Trends in the Burden of Disability in the United States, 1996-2018: Analysis Using Multistate Models

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Abstract

Using the Health and Retirement Study and advanced multistate models, this study is the first to examine the trends (1996-2006 and 2008-2018) in different aspects of disability burden, such as lifetime risk, age at onset, expectancy, and recovery from disability. We study the older U.S. population by gender, race/ethnicity, and educational attainment. For the over adult population, most (83%) of the increase in total life expectancy at age 50 is in years free of disability, accompanied by a significant postponement (1 year) in the onset and recovery from disability, with no change in lifetime risk of disability. However, we observe notable sociodemographic disparities, with mortality and disability trends translating into deteriorating conditions for Latinx and lower educated adults. Furthermore, the worsening of health for the lowest educated Whites has placed them in a more disadvantaged position than Blacks and Latinx.

Introduction

Increasing life expectancy and the understanding that mortality trends do not necessarily reflect trends in health lead to the question of whether additional life years are spent in good health (Crimmins and Beltrán-Sánchez 2011). This question has been a center of debate among population health researchers for many decades. A large body of literature has investigated the consequences of increased life expectancy on population health in the growing older U.S. population (Bardenheier et al. 2016; Crimmins 2015; Freedman et al. 2016; Crimmins et al. 1997a; Crimmins et al. 2009; Cai and Lubitz 2007s; Solé-Auró et al. 2014). However, the findings related to whether increased life expectancy is associated with more years of good health have been inconclusive.

Most of the research on health trends in older populations has focused on the trends with or without disability in the ability to perform basic activities of daily living (ADL) (Crimmins 2015). The ADLs such as eating, dressing, and walking, is a health dimension necessary for independent living. Disability in basic ADL is considered a more severe state of disability state than disability in instrumental activities of daily living (IADL) such as preparing meals and managing money (Wong et al. 2010). Considering the growing share of U.S. adults at risk of disability due to population aging and the substantial costs of disability for the affected, their families, and society (Freedman et al. 2002; Fried et al. 2001), it is important to carefully keep a track of the levels and trends in disability burden in the older U.S. population.

Health expectancies, which divide the total life expectancy into years lived in various health states, are widely used indicators to monitor trends in the burden of disability and health inequalities (Marmot 2010; Marmot and Goldblatt 2013). Changes in DFLE or DLE over time help to assess the overall effect of the trends in mortality and morbidity on population health (Robine et al. 1997). Health expectancies are likely to be influenced by several other key aspects of disability dynamics, such as the probability of ever experiencing disability or lifetime risk of disability, its age at onset, recovery after the onset, and life expectancy of the disabled. However, most of the research examining trends in disability burden has been limited to examining the trends in health expectancies only (Crimmins et al. 2016; Freedman et al. 2016; Jagger et al. 2016; Payne 2022; Solé-Auró et al. 2014), with some exceptions (Cai and Lubitz 2007; Crimmins et al. 2009). To get a more comprehensive overview of the evolution of disability dynamics in the older U.S. population, it is critical to examine the trends in different aspects of the disability burden.

Therefore, using advanced incidence-based multistate models based on the Health and Retirement Study, a high-quality nationally representative longitudinal survey of adults aged over 50 in the U.S., this study contributes to population health research in multiple important ways. First, we examine the trends in lifetime risk of disability at age 50, conditional on being not disabled at age 50, between the periods of 1996-2006 and 2008-2018. This will help us understand whether the probability of ever experiencing disability in one's lifetime is changing over the years. Second, we investigate the trends in mean age at onset of disability, conditional on being not disabled at age 50. Third, we estimate how disability free (DFLE) and disabled life expectancies (DLE) at age 50 are changing across the periods. Fourth, to understand the recovery and mortality dynamics for those who reach middle age with disability, we examine the trends in DFLE and total life expectancy (TLE) for adults disabled at age 50.

Moreover, a large body of literature suggests that in the older U.S. population the burden of disability varies considerably by sociodemographic factors. Relatively less attention has been given to the sociodemographic disparities in the trends of the metrics discussed above. It is essential to understand how the burden of disability for the disadvantaged subpopulations is evolving in terms of indicators representing different aspects of the disability burden. Therefore, beyond aggregate patterns, we also examine for the first time how the trends in health expectancies, lifetime risk, age at onset, and recovery from disability, and life expectancy of the disabled vary by the key sociodemographic factors of gender, race/ethnicity, and educational attainment. This has high policy relevance and important implications for the health care of the considerably growing and racially diversifying older U.S. population.

Furthermore, considering the divergent mortality and disability trends even among Whites by educational attainment, we also perform an in-depth analysis where we examine the trends in disability burden by educational attainment among Whites. This analysis is performed only among Whites as educational disparities in health are found to be more pronounced among Whites (Sasson 2016a) and sample sizes for

Blacks and Latinx are too small to yield reliable estimates of the educational disparities. The findings from this research may help the policymakers in planning social and health care and providing long-term care optimally for the most vulnerable population subgroups in the older U.S. population.

Background

Population aging is a global demographic megatrend (United Nations 2019). In particular, population aging places itself as the most dominant demographic trend in the U.S. The large Baby Boomer generation (the cohorts born between mid-1946 and mid-1964) will enter older adulthood (aged 65 and over) by 2030. As a result, the number of older adults, which was 49 million in 2016, is expected to reach 73 and 95 million by 2030 and 2060, respectively (Vespa et al. 2018). This has important implications for the health and well-being of the growing older population in the U.S.

Implications of population aging on population health

About four decades ago, theories about the potential implications of increased life expectancy and consequent population aging on older age health were proposed (Fries 1980; Gruenberg 1977; Manton 1982). Fries (1980) provided an optimistic view of population aging, known as the *compression of morbidity*. According to Fries, the promotion of health and prevention of diseases would raise the age at onset of morbidity and the pace of increase in the of morbidity onset would exceed that of total life expectancy (Fries 1980, 2005). This combination would lead to a shorter period of morbidity before death—compression of morbidity, increasing the number and proportion of years free of morbidity.

Gruenberg provides a pessimistic view of population aging, known as the *expansion of morbidity* (Gruenberg 1977; Gruenberg 2005). According to Gruenberg, increasing life expectancy resulting from medical advancement would prolong the life of adults experiencing morbidity without changing the age at onset, thereby allowing adults to live to advanced ages where the risk of morbidity is higher. This would lead to an expansion of morbidity, increasing the number and proportion of years lived with morbidity. According to this theory, life expectancy free of morbidity is not expected to increase.

In the third theory, known as *dynamic equilibrium*, Manton (1982) states that morbidity and mortality are interrelated processes and the forces that decrease mortality would also decrease the severity and rate of progression of morbidity. According to the theory, both life expectancy with and without morbidity will increase with increasing total life expectancy. Age at the onset of morbidity will also increase. In the case of *dynamic equilibrium*, both life expectancy with and without morbidity increase, so no conclusion can be drawn regarding whether the proportion of years lived with or without morbidity will increase.

These theories are given in terms of morbidity. However, morbidity can be a more difficult concept to quantify compared with the related concept of disability. Therefore, research often uses disability as a surrogate for morbidity (Fries 2003; Cai and Lubitz

2007; Crimmins et al. 2016; Crimmins et al. 1997a), which is usually defined as difficulty in performing activities usually required in our daily lives (Verbrugge and Jette 1994).

Trends in ADL disability

About 43 million older Americans aged 50 or over experienced at least one ADL disability during 1998-2014 (McGrath et al. 2019). With population aging, the number of adults experiencing disability is likely to increase rapidly (Crimmins et al. 2009). The odds of ADL disability have increased significantly between 2000 and 2015 in the U.S. (Tsai 2017; Zajacova and Montez 2017). This raises concerns about meeting the late-life care needs in the U.S. (Ankuda et al. 2020; Freedman and Spillman 2014); however, long-term care needs in the coming years will depend, in part, on how the burden of disability has evolved in the more recent periods. However, evidence regarding how DFLE and DLE are changing along with increasing TLE has not been clear (Bardenheier et al. 2016; Crimmins 2015; Crimmins et al. 1997a; Cai and Lubitz 2007; Crimmins et al. 2009). This discrepancy may partly be due to the use of different methods to investigate the trends (prevalence-based Sullivan vs incidence-based multistate method).

Crimmins et al. (1997a) report that between 1970 and 1980, the increase in TLE among older adults was mainly concentrated in DLE, leading to an expansion of morbidity during the period. A decade later Crimmins and colleagues (2009) found a slight but significant increase in DFLE, an insignificant increase in DLE, and a stable proportion of years lived free of ADL disability between 1984 and 1994 in the older adult US population, conforming neither to morbidity compression nor dynamic equilibrium. Cai and Lubitz (2007) report an increase in DFLE and a slight reduction in DLE between 1992 and 2002, leading to an increase in the proportion of total life expectancy free of ADL disability during the period, providing some support to both the compression of disability and dynamic equilibrium theory. In contrast, Solé-Auró et al. (2014) observed a decrease in DFLE and an increase in DLE between 1991 to 2001, leading to a decrease in the share of total life expectancy spent free of ADL disability during the period, indicating expansion of morbidity. Molla and Center for Disease Control and Prevention (CDC) (2013) find that although expectancy free of disability has increased, its share in total life expectancy has decreased between 1999 and 2008. Crimmins et al. (2016) report that both life expectancy with and without any (IADL/ADL) disability increased significantly between 1970 and 2010 and the proportion of TLE spent free of disability increased, providing some support to both compression of morbidity and dynamic equilibrium among older U.S. adults. In other words, evidence regarding the trends in the burden of disability has been inconsistent in the recent decades. Therefore, this evolving evidence base requires ongoing scrutiny.

Several aspects related to the burden of disability, such as lifetime risk of disability, age at onset of and recovery from disability, and mortality of the disabled, can influence the trends in health expectancies. For example, an increase in DFLE between two periods may be due to the decreased lifetime risk, delayed age at onset, increased recovery from disability, or increased mortality of the disabled over that period. Therefore, in addition to examining the trends in DFLE or DLE, it is also important to examine the trends in these key aspects related to the burden of disability to get a more comprehensive overview of the dynamic of ADL disability in the older US population.

Sociodemographic disparities in the burden of disability

The burden of disability is patterned by key sociodemographic factors, namely gender, race/ethnicity, and educational attainment, in the older U.S. population, with women, Whites, and adults with higher education lying on the advantaged end in terms of years lived free of disability (Mehta and Myrskylä 2017; Molla and CDC 2013; Sole´-Auro´ et al. 2015; Freedman and Spillman 2016; Garcia et al. 2017; Crimmins and Saito 2001; Chiu et al. 2016; Molla et al. 2004; Sole´-Auro´ et al. 2014). However, evidence for the trends in DFLE is inconclusive (Molla and CDC 2013; Freedman et al. 2016; Freedman and Spillman 2016; Sole´-Auro´ et al. 2015; Crimmins and Saito 2001; Sole´-Auro´ et al. 2014). For instance, Molla and CDC (2013) found an increase in DFLE and DLE for both Whites and Blacks from 1999-2008. Freedman and Spillman (2016) also found similar results for the larger period of 1982-2011. In contrast, Sole´-Auro´ et al. (2015) found a decline in DFLE for both Whites and Blacks and the opposite for DLE between 1991 and 2001. Although a large body of literature indicates a greater risk of disability for Latinx compared with Whites, research examining the trends in DFLE or DLE for Latinx is scarce in the older US population (Garcia et al. 2017).

Interestingly, the mortality and disability trends are not uniform even across the socioeconomically advantaged Whites. A large body of research indicates a declining adult life expectancy for lower educated Whites in the U.S. since 1990, widening educational disparities in mortality over the years (Case and Deaton 2015; Sasson 2016a; Sasson 2016b). Cantu et al. (2019) show that educational disparities in (ADL/IADL) DFLE have also increased between 2000 and 2010 among Whites aged 50 and over, with lower educated Whites experiencing a decrease in DFLE and higher educated Whites experiencing an increase. However, the trends in lifetime risk, age at first incidence, and recovery and mortality for the disabled by educational attainment among Whites are yet to be explored. Therefore, beyond the overall pattern, we also investigate the sociodemographic disparities in these trends.

Data and Methods

Data

This study uses data from the Health and Retirement Study (HRS), a nationally representative high-quality biennial survey of U.S. adults aged over 50 years and their partners of any age (Sonnega et al. 2014). With support from the National Institute on Aging (NIA) and the Social Security Administration (SSA), the survey was conducted by the University of Michigan (University of Michigan 2017; Bugliari et al. 2022). We use the period 1996-2018 from the RAND HRS Longitudinal File 2018 (V2) (Bugliari et al. 2022). We use data from the 1996 wave (wave 3) as from this wave, consistent information on ADLs is available at a regular two-year interval. After participants are included in the HRS, the study follows them even if they are institutionalized. Additional details of the HRS can be found elsewhere (Fisher and Ryan 2018).

In the multistate calculation, the unit of analysis is a transition, which results from observations in two consecutive waves. Therefore, the analytical sample includes adults and their partners/spouses aged 50-100 who have information on ADLs in at least two successive waves. Less than one-fifth of 1% on any of the predictors is missing. This leads to a final sample size of 38,816 adults aged 50-100, contributing to 232,636 observations during 1996-2018.

Measures

Dependent Variable

The dependent variable has three states. Two of them are transient states: *healthy* and *disability*. Reverse transitions are possible between these states. i.e., adults are allowed to transition to the state of *healthy* if they recover from *disability*. The third state is *death,* an absorbing state. These three states together constitute the Markov state space (Figure 1).

Disability

We conceptualize disability within the disablement process framework as discussed by Verbrugge and Jette (1994). In this framework, disability is conceptualized as a discrepancy between an individual's personal capacity and the demand of the activity in that individual's environment (Verbrugge and Jette 1994). Therefore, the trends in disability in an older population may be influenced by both the trends in the underlying cognitive and physical capacity of the older population and the trends in the available accommodations, e.g., environmental modification, external supports.

The most widely used measures of disability are ADLs and IADLs (Katz et al. 1963; Lawton and Brody 1969). This paper is focused on ADL disability. The ADLs reflect the core and most basic daily life activities and are considered more direct indicators of health and well-being at older ages (Taylor et al. 2018). ADL disability is a more expensive and severe form of disability than IADL disability and the expectancy with ADL disability is found to be longer than that of IADL disability (Cai and Lubitz 2007; Crimmins et al. 2009; Freedman et al. 2002; Wong et al. 2010). Furthermore, ADL disability is associated with a substantially greater risk of death than IADL disability (Cai and Lubitz 2007; Crimmins et al. 2009).

We assess disability using the questions from the ADL scale (Katz et al. 1963). We use subjective indicators to assess ADL disability as subjective indicators directly reveal the disability experience (Verbrugge and Jette 1994). Following a large body of research (Cai and Lubitz 2007; Freedman et al. 2013; Payne and Kobayashi 2022; Raymo and Wang 2022; Sauerberg and Canudas-Romo 2022), we classify adults as having ADL disability if they report difficulty, because of a health or memory problem, in any of the following six activities: dressing, walking, bathing, eating, getting in/out of bed, and/or using the toilet. We classify those as disability-free who report no ADL disabilities. We use proxy responses when interviews with the respondents were not possible (Sonnega et al. 2014). Evidence suggests that self-reports and proxy reports of disability may differ, introducing ‘proxy bias’ (Li et al. 2015; Todorov and Kirchner 2000). Therefore, to deal with the proxy bias, we include response status (self-report versus proxy response) in our regression models.

Independent variables

Independent variables include *age* (as a continuous variable) and *gender* (women and men). Self-reported *race* and *ethnicity* are categorized as non-Latinx Whites, non-Latinx Blacks, and Latinx (Cai and Lubitz 2007; Case and Deaton 2015; Payne 2022). We include non-Latinx Others in the analysis but do not show the results for this subgroup due to their small sample size. Level of *educational attainment* has four categories: less than high school, high school/general educational development (HS/GED), some college, and college or more (Hale 2017; Payne 2022). We use the categorical form of educational attainment to take the non-linear relation between education and health into account (Montez et al. 2012). Prior studies suggest that educational attainment in the form of credentials is important to understanding the trends in mortality (Hayward et al. 2015; Sheehan et al. 2018). The variable *period* is a categorical variable that captures the two periods under investigation: 1996-2006 and 2008-2018. We tried to divide 1996-2018 into three or more periods (e.g., 1996-2002, 2004-2010, 2012-2018); however, this leads to unstable estimates as the sample sizes get smaller. Finally, the categorical variable of *proxy* indicates whether the respondent is a proxy or not (self-respondent).

Statistical analysis

To derive the key metrics- lifetime risk[1], mean age at onset, and expectancy, we apply Markov chain multistate models (Dudel 2021; Kemeny and Snell 1983; Mehta and Myrskylä 2017). Markov chain multistate models help us model the transitions between various health states and the central inputs to the multistate calculations are the transition probabilities among the states (e.g., the probability of moving from *healthy* to *disability* or *death*). Figure 1 visually describes the states in the Markov state space used in this paper and the transitions among them.

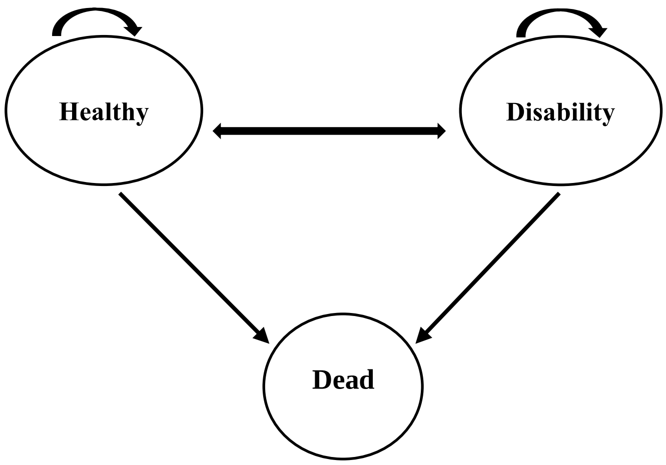

Figure 1. States in the Markov state space. The arrows represent transitions across the states.

To estimate the transition probabilities, we use multinomial logistic regression models (Allison 1982), commonly applied in multistate research (Cai and Lubitz 2007; Dudel 2021; Mehta and Myrskylä 2017; Sharma et al. 2023). To estimate the transition probabilities for the overall population and by gender, race/ethnicity, and

[1] The lifetime risk of disability is defined as the probability of ever experiencing disability before death (Kemeny and Snell 1983).

educational attainment, we estimate the following model separately for each subpopulation (e.g., women, Blacks, less than high school educated, Whites with HS/GED education, etc.), leading to a total of 10 multinomial logistic regression models. This implicitly interacts all the predictors in the following model with gender, race/ethnicity, and educational attainment.

$$\log \frac{p_{ij}}{p_{iH}} = a_{ij} + b_{1,ij} Age + b_{2,ij} Age^2 + \delta_{ij}{}^T DEMOGR$$

where p_{ij} is the transition probability from state i to j. The state j also includes the absorbing state *death*; H is the reference state of *healthy*; a_{ij} is the intercept; Age is the age in years; and δ_{ij} is a coefficient vector related to the variables in $DEMOGR$. $DEMOGR$ includes period, proxy status, and the interactions.

As discussed above, in estimating the transition probabilities by race/ethnicity (educational attainment), we do not control for educational attainment (race/ethnicity). This is because the goal of this study is to understand the trends in the burden of disability for racial/ethnic subgroups with different educational attainment and for educational subpopulations with varying racial/ethnic compositions as they actually exist in the older U.S. population. Notably, this approach is different from the approach that aims to understand the mechanisms behind the disparities, e.g., what would be racial/ethnic disparities in disability if Whites, Blacks, and Latinx do not differ in terms of their educational attainment?

To obtain the age-specific transition probabilities for each subpopulation for the first period, we set the first period (i.e., 1996-2006) to 1 and second period (2008-2018) to 0, with *proxy* status set to the sample average, i.e., controlling for response status. Similarly, we obtain the age-specific transition probabilities for the second period. The transition probabilities for each subpopulation from state i at age x to state j at age $x + 2$ are inserted into the Markov transition matrix, $\mathbf{M^T}$. Finally, matrix operations on $\mathbf{M^T}$ provide us the metrics of lifetime risk, mean age at onset, and expectancies. In supplementary material, we provide a detailed description of the multistate estimation procedure.

To understand the recovery and mortality dynamics across the periods for adults who reach age 50 with disability, we examine trends in conditional expectancies, i.e., expectancies for adults who are disabled at age 50. The indicator of expectancy summarizes health and disability experiences over the life course in a single estimate and thus provides a convenient way of comparing population subgroups in terms of their life course experiences.

Estimating transition probabilities requires the Markov assumption, which states that the probabilities of transition from the current state to the next depend only on the current state and the predictors, and not on the history of states. In other words, the estimation does not differentiate between an adult who has been disabled for one year and an adult who has been disabled for four years, if these adults have the same predictors values. However, the transition probabilities are accurate reflections of the current risk of disability in the population (Schoen 1988), and the Markov assumption, although strong, makes the multistate calculations tractable.

We conduct all the statistical analyses using STATA 17 (StataCorp 2021). The multistate calculations and the resulting metrics of lifetime risk, mean age at onset, and expectancies along with confidence intervals are obtained using the *dtms* package in STATA developed by Schneider (2023). To deal with the complex survey design of the HRS, we use the sampling weights, stratification, and clustering variables in the analysis (Fisher and Ryan 2018). These variables, developed by HRS co-investigators, help us compensate for the unequal selection probabilities and non-response in the sample and improve variance estimation considering the geographic clustering of the HRS sample.

Results

Descriptive characteristics

Table 1 shows the sociodemographic characteristics of the sample used in the analysis. The mean age of the sample is around 69 years in both the periods of 1996-2006 and 2008-2018. The sample includes more women than men and the distribution remains the same in both periods (56% vs. 44%). The share of Whites has decreased by 12 percentage points, whereas Blacks and Latinx have increased by about 5 percentage points, each. Compared with the first period (1996-2006), the percentage of adults with at least a high school education increased in the second period (2008-2018). The percentage of adults with ADL disability has remained stable across the periods.

Table 1 Descriptive characteristics of the sample

	1996–2006		2008–2018	
	n = 27,461	%	n = 29,374	%
Age (average)	69.1		69.3	

Women	15,378	56	16,581	56
Men	12,083	44	12,793	44
White	20494	75	18388	63
Black	4040	15	5815	20
Latinx	2318	8	3986	14
Less than high school	7,864	29	6026	20
High school/general equivalency degree	9,382	34	9790	33
Some college	5,394	20	7223	25
College or above	4,821	17	6335	22
ADL disability	9480	35	10306	35
Number of deaths	6795		7141	
Person-years	114,863		117,773	

Source: 1998–2018 Health and Retirement Study

Trends in the lifetime risk of disability

Table 2 shows the trends in lifetime risk of disability at age 50, conditional on being healthy at that age, across the periods of 1996-2006 and 2008-2018. For the overall population, there is no significant change in the lifetime risk of disability across the periods. Three out of four Americans, who are not disabled at age 50, are expected to experience disability in their remaining life expectancy, irrespective of the period. By gender, only men experience a significant increase in the lifetime risk of disability of (70% - 66% =) 4 percentage points.

Table 2. Trends in the lifetime risk of disability at age 50 in the U.S. with 95% confidence intervals (in parentheses)

Period	*1996-2006*	*2008-2018*
Total	75 (74, 76)	76 (75, 77)
Gender		
Women	82 (81, 83)	81 (79, 82)

Men	66 (65, 68)	70 (68, 71)
Race/ethnicity		
White	74 (72, 75)	74 (72, 75)
Black	80 (78, 82)	78 (76, 81)
Latinx	85 (82, 88)	87 (85, 89)
Educational attainment		
Less than high school	83 (81, 85)	84 (82, 86)
High school/general equivalency degree	75 (73, 76)	77 (76, 79)
Some college	74 (71, 76)	76 (74, 78)
College or above	67 (64, 70)	68 (65, 71)

Source: 1996–2018 Health and Retirement Study

Whites experience no change in the lifetime risk, with Blacks and Latinx experiencing a non-significant decrease and increase, respectively. Apart from adults with HS/GED education, who experience a significant increase of two percentage points, no other educational categories experience significant changes in the lifetime risk of disability.

Trends in the mean age at onset of disability

Table 3 shows trends in the mean age at first incidence of disability, conditional on being healthy at age 50, across the periods of 1996-2006 and 2008-2018. For the overall population, the mean age at onset of disability has increased significantly by (66.9 – 66.0 =) 0.9 year across the periods. Women experience a slightly greater postponement in the age at onset than men (1.1 vs. 0.8 year).

Table 3. Trends in the mean age at onset of disability in the U.S. with 95% confidence intervals (in parentheses)

Period	*1996-2006*	*2008-2018*
Total	66.0 (65.6, 66.4)	66.9 (66.5, 67.4)

Gender		
Women	65.8 (65.3, 66.3)	66.9 (66.4, 67.5)
Men	65.7 (65.3, 66.2)	66.5 (66.0, 67.1)
Race/ethnicity		
White	67.0 (66.6, 67.3)	68.1 (67.7, 68.5)
Black	62.1 (61.4, 62.7)	63.0 (62.4, 63.6)
Latinx	64.4 (63.4, 65.3)	64.3 (63.5, 65.2)
Educational attainment		
Less than high school	60.8 (60.2, 61.4)	60.3 (59.7, 61.0)
High school/general equivalency degree	65.5 (65.0, 66.1)	65.6 (65.1, 66.1)
Some college	66.8 (66.2, 67.5)	67.1 (66.5, 67.8)
College or above	70.8 (70.0, 71.5)	72.6 (71.9, 73.3)

Source: 1996–2018 Health and Retirement Study

Over this period, Whites and Blacks experienced a significant postponement of 1.1 and 0.9 year in the mean age at first incidence of disability, respectively, with the White-Black disparity remaining stable at around 5 years. However, the age at onset has remained almost stable for Latinx at about the age of 64, increasing the White-Latinx disparity from 2.6 to 3.8 years. College or above educated adults experience a significant postponement of about two years (from 70.8 years to 72.6 years) in the mean age at onset of disability. However, some college and HS/GED educated adults experience the first incidence at around the age of 67 and 65.5 years, respectively, in both periods. Less than high school educated adults experience a decrease, although insignificant, in the mean age at onset of disability.

Trends in total life expectancy (TLE), disability free life expectancy (DFLE), and disabled life expectancy (DLE) at age 50

Table 4 shows trends in TLE, DFLE, and DLE across the periods of 1996-2006 and

2008-2018. For the overall population, TLE[2] at age 50 has increased by (31.5 - 30.4 =) 1.1 years across the periods. DFLE has increased significantly by 0.9 years from 24.9 to 25.8 years. There is a small but insignificant increase of 0.2 year in DLE at age 50. Therefore, most of the increase in TLE between the periods is in DFLE (82%).

The TLE at age 50 for women, as expected, is significantly greater than that of men. However, men experience a greater increase in TLE than women (1.5 vs. 0.7 years). Consequently, the gender disparity in TLE has narrowed from 4 to 3 years between the periods. The increase in DFLE (0.9 year) is the same for both women and men. While men experience a significant increase of 0.6 year in DLE, women experience a slight but insignificant decline of 0.3 year. Consequently, the gender disparity in DFLE has persisted at around 1.3 year, whereas it narrowed for DLE from 3 to 2 years.

Table 4. Trends in (unconditional) expectancies at age 50 in the U.S. with 95% confidence intervals (in parentheses)

Period	*1996-2006*	*2008-2018*
Overall		
DFLE	24.9 (24.6, 25.3)	25.8 (25.4, 26.1)
DLE	5.5 (5.4, 5.7)	5.7 (5.5, 5.9)
TLE	30.4 (30.1, 30.8)	31.5 (31.1, 31.8)
Men		
DFLE	24.2 (23.7, 24.7)	25.1 (24.6, 25.5)
DLE	4.1 (3.9, 4.2)	4.7 (4.5, 4.9)
TLE	28.3 (27.7, 28.8)	29.8 (29.3, 30.1)
Women		
DFLE	25.5 (25.0, 25.9)	26.4 (25.9, 27.0)
DLE	6.9 (6.6, 7.1)	6.6 (6.3, 6.9)

[2] Our calculated TLE at age 50 for the total population and men and women are similar to the US National Vital Statistics life expectancy estimates for the reference year 2001 (total: 30.3 years; men: 28.2; women: 32.1) and 2013 (total: 31.6 years; men: 29.7; women: 33.3).

TLE	32.3 (31.8, 32.8)	33.0 (32.5, 33.6)
Whites		
DFLE	25.8 (25.4, 26.1)	26.8 (26.5, 27.2)
DLE	5.1 (4.9, 5.3)	5.0 (4.9, 5.2)
TLE	30.9 (30.5, 31.2)	31.8 (31.5, 32.2)
Blacks		
DFLE	19.6 (18.8, 20.4)	20.8 (20.0, 21.7)
DLE	7.3 (6.8, 7.9)	7.4 (6.9, 7.8)
TLE	26.9 (26.0, 27.9)	28.2 (27.2, 29.2)
Latinx		
DFLE	24.0 (22.9, 25.2)	23.9 (23.0, 24.9)
DLE	7.7 (6.9, 8.4)	9.4 (8.7, 10.1)
TLE	31.7 (30.4, 33.0)	33.3 (32.2, 34.3)
Less than high school		
DFLE	19.1 (18.5, 19.8)	18.2 (17.4, 19.0)
DLE	7.4 (7.1, 7.8)	8.3 (7.8, 8.7)
TLE	26.5 (25.8, 27.4)	26.5 (25.6, 27.3)
High school/general equivalency degree		
DFLE	24.9 (24.4, 25.5)	25.0 (24.5, 25.5)
DLE	5.7 (5.4, 5.9)	5.9 (5.6, 6.1)
TLE	30.6 (30.0, 31.2)	30.9 (30.3, 31.4)
Some college		
DFLE	26.1 (25.4, 26.8)	26.0 (25.3, 26.6)
DLE	5.2 (4.8, 5.5)	5.8 (5.5, 6.1)
TLE	31.3 (30.5, 32.1)	31.8 (31.1, 32.4)
College or above		
DFLE	29.1 (28.3, 29.8)	30.9 (30.3, 31.5)
DLE	4.1 (3.8, 4.5)	4.3 (4.0, 4.7)
TLE	33.2 (32.4, 34.0)	35.2 (34.6, 35.9)

Source: 1996–2018 Health and Retirement Study

Latinx (1.6 years) and Blacks (1.3 years) experience a greater increase in TLE at age 50 across the periods than Whites (0.9 year). However, DFLE has remained almost stable for Latinx and increased only for Whites (1 year) and Blacks (1.2 years). Consequently, almost all of the increase in TLE for Whites and Blacks is in DFLE. In contrast, DLE at age 50 has increased by 1.7 years for Latinx. Thus, they live all their additional life years with disability. Consequently, the White-Black disparities in DFLE and DLE have remained stable at around 6 and 2 years, respectively. In contrast, the White-Latinx disparity in DFLE has increased from 1.7 to 2.9 years, and that in DLE has increased from 2.6 to 4.3 years.

The TLE at age 50 has increased significantly for college or above educated adults from 33.2 to 35.2 years across the periods. Of this increase, (30.9 – 29.1 =) 1.8 years (90%) are in DFLE and the increase in DLE is insignificant. However, HS/GED and some college educated adults experience no significant change in TLE and DFLE, widening their disparities with college or above educated in these indicators. In contrast, less than high school educated adults experience a reduction of about 1 year in DFLE and an increase of equal magnitude in DLE, with TLE remaining stable at 26.5 years. In addition to the lowest educated, some college educated adults also experience an increase of 0.6 year in DLE. Consequently, the disparity between less than high school educated and college or above educated in TLE has increased from about 7 to 9 years across the periods. The disparity between these two subgroups in DFLE exceeds that of in TLE, increasing from 10 years to 13 years.

Trends in recovery and mortality for adults disabled at age 50

Table 5 shows trends in recovery and mortality for adults who reach age 50 with disability across the periods of 1996-2006 and 2008-2018. Overall, total life expectancy of those reaching their middle age with disability has increased by 0.8 year and 0.6 out of this 0.8 year is lived free of disability.

Compared with women who live all of their additional life years healthy, men live about 54% of their additional years with disability. Whites and Blacks live the majority of the added years disability free. However, the increase in TLE is all concentrated in DLE for Latinx and the pace of increase in DLE (2 years) even exceeds that of TLE (1.7 years).

There exist substantial educational disparities in recovery and mortality dynamics for those disabled aged 50. For college or above educated adults, more than 80% of the increase in TLE (2.1 years) is concentrated in DFLE (1.7 years). However, we observe almost stagnation in TLE for all the lower educated subpopulations. Less than high school and some college educated adults, especially the former, experience a decline in DFLE and an increase in DLE across the study periods.

Table 5. Trends in (conditional) expectancies for adults disabled at age 50 in the U.S. with 95% confidence intervals (in parentheses)

Period	*1996-2006*	*2008-2018*
Overall		
DFLE	21.1 (20.7, 21.6)	21.7 (21.2, 22.2)
DLE	7.8 (7.5, 8.0)	8.0 (7.7, 8.3)
TLE	28.9 (28.4, 29.4)	29.7 (29.3, 30.2)
Men		
DFLE	20.2 (19.4, 20.9)	20.8 (20.2, 21.4)
DLE	6.3 (6.0, 6.5)	7.0 (6.7, 7.4)
TLE	26.5 (25.7, 27.2)	27.8 (27.3, 28.4)
Women		
DFLE	21.8 (21.2, 22.4)	22.5 (21.8, 23.2)
DLE	9.1 (8.7, 9.4)	8.9 (8.5, 9.3)
TLE	30.9 (30.3, 31.5)	31.4 (30.7, 32.2)
Whites		
DFLE	22.1 (21.6, 22.5)	22.9 (22.3, 23.4)
DLE	7.3 (7.0, 7.5)	7.2 (7.0, 7.5)
TLE	29.3 (28.8, 29.8)	30.1 (29.5, 30.6)
Blacks		
DFLE	15.9 (14.9, 16.9)	17.0 (16.0, 17.9)

DLE	9.4 (8.8, 10.1)	9.7 (9.1, 10.2)
TLE	25.3 (24.1, 26.5)	26.6 (25.5, 27.8)
Latinx		
DFLE	20.9 (19.5, 22.2)	20.6 (19.5, 21.7)
DLE	9.8 (8.9, 10.7)	11.8 (11.0, 12.7)
TLE	30.7 (29.1, 32.2)	32.4 (31.3, 33.6)
Less than high school		
DFLE	15.8 (15.0, 16.7)	14.9 (14.0, 15.8)
DLE	9.4 (8.9, 9.9)	10.3 (9.7, 10.9)
TLE	25.2 (24.2, 26.2)	25.2 (24.2, 26.2)
High school/general equivalency degree		
DFLE	21.1 (20.4, 21.8)	21.1 (20.4, 21.8)
DLE	8.0 (7.7, 8.4)	8.1 (7.7, 8.4)
TLE	29.1 (28.4, 29.9)	29.2 (28.4, 30.0)
Some college		
DFLE	22.3 (21.3, 23.2)	21.7 (20.8, 22.6)
DLE	7.4 (6.9, 7.8)	8.2 (7.7, 8.7)
TLE	29.7 (28.6, 30.6)	29.9 (28.9, 30.8)
College or above		
DFLE	25.4 (24.3, 26.4)	27.1 (26.1, 28.0)
DLE	6.2 (5.7, 6.7)	6.6 (6.1, 7.0)
TLE	31.6 (30.5, 32.7)	33.7 (32.6, 34.6)

Source: 1996–2018 Health and Retirement Study

Trends in the burden of disability by educational attainment among Whites

Lifetime risk of disability for Whites by educational attainment

Figure 2 shows trends in the lifetime risk of disability for Whites with different educational attainment across the periods of 1996-2006 and 2008-2018. Apart from HS/GED educated Whites, no educational subgroup experiences a significant change in the lifetime risk of disability. Whites with HS/GED education experience a three-percentage point increase (77%-74%) in the lifetime risk of disability across the periods.

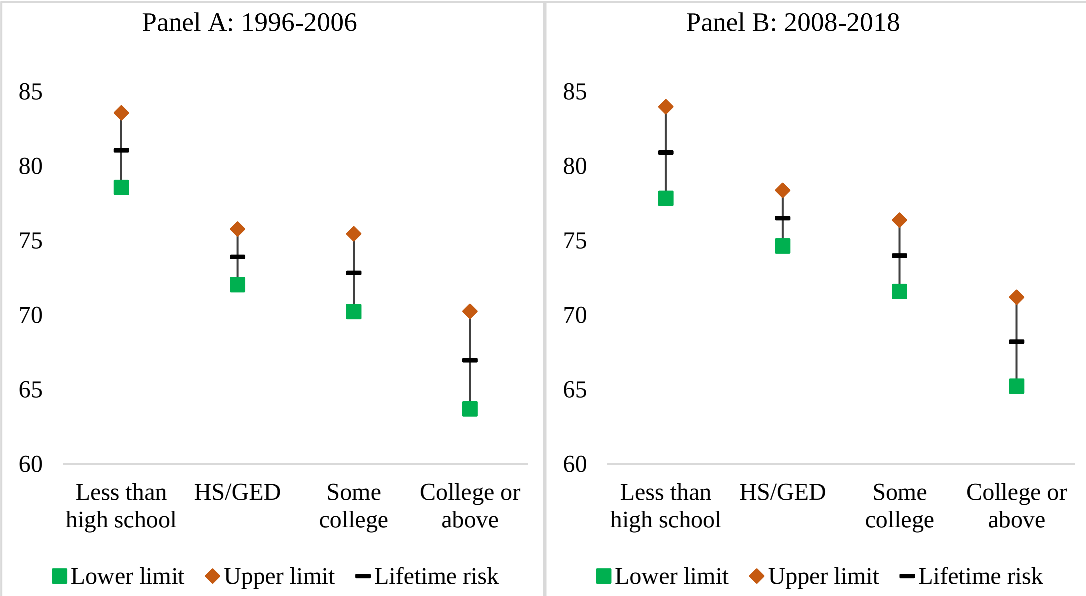

Figure 2. Trends in the lifetime risk of disability by educational attainment among Whites in the U.S. with 95% confidence intervals
Note: HS = High school, GED = General equivalency degree.
Source: 1996–2018 Health and Retirement Study

Mean age at onset of disability for Whites by educational attainment

Figure 3 shows trends in the mean age at first incidence of disability for Whites with different educational attainment across the periods of 1996-2006 and 2008-2018. Only Whites with college or above education experience a considerable postponement of about two years in the mean age at onset of disability across the period. Although some college and less than high school educated Whites experience slight increase and decrease in the age at onset, respectively, the changes are not significant.

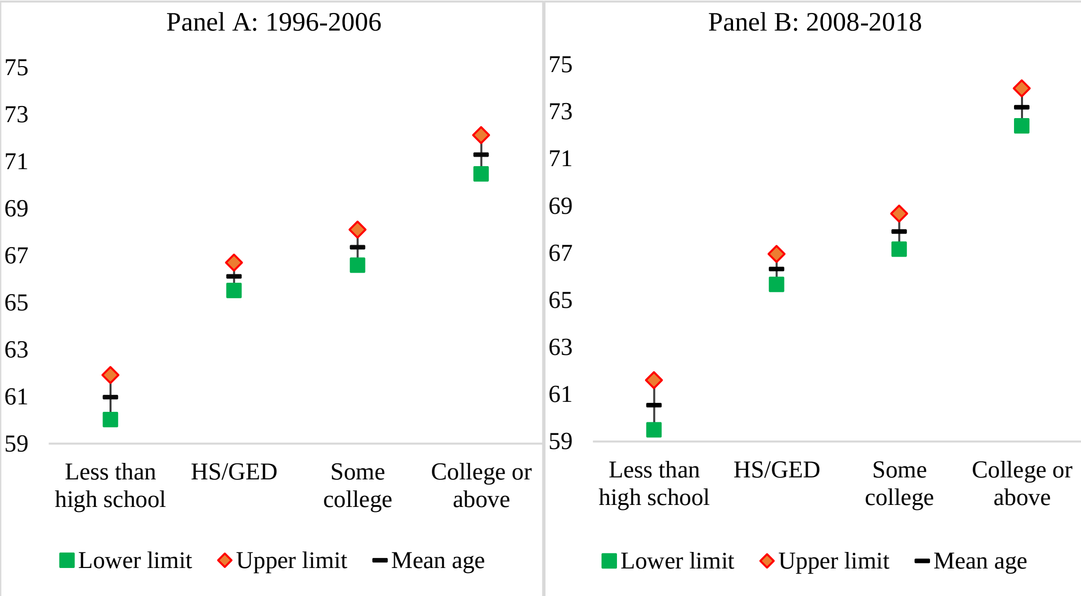

Figure 3. Trends in the mean age at onset of disability by educational attainment among Whites in the U.S. with 95% confidence intervals
Note: HS = High school, GED = General equivalency degree.
Source: 1996–2018 Health and Retirement Study

TLE, DFLE, and DLE at age 50 for Whites by educational attainment

In Table 6, we present the trends in expectancies for Whites by educational attainment across the periods of 1996-2006 and 2008-2018. Apart from college or above educated Whites, no lower educated Whites experience a considerable increase in TLE at age 50. In particular, less than high school educated Whites experience a decline of about 1.3 years in TLE across the period. For Whites with college or above education, all of their increase in TLE (2.2 years) at age 50 is in DFLE (2.2 years), indicating compression of morbidity. In contrast, the loss in TLE for less than high school educated Whites is entirely concentrated in DFLE. Consequently, the disparity between the highest and lowest educated Whites in TLE has increased from about 7 to 11 years, and in DFLE, the disparity has increased from 10 years to 14 years.

Table 6. Trends in (unconditional) expectancies at age 50 by educational attainment

among Whites in the U.S. with 95% confidence intervals (in parentheses)

Period	*1996-2006*	*2008-2018*
Less than high school		
DFLE	19.2 (18.2, 20.2)	17.9 (16.7, 19.2)
DLE	6.7 (6.2, 7.2)	6.8 (6.2, 7.5)
TLE	25.9 (24.8, 27.1)	24.8 (23.4, 26.1)
High school/general equivalency degree		
DFLE	25.4 (24.8, 25.9)	25.6 (25.0, 26.3)
DLE	5.4 (5.1, 5.8)	5.5 (5.2, 5.7)
TLE	30.8 (30.2, 31.4)	31.1 (30.4, 31.7)
Some college		
DFLE	26.5 (25.8, 27.3)	26.4 (25.7, 27.2)
DLE	4.9 (4.5, 5.3)	5.4 (5.0, 5.8)
TLE	31.4 (30.6, 32.3)	31.8 (31.1, 32.6)
College or above		
DFLE	29.3 (28.5, 30.0)	31.5 (30.8, 32.1)
DLE	4.1 (3.7, 4.5)	4.1 (3.8, 4.5)
TLE	33.4 (32.6, 34.2)	35.6 (34.9, 36.3)

Source: 1996–2018 Health and Retirement Study

Recovery and mortality for Whites disabled at age 50 by educational attainment

In Table 7, we present trends in recovery and mortality dynamics by educational attainment for Whites disabled at age 50 across the periods of 1996-2006 and 2008-2018. Whites with college or above education disabled at age 50 experience significant recovery from disability as all of their increase in TLE (2.3 years) is concentrated in DFLE (2.3 years), again indicating compression of morbidity. Those with HS/GED education experience stagnation in their disability and mortality situation. Adults with some college education experience a significant increase in DLE despite no change in TLE. In particular, Whites with less than high school education disabled at age 50 experience losses in TLE and DFLE, and all their loss in TLE is concentrated in DFLE.

Table 7. Trends in (conditional) expectancies at age 50 by educational attainment for Whites disabled at age 50 with 95% confidence intervals (in parentheses)

Periods	1996-2006	2008-2018
Less than high school		
DFLE	15.6 (14.3, 16.8)	14.4 (12.9, 15.8)
DLE	8.6 (8.0, 9.3)	8.7 (7.9, 9.5)
TLE	24.2 (22.7, 25.7)	23.0 (21.4, 24.7)
High school/general equivalency degree		
DFLE	21.6 (20.8, 22.4)	21.8 (21.0, 22.7)
DLE	7.8 (7.4, 8.2)	7.6 (7.2, 8.0)
TLE	29.4 (28.5, 30.2)	29.4 (28.5, 30.3)
Some college		
DFLE	22.8 (21.8, 23.9)	22.2 (21.1, 23.2)
DLE	7.0 (6.5, 7.5)	7.7 (7.2, 8.3)
TLE	29.8 (28.7, 30.9)	29.9 (28.8, 31.0)
College or above		
DFLE	25.8 (24.7, 26.9)	28.1 (27.1, 29.1)
DLE	6.1 (5.6, 6.6)	6.1 (5.6, 6.6)
TLE	31.9 (30.8, 33.0)	34.2 (33.2, 35.2)

Source: 1996–2018 Health and Retirement Study

Discussion

In a rapidly aging population such as the U.S., information regarding the trends in the burden of disability bears enormous importance. It can play a key role in informing the provision of social and health care for the growing older population vulnerable to adverse health conditions. However, evidence has not been clear in the older U.S. population and prior research is largely based on a single indicator of health expectancy. Also, how the trends vary by the key sociodemographic factors of gender, race/ethnicity, and educational attainment are underexplored. This information is critical in formulating appropriate policies targeted to the highly vulnerable subpopulations (tertiary prevention). Based on a quality nationally representative longitudinal survey of U.S. adults, we derive multiple key indicators from incidence-based discrete-time Markov chain multistate models, which reflect different aspects of the disability burden. We contribute to the population health literature with four major findings.

First, we find no significant increase in the lifetime risk of disability in the overall older U.S. population across the study periods. About 75% of adults, conditional on being healthy at age 50, are predicted to experience disability in their remaining life expectancy in both periods. Subgroup analyses show that only men and adults with HS/GED education experience a significant increase in the lifetime risk of disability. A considerable (two-fold) increase in the odds of disability for men compared with women is observed in a study during the period 2000-2015 (Zajacova and Montez 2017), however, the study is focused on the age group 45-64. Freedman et al. (2007) find that the probability of disability declined for older adult women and increased for older adults with high school education from 1997-2004.

Although the lifetime risk of disability has remained stable in the older U.S. population, due to substantial population aging, the number of adults with disability is likely to increase considerably. This is likely to increase pressure on family members and society for the provision of health care considerably. About 40% of adults with difficulty in one ADL and 90% of adults with difficulty in at least three ADLs require caregiving assistance (Johnson and Wiener 2006). This raises major concerns about meeting the healthcare needs of older Americans with disability. For instance, most of the U.S. adults with disability live in the community, and one in three experience adverse consequences because of an unmet need (Freedman and Spillman 2014). Ankuda et al. (2020) report that a large percentage of U.S. adults report getting no assistance despite experiencing disability in their ADLs.

Second, most of the increase in TLE at age 50 is in DFLE, whereas DLE increased insignificantly. Across the periods, we observe a postponement in the age at onset of disability. Further, although the survivability of the disabled has increased significantly over the years, they live the majority of the additional years free of disability. All these processes may explain, in part, why almost all of the increase in TLE is concentrated in years free of disability. The increase in DFLE along with the increase in TLE and a postponement of disability are in accord with the theory of compression of morbidity as well as dynamic equilibrium. However, compression of morbidity predicts a decline in DLE, whereas dynamic equilibrium predicts an increase. Compression of morbidity also suggests that the share of TLE free of disability will increase. We find an increase in DLE over the years, although insignificant, and the share of DFLE in TLE has remained almost stable. Thus, for the overall older population, we find some evidence of dynamic equilibrium.

Third, we find notable sociodemographic variations in the trends in the burden of disability in the older U.S. population, leading to variations in terms of which scenario (compression, expansion, or dynamic equilibrium) is emerging by key population subgroups. Variations in the trends in disability burden indicate inequality in health progress.

Men experience a more than two-fold increase in TLE at age 50 than women, narrowing the gender disparity in mortality. DFLE has increased for both women and men. However, for women, the pace of increase in DFLE exceeds that of TLE. Women experience a greater postponement in the onset of and recovery from disability than men, and women with disability aged 50 experience a considerably lower decline in mortality than their men counterparts. This may lead to women's increase in DFLE exceeding their increase in TLE, increasing the share of DFLE in TLE. On the other hand, men disabled at age 50 live more than half of their additional years with disability. This lower recovery for the disabled, in addition to men's greater increase in TLE and increase in lifetime risk, may translate into a significant increase in DLE for men, decreasing the share of DFLE in TLE.

The increase in DFLE and DLE with increasing TLE and a postponement in the age at onset of disability for men are in accord with dynamic equilibrium. For women, the increase in DFLE and a slight but insignificant decrease in DLE with increasing TLE and a postponement in the age at onset of disability are mostly in accord with compression of morbidity. Further research is warranted to investigate the underlying mechanisms leading to a variation in the trends in disability burden for women and men. For instance, the socioeconomic disparity between men and women may be narrowing at older ages or women may increasingly live in environments that are more supportive to their daily life activities compared to men. A study also suggests greater rates of increase in chronic conditions for men than women, such as hypertension, which is associated with disability (Wu et al. 2007), between 2000 and

2014 (Tsai 2017).

The greater increase in TLE at age 50 for Blacks and Latinx has narrowed the Black-White and increased the Latinx-White disparities in mortality. Whites and Blacks both experience postponement in the age at first incidence of disability. Whites and Blacks disabled at age 50 also experience considerable recovery from disability as most of the increase in TLE is concentrated in DFLE. This may lead to an increase in DFLE as well as its share in TLE for Whites and Blacks across the period. In contrast, Latinx experience no change in the age at onset of disability. Latinx disabled at age 50 experience a greater increase in survivability than their White and Black counterparts. Importantly, their increase in DLE even exceeds their increase in TLE, indicating worsening of health for Latinx who reach middle age with poor health. These processes may translate into an increase in DLE and a decline in the share of TLE lived disability free for Latinx.

Although both Whites and Blacks experience a postponement in the onset of disability and an increase in DFLE, the White-Black disparities have persisted across the periods. The situation is more concerning for White-Latinx disparity, which has widened over the years due to the worsening of health for Latinx. Notably, Blacks and Latinx are the growing subpopulations in the U.S., especially the latter, and their share is expected to increase to 43% by 2060 (Jones et al. 2021; Vespa et al. 2018). The persistent or widening racial/ethnic disparities combined with the growing share of minority subgroups may adversely affect the overall health progress of the older U.S. population, affecting national health indicators. Therefore, continuous monitoring of the burden of disability for minority subgroups is warranted.

The delayed onset of disability, increased DFLE and slight (although non-significant) decline in DLE with increasing TLE provide some support to compression of morbidity for Whites. We find some evidence of dynamic equilibrium for Blacks as they experience a delayed onset of disability, increased DFLE, and a slight (although non-significant) increase in DLE with increasing TLE. In contrast, the findings for Latinx are mostly in accord with the expansion of morbidity as they experience almost no change in the age at onset of disability and DFLE but experience an increase in DLE with increasing TLE.

College or above educated adults experience a considerably greater increase in TLE than some college or HS/GED educated adults, with less than high school educated adults experiencing stagnation in TLE. This substantially increases the educational disparities in mortality in the older U.S. population, especially between the highest and lowest educated. The educational disparities in disability have become wider than that of mortality over the years. Only college or above educated adults experience an increase in DFLE, a delayed onset of disability, and recovery from disability. In contrast, the DFLE even decreases for less than high school educated adults, and they, along with some college educated, experience an increase in DLE. In other words, only college or above educated adults have been able to considerably gain both quantity and quality of life across the periods.

The findings, thus, provide some support to the theory of dynamic equilibrium for college or above educated. It is difficult to draw a clear conclusion about exactly which scenario is emerging for the lower educated. This is because the lower educated adults have not experienced a significant increase in total life expectancies across the period and all these three theories hypothesize that total life expectancy increases significantly over time.

There may be multiple factors that contribute to the declining burden of disability in the older U.S. population. For instance, chronic diseases known to be important causes of disability, such as arthritis, vision impairment, and cardiovascular disease, have become less disabling over time (Freedman et al. 2007; Schoeni et al. 2008; Schoeni et al. 2009). For instance, increases in joint-replacement surgeries and antirheumatic drug use may lead to a reduction in disability related to arthritis (Kurtz et al. 2005; Ward and Fries 1998). Stroke is an important cause of disability and about half of the stroke survivors experience ADL disability (Crichton et al. 2016; Murray et al. 2015). In recent decades, the incidence of stroke has declined in the older U.S. population (Koton et al. 2020). However, the prevalence of obesity has increased considerably in the older U.S. population (Hales et al. 2020; Parikh et al. 2007). The prevalence of diabetes has also increased in recent decades and is expected to increase in the years to come (Lin et al. 2018). Although the prevalence of obesity and diabetes has increased, the availability of treatments and control of these medical conditions has also increased in the U.S. (Crimmins 2015). This may have weakened the link between these conditions and disability. For instance, Alley and Chang (2007) report no increase in the odds of ADL disability for obese adults aged 60 and over between

1988 and 2004.

Furthermore, a large body of literature suggests that the burden of cognitive impairment, which is a strong risk factor for disability (Andrews et al. 2017; Thomas 2001), has declined in recent decades in the older U.S. population (Crimmins et al. 2016; Langa et al. 2008; Langa et al. 2017). This may contribute, in part, to the declining burden of disability. While the cognitive impairment prevalence declined for older Whites and Blacks during 2002-2012, Latinx experienced no reduction in the prevalence during the period (Chen and Zissimopoulos 2018). This may partly explain the racial/ethnic variations in the trends in the burden of disability observed in this study.

The rise in educational attainment may also explain, in part, the declining burden of disability. The share of older adults in the U.S. with a high school diploma has increased from 72% to 84% and the share of adults with a bachelor’s degree has increased from 17% to 27% from 2003 to 2015 (Federal Interagency Forum on Aging-Related Statistics 2016). Our results suggest that adults with college or more education have the most positive trends in the burden of disability. In a recent study, Fuller-Thomson et al. (2023) report a significant decline in the odds of ADL disability in the older U.S. population in the recent decade, with education playing a substantial role in the decline. The contribution of increasing educational attainment in reducing the levels of disability is also indicated in other research (Schoeni et al. 2008; Martin and Schoeni 2014).

Although there has been an increase in the level of educational attainment in the older U.S. population in recent decades, the present study reveals widening educational disparities in terms of the age at onset of and recovery from disability and DFLE. Prior studies also indicate widening educational disparities in terms of the likelihood of ADL disability between 2000 and 2014/2015, with less than high school educated adults experiencing a significant increase in the likelihood and college or above educated experiencing no significant change (Tsai 2017; Zajacova and Montez 2017). Educational disparities in the burden of disability may reflect disparities in social environment, such as living environment and social support, access to quality health care, lifestyle behaviors (diet, smoking, and drinking), knowledge regarding treatments and prevention, employment status, and income (Krebs-Smith et al. 1995; Pamuk 1999; Ross and Wu 1995; Singh et al. 2011). Less than high school educated adults are experiencing increasing trends in chronic conditions such as hypertension (Tsai 2017). Economic well-being has been compromised in the U.S. in recent decades and the worsening of economic condition has been most pronounced for the lowest educated (Case and Deaton 2015; Montez and Zajacova 2013). This may explain, in part, the growing educational disparities in the burden of disability.

It is important to note that in addition to the changes in the innate ability to function, the trends in the burden of disability may also be influenced by the environmental changes leading to reducing the barriers to functioning (Freedman et al. 2006). The use of assistive technology is increasing (Schoeni et al. 2008), which is likely to improve the ability of adults to function independently. This may lower their probability of reporting difficulties with ADLs (Spillman 2004; Schoeni et al. 2008). For instance, Freedman et al. (2006) found increasing use of assistive technology played a substantial role in the decline in ADL disability during the last decade of the 20th century.

We find considerable disparities in the trends in health even among advantaged Whites. Whites experience the slowest increase in TLE at age 50 compared with Blacks and Latinx. Prior studies also report a surprising increase in mortality among middle- and older-aged Whites during 1999-2014 (Case and Deaton 2015; Shiels et al. 2017), mainly driven by lower educated Whites, who experienced the greatest increase. Although we find that the disability burden has decreased for overall Whites across the study periods, in-depth analyses among Whites reveal that this improvement is largely driven by the college or above educated Whites. Only the college or above educated Whites have experienced considerable postponement in the onset and recovery from disability and increase in DFLE. In contrast, there has been either stagnation or worsening of the health of the lower educated Whites.

Another key finding is that the less than high school educated Whites are an even more disadvantaged subgroup than Blacks and Latinx. Less than high school educated Whites experience a greater lifetime risk of disability than Blacks. Compared with Blacks and Latinx, they have shorter DFLE and TLE and experience an earlier onset of disability. Furthermore, less than high school educated Whites who reach middle age with disability experience substantially worsening situations in terms of disability and mortality. Notably, their disparities with Blacks and Latinx in these key indicators have widened over the years.

Limitations

This study has some limitations. First, the multistate calculation is based on the Markov assumption, according to which the probabilities of transition depend only on the current state and predictors, disregarding the history of state occupancies. This assumption, however, keeps the multistate calculations tractable and is a useful simplification in our case as we focus on the estimation of population-level characteristics only (e.g., expectancy, which is a summary measure), not on predicting individual trajectories, for which the assumption may be problematic.

Second, the metrics derived from the multistate models are based on the assumption that the transition probabilities during a period (e.g., 1996-2006) hold throughout the lives of the members of a synthetic cohort (known as the period perspective). This indicates that the results based on the period perspective do not necessarily reflect the disability burden experienced by actual birth cohorts, for instance, war babies or baby boomer cohorts (Dudel and Myrskylä 2020). However, period perspective does help us measure the sociodemographic disparities in a straightforward manner and is widely used in research studies (Cantu et al. 2019; Dudel and Myrskylä 2020; Dudel and Myrskylä 2017; Freedman and Spillman 2016; Hale et al. 2021). Nevertheless, as mortality and morbidity are strongly related to cohort-specific experiences, examining how lifetime risk of disability, age at onset and recovery from disability, and survivability of the disabled are changing across successive birth cohorts would be potential avenues for future investigations. In a recent study, Payne (2022) compared partial cohort life expectancies and DFLEs across successive birth cohorts.

Third, the assessment of disability is based on self-reported ADL. The HRS does include other versions of ADLs such as 'uses equipment' or 'gets help' in performing the ADLs, which are less subjective than the 'difficulty' version used in this study. However, the 'uses equipment' version is asked for only two ADLs (walking and getting in and out of bed). These questions are asked irrespective of the response to the 'difficulty' questions (Bugliari et al. 2020). Also, the 'gets help' version is only asked of respondents who report 'difficulty' with the corresponding ADLs, identifying a much smaller and more disabled group of adults versus those who simply identify a difficulty (Gill et al. 1998). However, research suggests a significant correlation between self-reported and objective ADL measures (Bravell et al. 2011). Moreover, a substantially large body of research has used self-reported ADLs to assess disability (Cai and Lubitz 2007; Freedman et al. 2013; Mehta and Myrskylä 2017; Payne and Kobayashi 2022; Raymo and Wang 2022; Sauerberg and Canudas-Romo 2022). Nevertheless, future studies may examine whether the patterns observed using self-reported ADL differ from those observed using objective ADL measures.

Finally, we have investigated the educational disparities in the trends in disability burden only among Whites. The small sample sizes in the HRS do not allow us to examine the trends by educational attainment among Blacks and Latinx. These subpopulations have experienced considerable increases in educational attainment in recent decades (Everett et al. 2011; U.S. Census Bureau 2022). Future studies should investigate the trends in the burden of disability by educational attainment for racial/ethnic minority subgroups using a sufficiently large sample to understand whether these trends differ from the pattern observed for Whites.

Conclusions

In conclusion, the trends in mortality and disability have combined to create favorable health conditions for the overall older population in the U.S. in recent decades. However, analyses by key sociodemographic factors reveal the presence of remarkable disparities in health progress in the older U.S. population. In particular, mortality and disability trends translate into worsening health for Latinx and less than high school educated adults. Further investigations reveal that almost all the improvement in health for Whites over the years is driven by the college or above educated Whites. Social disparity in population health is one of the most important public health issues the U.S. is experiencing today. Consequently, to reduce socioeconomic disparities and improve population health, both primary as well as tertiary health interventions need to be targeted towards Latinx and socioeconomically disadvantaged older U.S. Americans to not only delay their onset of disability but also to provide support services as years lived with disability has increased for these subpopulations. Furthermore, particular attention also needs to be given to less than high school educated Whites for whom both quantity as well as quality of life have deteriorated, placing them in a position more vulnerable compared with Blacks and Latinx.

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