educational disparity in white men's disability-free life expectancy over the decade. White women's educational gap was stable in the 1990s, because HLE declined at all levels of education. However, it remains unclear whether these period-based patterns have changed from 2000 to 2010.

To summarize, previous research has shown mixed results with respect to trends in HLE by education and gender in the United States. Between 1970 and 1990, educational disparities in HLE generally expanded, owing to greater gains among better-educated persons. During the 1990s, educational disparities continued to widen among white men, driven by substantial losses in HLE for less-educated men and gains in HLE for better-educated men. However, the 1990s were also characterized by stable or modestly declining educational disparities for white women, driven by declines in women's HLE across all education groups. For less-educated whites, it is clear that HLE did not improve, but rather declined between 1970 and 2000. Worsening health among the less-educated appears to be a long-term trend in the United States. We contribute to this line of research by documenting HLE and TLE by education, gender, and age-group for whites from 2000 to 2010, a period of unprecedented divergence in TLE by education and a period in which trends in HLE educational disparities among American whites have heretofore not been documented.

Method

Data

The data for this investigation came from three sources: the U.S. Multiple Cause of Death public use files (Centers for Disease Control and Prevention 2013), the IPUMS from the 2000 Census and the 2010 American Community Survey (Ruggles et al., 2019), and the HRS. The IPUMS is a 5% sample of the 2000 U.S. Census data; the American Community Survey, which replaced the census long form in 2010, is a 1% sample of all U.S. households. We derived age-specific mortality rates in 5-year intervals, from ages 50–54 to 85–89, from the U.S. Multiple Cause of Death public use files and the IPUMS data for the years 2000 and 2010. Detailed documentation of mortality estimation for each gender and education group is available elsewhere (Sasson, 2016b).

The HRS is a multiwave, multicohort longitudinal analysis of middle-aged and elderly U.S. adults, updated biannually since 1992. We used the 2000 and 2010 HRS waves. The HRS implemented a cohort-based design that allows period-based estimation. The 2000 HRS sample combined multiple cohorts: Asset and Health Dynamics Among the Oldest of Old (born before 1924), Children of the Great Depression (born 1924–1930), Health and Retirement (born 1931–1941), and War Baby (born 1942–1947). The 2010 sample included members from the 2000 cohorts as well as additional birth cohorts, which by then have become age-eligible for inclusion in the study: the Early (born 1948–1953) and Mid (born 1954–1959) Baby Boomer cohorts. Our analysis was limited to non-Hispanic white respondents age 50–89, because other racial/ethnic groups were too small in the HRS sample to reliably estimate disability prevalence by age, gender, and educational attainment. The analytic sample sizes from the HRS for disability prevalence estimates were 14,213 (6,166 males and 8,047 females) in 2000 and 13,178 (5,813 males and 7,365 females) in 2010 (Table 1). Sample estimates were appropriately weighted to account for the complex survey design. The HRS data were taken from the harmonized Rand "O" HRS file (Rand, 2018).

Measures

Disability information came from the HRS and was defined by the inability to perform both Instrumental Activities of Daily Living (IADLs) and Activities of Daily Living (ADLs). IADL disability measures conditions related to independent living, whereas ADL disability measures conditions related to self-care; as a result, ADL disability is a measure of greater disability than IADL disability (Verbrugge & Jette, 1994). ADL disability was determined by not being able to bathe, dress, eat, get in and out of bed, or walk across a room, because of a physical, mental, emotional, or memory problem. IADL disability was determined by not being able to use a phone, manage money, take medication, go grocery shopping, or prepare a hot meal, because of a health or memory problem. The two measures of disability were combined into a single disability measure. A respondent who reported having an ADL was considered ADL disabled regardless of the reports of IADL. Among persons reporting no ADL difficulty, a respondent who reported any IADL was considered IADL disabled. A respondent who reported neither type of disability was considered nondisabled. Education was measured using categories of completion: less than a high school education (including GED; hereafter LTHS), high school graduate (hereafter HS), some college (any college experience that does not result in a bachelor's degree; hereafter SC), and college plus. Research shows that educational attainment, especially in the form of credentials, is important for understanding trends in mortality (Hayward et al., 2015; Sheehan, Montez, & Sasson, 2018).

In order to estimate TLE, we derived age-specific mortality rates in 5-year age intervals for each educational attainment, by gender, using the U.S. Multiple Cause of Death public use files and the respective IPUMS samples of 2000 and 2010. We used period life expectancy because period measures are better suited than cohort measures for gauging population health levels at a single point in time (and change over time). However, unlike cohort life expectancy, period life expectancy does not necessarily reflect the experience of any real individual in the study population (we return to this point in *Discussion*). HLE was the average number of years a member of the synthetic cohort can expect to live without disability (i.e., with neither ADL nor IADL limitation). Changes in HLE were decomposed into changes in mortality rates and changes in disability prevalence by age.

Table 1. Characteristics of Non-Hispanic White Participants Age 50–89 in the HRS Samples for 2000 and 2010

	2000		2010	
	(*n* = 14,213)		(*n* = 13,178)	
	Men	Women	Men	Women
Variables	(*n* = 6,166)	(*n* = 8,047)	(*n* = 5,813)	(*n* = 7,365)
Mean age (years)	65.4	66.8	64.1	65.0
Education (%)				
Less than HS	23.1%	21.8%	13.9%	12.5%
High school	28.8%	38.5%	26.3%	32.2%
Some college	20.2%	22.7%	25.4%	27.6%
College plus	27.9%	16.9%	34.5%	27.6%
IADL disability (%)	4.5%	4.1%	5.3%	4.9%
ADL disability (%)	11.7%	14.9%	12.4%	12.2%
Any (IADL + ADL) disability (%)	16.2%	19.0%	17.7%	17.1%

Note: Means and percentages were estimated using sample weights; *n* corresponds to the actual analytic sample size.
Source HRS 2000 and 2010.

In order to simplify the presentation of key results, we combined the age groups into two broad groups, ages 50–69 and 70–89, which allowed us to differentiate between changes among the middle-aged and the old.

Analytic Approach

We used Sullivan method multistate life tables (Sullivan, 1971) to estimate HLE for two time periods, 2000 and 2010, for different levels of education by gender. Five-year-interval age-specific mortality rates for those aged 50–54 to 84–89 were derived from the U.S. Multiple Cause of Death public use files and the 5% Integrated Public Use Microdata Sample for the years 2000 and 2010 and were used to calculate TLE. Disability prevalence came from the HRS for gender and education groups in 5-year age groups from ages 50–54 to 84–89, weighted to account for the complex survey design. Using the disability prevalence for each 5-year interval, we estimated the proportion of life years in each interval with IADL and ADL disability. The Sullivan method assumed constant mortality over the 5-year intervals and equal mortality rates for both disabled and healthy individuals. This assumption was conservative with respect to mortality rates among disabled persons, which are likely higher than those of the general population. Using multistate life tables, we apportioned the number of life years spent in each state—healthy, IADL disabled, and ADL disabled—and summed across all age groups to obtain an estimate for the entire age range. To account for variation in the estimates of disability prevalence, we estimated confidence intervals for HLE using a bootstrap approach with no duplication, and combined these estimates with mortality rates derived from vital registry data. Due to large sample size for the mortality data, there was little variation in TLE and not shown here. Finally, using the number of life years spent with IADL and ADL disability in each age interval, we examined at what ages healthy life years were gained or lost (Arriaga, 1984). In order to examine whether changes in healthy life expectancy were due to changes at earlier ages or older ones, we decomposed the changes into the proportions attributable to mortality rates and disability prevalence for ages 50–69 and ages 70–89.

Results

Table 1 shows the prevalence of IADL-only disability, ADL disability, and any disability by sex for the years 2000 and 2010. Figure 1 illustrates the changes in ADL prevalence by age, sex, and education. All white women aged 70–89 except those in the high school category had decreases in ADL disability. In contrast, all white males except for college-educated males aged 50–69 had increases in ADL disability. The descriptive results also show broad increases in ADL and IADL disability between 2000 and 2010 (Supplementary Table S1).

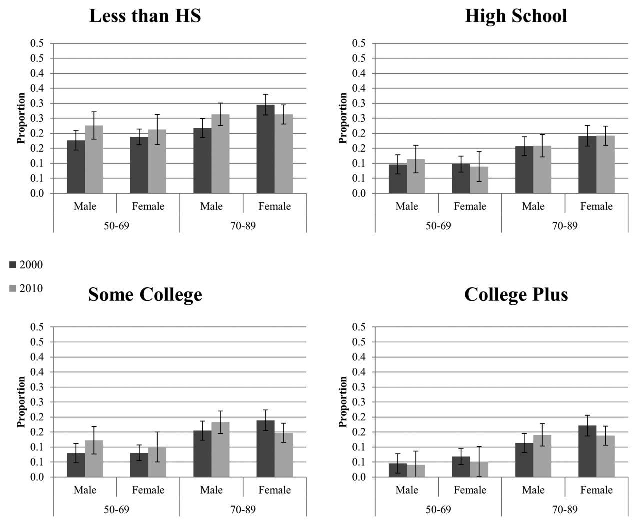

Figure 1. Proportion with ADL difficulties in 2000 and 2010 by sex, age, and education group. Vertical bars represent 95% Confidence interval. Source HRS 2000 and 2010.

Increases in Total Life Expectancy by Level of Educational Attainment

Table 2 presents results from multistate life table estimates of total, healthy, and disabled life expectancy for those aged 50 and 89. White males and females with less than a high school education had little change or decreases in TLE over the period (−0.02 for women and 0.09 for men), whereas the college educated had increases. College-educated white men and women added 3.13 and 2.03 years of TLE, respectively, a finding that accords with previous estimates using these data (Sasson, 2016b).

Changes in Healthy Life Expectancy Among Americans With Low Educational Attainment

HLE is the number years of life expectancy without either ADL or IADL disability. For clarity, we focused on the most and least educated, as they exhibit the most significant changes in HLE (changes that were statistically significant). While TLE increased for all groups except white women with LTHS education, significant changes in HLE were most evident for the most and least educated. White men and women with LTHS both had decreases in HLE (−1.54 years each coincidentally), whereas white men and college-educated women had increases in HLE (1.72 years for men and 2.15 years for women).

Decomposition of Changes in Mortality and Disability

Next, we decomposed the changes in HLE by mortality rates, ADL prevalence, and IADL prevalence for those aged 50–69 and 70–89 (Table 3). Again, for clarity, we focused on the most and least educated, as they exhibited the largest

Table 2. Total Life Expectancy, Healthy Life Expectancy, IADL Life Expectancy, and ADL Life Expectancy by Race, Sex, and Education, at Age 50: 2000 and 2010

	Total Life Expectancy		Healthy Life Expectancy		IADL Life Expectancy		ADL Life Expectancy	
	Male	Female	Male	Female	Male	Female	Male	Female
Panel A:1998–2002								
Education								
LTHS	25.14	30.58	17.64	21.06	1.99	2.04	5.51	7.49
(sd)			(0.31)	(0.31)	(0.17)	(0.17)	(0.29)	(0.29)
HS	27.93	33.18	23.20	26.40	1.06	1.30	3.67	5.47
(sd)			(0.25)	(0.26)	(0.14)	(0.15)	(0.24)	(0.24)
SC	29.43	33.04	24.39	26.81	1.36	1.27	3.68	4.97
(sd)			(0.37)	(0.37)	(0.24)	(0.19)	(0.31)	(0.36)
C+	31.57	36.41	27.76	29.23	0.92	0.98	2.88	6.20
(sd)			(0.35)	(0.62)	(0.22)	(0.28)	(0.30)	(0.60)
Panel B: 2008–2012								
Education								
LTHS	25.23	30.56	16.10	19.52	2.57	2.78	6.56	8.26
(sd)			(0.30)	(0.37)	(0.20)	(0.21)	(0.28)	(0.35)
HS	28.96	34.45	22.70	26.61	1.87	2.09	4.39	5.76
(sd)			(0.31)	(0.31)	(0.19)	(0.26)	(0.27)	(1.93)
SC	30.40	34.42	24.05	27.36	1.82	1.93	4.53	5.13
(sd)			(0.37)	(0.36)	(0.23)	(0.24)	(0.34)	(0.31)
C+	34.69	38.44	29.48	31.38	1.71	2.09	3.50	4.97
(sd)			(0.41)	(0.60)	(0.29)	(0.41)	(0.33)	(0.58)
Panel C:Change over time								
Education								
LTHS	0.09	-0.02	−1.54***	−1.54***	0.58*	0.75**	1.05**	0.78+
(t)			−(3.52)	−(3.16)	(2.17)	(2.71)	(2.83)	(1.81)
HS	1.03	1.28	−0.50	0.21	0.81***	0.78***	0.72*	0.28
(t)			−(1.27)	(0.52)	(3.46)	(3.36)	(2.03)	(0.79)
SC	0.97	1.38	−0.34	0.55	0.45	0.66*	0.86+	0.17
(t)			−(0.65)	(1.07)	(1.35)	(2.15)	(1.85)	(0.35)
C+	3.13	2.03	1.72***	2.15*	0.79*	1.10*	0.62	−1.22
(t)			(3.22)	(2.49)	(2.18)	(2.22)	(1.38)	−(1.46)

Note: Panels A and B standard errors in parentheses. Panel C *t* statistics in parentheses. Healthy life expectancy represents years with no disability; IADL life expectancy represents years with only IADL disability and no ADL conditions. ADL life expectancy is life expectancy with at least 1 ADL disability. All results take into account the complex survey design including sample weights to represent the noninstitutionalized adult U.S. population.
+$p \le .10$; *$p \le .05$; **$p \le .01$; ***$p \le .001$(two-tailed tests).

Table 3. Decomposition of Changes in Healthy Life Expectancy 2000–2010 by Age for Mortality and Condition Prevalence

White	HLE Dif	Education	Age	Mortality	Prev IADL	Prev ADL
Male	−1.54	LT	50–69	−0.16	−0.36	−0.44
			70–89	0.12	−0.19	−0.52
	−0.50	HS	50–69	−0.04	−0.51	−0.48
			70–89	0.69	−0.22	0.05
	−0.34	SC	50–69	0.03	−0.39	−0.50
			70–89	0.60	0.04	−0.13
	1.72	C+	50–69	0.25	−0.14	0.16
			70–89	2.03	−0.40	−0.17
Female	HLE Dif	Education	Age	Mortality	Prev IADL	Prev ADL
	−1.54	LT	50–69	−0.17	−0.61	−0.89
			70–89	0.04	−0.12	0.22
	0.21	HS	50–69	−0.01	−0.44	−0.01
			70–89	0.70	−0.22	0.19
	0.55	SC	50–69	0.05	−0.29	−0.51
			70–89	0.81	-0.25	0.74
	2.15	C+	50–69	0.15	-0.30	0.21
			70–89	1.13	-0.67	1.64

Note: Healthy life expectancy represents years with no disability. All results take into account the complex survey design including sample weights to represent the noninstitutionalized adult U.S. population.
Source. HRS 2000 and 2010.

changes in HLE. White males and females aged 50–69 with LTHS or a high school education had increases in mortality that reduced HLE, whereas all other education and age groups had decreases in mortality that increased HLE.

The increase in HLE between 2000 and 2010 for college-educated white men can be broken down into 2.03 years from decreased mortality between ages 70 and 89, 0.25 years from decreased mortality between ages 50 and 69, and 0.14 years from reduced IADL prevalence between ages 50 and 69. The three other components of the change in HLE were negative: increased ADL disability between ages 50 and 69 decreased HLE by −0.14 years, and the increased prevalence of ADL and IADL disability between ages 70 and 89 decreased HLE by −0.17 and −0.40 years, respectively. The decrease in HLE for white men with LTHS education was due to mortality between the ages of 50–69 and an increased prevalence of both IADL and ADL disability in both age ranges. The largest components of the decrease in HLE for white males with LTHS education were due to increased ADL disability: −0.44 years between ages 50 and 69 and −0.52 years between ages 70 and 89. That is, white males with LTHS education had more disability in 2010 than in 2000 and this disability occurred at younger ages.

Decomposing white women's changes in HLE reveals similar patterns; the increases in HLE for the most educated were due to improved health for those between ages 70 and 89, whereas losses in HLE for the least educated were due to worsening health between ages 50 and 69 (see Figure 2). White women with college education had increases in HLE due to decreased mortality (1.13 years) and to decreased prevalence of ADL (1.64 years) between ages 70 and 89.

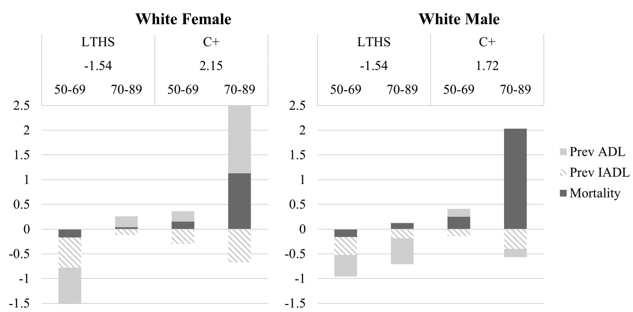

Figure 2. Decomposition of changes in healthy life expectancy between 2000 and 2010 by sex, age, and education group for whites.

White women with LTHS education lost years of HLE because of increased mortality (−0.17 years), IADL disability (−0.61 years), and ADL disability (−0.89 years) between ages 50 and 69. Figure 2 illustrates that the increases in HLE for the most educated were due to improvements in mortality and disability after age 70 and the decreases in HLE for the least educated were due to worsening mortality and disability between ages 50 and 69.

Discussion

Substantial attention has been paid to widening inequality in TLE by level of education in the United States. Between 2000 and 2010, inequality in TLE by educational attainment increased; college-educated whites saw increases in TLE, whereas those with less than a high school education experienced decreases or stagnant life expectancy (Sasson, 2016b). Here, we found, in addition to increasing educational disparities in TLE, an even greater widening of HLE. In other words, whereas previous research and national media attention have focused on decreasing life expectancy among whites with low levels of education, our results suggested that their lives were not only shorter, on average, but also increasingly burdened with disability. Conversely, increases in TLE among the college educated were accompanied by additional years lived without disability. These divergent trends resulted in widening inequality in both TLE and HLE between 2000 and 2010. Our results indicated only marginally significant trends for whites with high school education. As individuals with less than a high school education become increasingly rare, those with a high school education may become the reference for less educated. The difference between whites with a college education and those with a high school education was also one of the widening disparities in HLE over the period examined.

The results suggested a continuation of HLE patterns from 1990 to 2000 for white men (Solé-Auró et al., 2015), whereas trends for white women changed in important ways. Specifically, from 1990 to 2000 increasing educational disparities in HLE among white women were a result of greater decreases in HLE for the least educated. From 2000 to 2010, however, not only did the least educated lose years of HLE, but the college educated gained them. These results accord with a growing body of research, which suggests that educational attainment is becoming increasingly important for longevity (Sasson, 2016a, 2016b). Education confers both material and nonmaterial resources, and people with higher education are benefiting from education through not only material returns on education (income and jobs) but also behavioral (healthy lifestyles) and social assets (networks) (Hayward et al., 2015). Indeed, the highly educated are also better able to navigate increasingly complex health information (Hayward et al., 2015). The income premium of a college education has also increased (Buchmann & DiPrete, 2006), as has educational marital homogamy (Schwartz & Mare 2005), both of which are important for health.

On the other hand, the decrease in HLE among less-educated individuals over this period may be attributed to greater concentration of unhealthy behaviors in this group (Solé-Auró et al., 2015, Skalamera & Hummer 2016). Additionally, place and policy informs educational disparities; state policies may differentiate the level of educational disparity for states (Montez, Hayward & Zajacova 2019). That is to say, at the low end of education distribution, health is more heavily dependent on state policy and institutions, and the changing institutional context in the United States appears to be fomenting health inequalities in significant ways. The widening disparity in HLE reflects both an accumulation of resources (health behaviors, networks, and material resources) for the most educated and a concentration of consequences (negative health behaviors and lack of resources) in the least educated. These patterns have resulted in diverging health and longevity among the highly and low educated in the early twenty-first century.

From 2000 to 2010, while increases in HLE for the most educated were due to decreases in age-specific mortality at older ages, decreases in HLE for the least educated were due to increases in disability prevalence at younger ages. However, increases in IADL disability across all ages limited the increases in HLE for whites with college plus education. College-educated white women in both age groups had decreases in ADL prevalence. This suggests that, unlike the broader U.S. population (Crimmins & Beltrán-Sánchez, 2011), the most-educated white women experienced a compression of disability over this period. It is important to consider these trends in the broader context of socioeconomic health inequalities across high-income countries. Evidence from European countries points to similar increases in socioeconomic disparities in mortality (Bopp & Mackenbach, 2019) through increasing advantages for high socioeconomic groups. These findings from Europe are consistent with the findings presented here: the highly educated are increasingly healthier in late life while the health of the least educated is stagnant, declining, or improving to a lesser degree than that of the most educated. While some research has suggested that whites are experiencing delayed disability in late life (Freedman & Spillman, 2016), our findings highlight that there are important differences in HLE trends by level of education. Increased disability and midlife mortality for whites with less than a high school education reduced their HLE. While global trends towards increased life expectancy have been accompanied by a compression of morbidity (Fries, Bruce, & Chakravarty, 2011; Jagger et al., 2008), our research and that of Yong and Saito (2009) point to an expansion of disability in several high-income countries, especially for less educated groups.

This study has several limitations. First, as in any analysis of period trends, our findings may be masking cohort effects. While we document changes in period HLE, previous research has shown that increasing educational differences in mortality at older ages were rooted in cohort effects, because educational attainment occurs early in the life course and may have a lasting effect well into old age (Masters et al., 2012). Our life table methods do not take into account cohort effects and may therefore overestimate or underestimate the life expectancy of cohorts (Vaupel, Manton, & Stallard, 1979). Specifically, heterogeneity in "frailty" or differential age-specific mortality between cohorts included in period life tables may result in life expectancies that do not reflect the life experience of any cohort included. Second, our analysis of period mortality trends does not permit a life-course interpretation of the effect of education on one's health. Indeed, period measures of life expectancy combine multiple cohorts into a synthetic cohort, which may not reflect the life course of any real individual. Nevertheless, period measures are useful summary measures of population health and allow the comparison of repeated cross-sectional measurements over time. Third, changes in the proportions of education groups over the study period could be accompanied by "lagged selection bias" (Dowd & Hamoudi, 2014; Hendi, 2015), thus exaggerating educational differences in TLE and HLE. The negative selection of the least educated and its effect on health and mortality at younger ages is especially important due to lifetable entropy, which means life expectancy is most sensitive to reductions (or increases) in deaths at younger ages (Olshansky, Carnes, & Désesquelles, 2001). However, prior research has shown that increasing educational disparities in mortality persisted after adjusting for changes in educational composition (Bound et al. 2015); given the brevity of the study period, the lagged selection bias is likely small. Fourth, we were able to analyze only data on non-Hispanic whites; it is critical to understand HLE and TLE changes among racial/ethnic minorities, but small cell sizes in the HRS made that analysis impossible. Future research should analyze these trends for non-Hispanic blacks and Hispanics.

In conclusion, our results show that educational attainment is becoming more consequential for health and longevity than ever before. Between 2000 and 2010, whereas college-educated white men and women experienced substantial increases in HLE, the less-educated experienced stagnating or declining HLE. These trends were driven by decreases in mortality at older ages among the highly educated and increases in disability prevalence at younger ages among the least educated. Given the results of our decomposition, we speculate that these trends will cause continuing divergence in HLE due to further reductions in mortality at older ages among the college educated. Whether increasing disability at younger ages among the less-educated will occur is less clear, although evidence of rising levels of obesity and cardiovascular risk factors points to the likelihood of rising disability.

Supplementary Material

Supplementary data are available at *The Journals of Gerontology, Series B: Psychological Sciences and Social Sciences* online.

Funding

This study was partially supported by a grant from the National Institute of Child Health and Human Development [NICHD] (1 R01-HD053696 [PI Robert A. Hummer, PI]). We thank the Texas Resource Center for Minority Aging Research for their support (P30AG059301). We thank the University of Texas Population Research Center (Grants R24 HD42849 and P2CHD042849, NICHD) for administrative and computing support, and the NICHD Ruth L. Kirschstein National Research Service Award (T32 HD007081) and the National Institute of Aging (T32 AG000037) for training support. The contents of this manuscript are solely the responsibility of the authors and do not represent the official views of their respective universities.

Authors' Contributions

P. Cantu wrote the initial draft and performed analysis. M. Hayward conceptualized the study. I. Sasson derived mortality schedules. All authors provided critical revisions in content, data analysis and interpretation, and manuscript revision.

Conflict of Interest

None declared.

References

Arriaga, E. E. (1984). Measuring and explaining the change in life expectancies. *Demography,* **21**, 83–96. doi:10.2307/2061029

Bopp, M., & Mackenbach, J. P. (2019). [Death is a respecter of persons: 30 years of research comparing European countries regarding social inequality in mortality]. *Zeitschrift fur Gerontologie und Geriatrie,* **52**, 122–129. doi:10.1007/s00391-019-01530-6

Bound, J., Geronimus, A. T., Rodriguez, J. M., & Waidmann, T. A. (2015). Measuring Recent Apparent Declines In Longevity: The Role Of Increasing Educational Attainment. *Health affairs (Project Hope),* **34**, 2167–2173. doi:10.1377/hlthaff.2015.0481

Brown, D. C., Hayward, M. D., Montez, J. K., Hummer, R. A., Chiu, C. T., & Hidajat, M. M. (2012). The significance of education for mortality compression in the United States. *Demography,* **49**, 819–840. doi:10.1007/s13524-012-0104-1

Buchmann, C., & DiPrete, T. A. (2006). The growing female advantage in college completion: The role of family background and academic achievement. *American Sociological Review*, **71**, 515–541. doi:10.1177/000312240607100401

Cai, L., & Lubitz, J. (2007). Was there compression of disability for older Americans from 1992 to 2003? *Demography,* **44**, 479–495. doi:10.1353/dem.2007.0022

Case, A., & Deaton, A. (2015). Rising morbidity and mortality in midlife among white non-Hispanic Americans in the 21st century. *Proceedings of the National Academy of Sciences of the United States of America,* **112**, 15078–15083. doi:10.1073/pnas.1518393112

Case, A., & Deaton, A. (2017). Mortality and morbidity in the 21st century. *Brookings Papers on Economic Activity,* **2017**, 397–476. doi:10.1353/eca.2017.0005

Crimmins, E. M., & Beltrán-Sánchez, H. (2011). Mortality and morbidity trends: Is there compression of morbidity? *The Journals of Gerontology. Series B, Psychological Sciences and Social Sciences,* **66**, 75–86. doi:10.1093/geronb/gbq088

Crimmins, E. M., & Saito, Y. (2001). Trends in healthy life expectancy in the United States, 1970–1990: Gender, racial, and educational differences. *Social Science and Medicine*, **52**, 1629–1641. doi:10.1016/S0277-9536(00)00273-2

Crimmins, E. M., Zhang, Y., & Saito, Y. (2016). Trends over 4 decades in disability-free life expectancy in the United States. *American Journal of Public Health,* **106**, 1287–1293. doi:10.2105/AJPH.2016.303120

Dowd, J. B., & Hamoudi, A. (2014). Is life expectancy really falling for groups of low socio-economic status? Lagged selection bias and artefactual trends in mortality. *International Journal of Epidemiology,* **43**, 983–988. doi:10.1093/ije/dyu120

Fogel, R. W., & Costa, D. L. (1997). A theory of technophysio evolution, with some implications for forecasting population, health care costs, and pension costs. *Demography,* **34**, 49–66. doi:10.2307/2061659

Freedman, V. A., & Martin, L. G. (1999). The role of education in explaining and forecasting trends in functional limitations among older Americans. *Demography,* **36**, 461–473. doi:10.2307/2648084

Freedman, V. A., & Spillman, B. C. (2016). Active life expectancy in the older US population, 1982-2011: Differences between blacks and whites persisted. *Health affairs (Project Hope),* **35**, 1351–1358. doi:10.1377/hlthaff.2015.1247

Freedman, V. A., Spillman, B. C., Andreski, P. M., Cornman, J. C., Crimmins, E. M., Kramarow, E.,…Waidmann, T. A. (2013). Trends in late-life activity limitations in the United States: An update from five national surveys. *Demography,* **50**, 661–671. doi:10.1007/s13524-012-0167-z

Fries, J. F., Bruce, B., & Chakravarty, E. (2011). Compression of morbidity 1980-2011: A focused review of paradigms and progress. *Journal of Aging Research,* **2011**, 261702. doi:10.4061/2011/261702

Hayward, M. D., Hummer, R. A., & Sasson, I. (2015). Trends and group differences in the association between educational attainment and U.S. adult mortality: Implications for understanding education's causal influence. *Social Science & Medicine (1982),* **127**, 8–18. doi:10.1016/j.socscimed.2014.11.024

Health and Retirement Study, Rand "O" HRS file public use dataset. Produced and distributed by the University of Michigan with funding from the National Institute on Aging (grant number NIA U01AG009740). Ann Arbor, MI, (2018).

Hendi, A. S. (2015). Trends in U.S. life expectancy gradients: The role of changing educational composition. *International Journal of Epidemiology,* **44**(3), 946–955. doi:10.1093/ije/dyv062

Hummer, R. A., & Hernandez, E. M. (2013). The effect of educational attainment on adult mortality in the United States. *Population Bulletin,* **68**, 1–16.

Hummer, R. A., & Lariscy, J. T. (2011). Educational attainment and adult mortality. In R. G. Rogers & E. M. Crimmins (Eds.), *International handbook of adult mortality* (pp. 241–261). Springer, Dordrecht. doi:10.1007/978-90-481-9996-9_12

Jagger, C., Gillies, C., Moscone, F., Cambois, E., Van Oyen, H., Nusselder, W.,…Robine, J. M.; EHLEIS team. (2008). Inequalities in healthy life years in the 25 countries of the European Union in 2005: A cross-national meta-regression analysis. *Lancet (London, England),* **372**, 2124–2131. doi:10.1016/S0140-6736(08)61594-9

Jagger, C., & Robine, J.-M. (2011). Healthy life expectancy. In R. G. Rogers & E. M. Crimmins (Eds.), *International handbook of adult mortality* (pp. 551–568). Springer, Dordrecht. doi:10.1007/978-90-481-9996-9_26

Jeune, B., & Brønnum-Hansen, H. (2008). Trends in health expectancy at age 65 for various health indicators, 1987-2005, Denmark. *European Journal of Ageing,* **5**, 279. doi:10.1007/s10433-008-0100-x

Kochanek, K. D., Arias, E., & Anderson, R. (2013). *How did cause of death contribute to racial differences in life expectancy in the United States in 2010?* (NCHS Data Brief No. 125). Retrieved from National Center for Health Statistics: http://health-equity.lib.umd.edu/4148/1/How_Did_Cause_of_Death_Contribute_to_Racial_Differences.pdf

Kochanek, K. D., Arias, E., & Bastian, B. A. (2016). *The effect of changes in selected age-specific causes of death on non-Hispanic white life expectancy between 2000 and 2014.* (NCHS Data Brief No. 250). Retrieved from National Center for Health Statistics: https://pdfs.semanticscholar.org/e38b/785511fe2125a5c3548de8e6293e2680ea8e.pdf

Mackenbach, J. P., Valverde, J. R., Artnik, B., Bopp, M., Brønnum-Hansen, H., Deboosere, P.,…Nusselder, W. J. (2018). Trends in health inequalities in 27 European countries. *Proceedings of the National Academy of Sciences of the United States of America,* **115**, 6440–6445. doi:10.1073/pnas.1800028115

Mäki, N., Martikainen, P., Eikemo, T., Menvielle, G., Lundberg, O., Ostergren, O.,…Mackenbach, J. P.; EURO-GBD-SE consortium. (2013). Educational differences in disability-free life expectancy: A comparative study of long-standing activity limitation in eight European countries. *Social Science & Medicine (1982),* **94**, 1–8. doi:10.1016/j.socscimed.2013.06.009

Martin, L. G., Freedman, V. A., Schoeni, R. F., & Andreski, P. M. (2009). Health and functioning among baby boomers approaching 60. *The Journals of Gerontology. Series B, Psychological Sciences and Social Sciences,* **64**(3), 369–377. doi:10.1093/geronb/gbn040

Martin, L. G., Freedman, V. A., Schoeni, R. F., & Andreski, P. M. (2010). Trends in disability and related chronic conditions among people ages fifty to sixty-four. *Health Affairs (Project Hope),* **29**, 725–731. doi:10.1377/hlthaff.2008.0746

Martin, L. G., & Schoeni, R. F. (2014). Trends in disability and related chronic conditions among the forty-and-over population: 1997–2010. *Disability and Health Journal,* **7**(1, Supplement), S4–S14. doi:10.1016/j.dhjo.2013.06.007

Masters, R. K., Hummer, R. A., & Powers, D. A. (2012). Educational differences in U.S. adult mortality: A cohort perspective. *American Sociological Review,* **77**, 548–572. doi:10.1177/0003122412451019

Mathers, C. D., Sadana, R., Salomon, J. A., Murray, C. J., & Lopez, A. D. (2001). Healthy life expectancy in 191 countries, 1999. *Lancet (London, England),* **357**, 1685–1691. doi:10.1016/S0140-6736(00)04824-8

Mirowsky, J., & Ross, C. E. (2015). Education, health, and the default American Lifestyle. *Journal of Health and Social Behavior,* **56**, 297–306. doi:10.1177/0022146515594814

Montez, J. K., Hayward, M. D., & Zajacova, A. (2019). Educational disparities in adult health: U.S. States as Institutional Actors on the Association. *Socius,* **5**, doi:10.1177/2378023119835345

Montez, J. K., Zajacova, A., Hayward, M. D., Woolf, S. H., Chapman, D., & Beckfield, J. (2019). Educational disparities in adult mortality across U.S. States: How do they differ, and have they changed since the Mid-1980s? *Demography,* **56**, 621–644. doi:10.1007/s13524-018-0750-z

Olshansky, S. J., Antonucci, T., Berkman, L., Binstock, R. H., Boersch-Supan, A., Cacioppo, J. T., … Rowe, J. (2012). Differences in life expectancy due to race and educational differences are widening, and many may not catch up. *Health Affairs,* **31**(8), 1803–1813. doi:10.1377/hlthaff.2011.0746

Olshansky, S. J., Carnes, B. A., & Désesquelles, A. (2001). Demography. Prospects for human longevity. *Science (New York, N.Y.)*, **291**, 1491–1492. doi:10.1126/science.291.5508.1491

Omran, A. R. (1971). The epidemiologic transition. A theory of the epidemiology of population change. *The Milbank Memorial Fund Quarterly,* **49**, 509–538.

Pérez-Hernández, B., Rubio-Valverde, J. R., Nusselder, W. J., & Mackenbach, J. P. (2019). Socioeconomic inequalities in disability in Europe: Contribution of behavioral, work-related and living conditions. *European Journal of Public Health,* **29**, 640–647. doi:10.1093/eurpub/ckz009

Picavet, H. S., & Hoeymans, N. (2002). Physical disability in The Netherlands: Prevalence, risk groups and time trends. *Public Health,* **116**, 231–237. doi:10.1038/sj.ph.1900864

Rowland, D. T. (2003). *Demographic methods and concepts*. Oxford: Oxford University.

Rudd, R. A. (2016). Increases in drug and opioid-involved overdose deaths—United States, 2010–2015. *MMWR. Morbidity and Mortality Weekly Report,* **65**, 1445–1452. doi: 10.15585/mmwr.mm655051e1

Ruggles, S., Flood, S., Goeken, R., Grover, J., Meyer, E., Pacas, J., & Sobek, M. *IPUMS USA: Version 9.0 [dataset]*. Minneapolis, MN: IPUMS, 2019. doi:10.18128/D010.V9.0

Salomon, J. A., Wang, H., Freeman, M. K., Vos, T., Flaxman, A. D., Lopez, A. D., & Murray, C. J. L. (2012). Healthy life expectancy for 187 countries, 1990–2010: A systematic analysis for the Global Burden Disease Study 2010. *The Lancet,* **380**(9859), 2144–2162. doi: 10.1016/S0140-6736(12)61690-0

Sasson, I. (2016a). Diverging trends in cause-specific mortality and life years lost by educational attainment: Evidence from United States vital statistics data, 1990–2010. *PLoS One,* **11**(10), e0163412. doi:10.1371/journal.pone.0163412

Sasson, I. (2016b). Trends in life expectancy and lifespan variation by educational attainment: United States, 1990–2010. *Demography,* **53**(2), 269–293. doi:10.1007/s13524-015-0453-7

Schoeni, R. F., Liang, J., Bennett, J., Sugisawa, H., Fukaya, T., & Kobayashi, E. (2006). Trends in old-age functioning and disability in Japan, 1993-2002. *Population Studies,* **60**, 39–53. doi:10.1080/00324720500462280

Schwartz, C. R., & Mare, R. D. (2005). Trends in educational assortative marriage from 1940 to 2003. *Demography,* **42**, 621–646. doi:10.1353/dem.2005.0036

Sheehan, C., Montez, J. K., & Sasson, I. (2018). Does the Functional Form of the Association Between Education and Mortality Differ by U.S. Region? *Biodemography and Social Biology,* **64**, 63–81. doi:10.1080/19485565.2018.1468239

Skalamera, J., & Hummer, R. A. (2016). Educational attainment and the clustering of health-related behavior among U.S. young adults. *Preventive Medicine,* **84**, 83–89. doi:10.1016/j.ypmed.2015.12.011

Solé-Auró, A., Beltrán-Sánchez, H., & Crimmins, E. M. (2015). Are differences in disability-free life expectancy by gender, race, and education widening at older ages? *Population Research and Policy Review,* **34**(1), 1–18. doi:10.1007/s11113-014-9337-6

Stone, D. M., Simon, T. R., Fowler, K. A., Kegler, S. R., Yuan, K., Holland, K. M.,…Crosby, A. E. (2018). Vital Signs: Trends in State Suicide Rates - United States, 1999-2016 and Circumstances Contributing to Suicide - 27 States, 2015. *MMWR. Morbidity and Mortality Weekly Report,* **67**, 617–624. doi:10.15585/mmwr.mm6722a1

Sullivan, D. F. (1971). A single index of mortality and morbidity. *HSMHA Health Reports,* **86**, 347–354.

Tsai, Y. (2017). Education and disability trends of older Americans, 2000-2014. *Journal of Public Health (Oxford, England),* **39**, 447–454. doi:10.1093/pubmed/fdw082

Vaupel, J. W., Manton, K. G., & Stallard, E. (1979). The impact of heterogeneity in individual frailty on the dynamics of mortality. *Demography,* **16**, 439–454. doi:10.2307/2061224

Verbrugge, L. M., & Jette, A. M. (1994). The disablement process. *Social Science & Medicine (1982),* **38**, 1–14. doi:10.1016/0277-9536(94)90294-1

Yong, V., & Saito, Y. (2009). Trends in healthy life expectancy in Japan: 1986–2004. *Demographic Research,* **20**, 467–494.

Zajacova, A., & Montez, J. K. (2017). Physical Functioning Trends among US Women and Men Age 45-64 by Education Level. *Biodemography and Social Biology,* **63**, 21–30. doi:10.1080/19485565.2016.1263150