Educational Inequalities in Life Expectancy and Disabled Life Expectancy in the U.S.: An Intersectional Cohort Analysis by Race and Sex

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Abstract

Substantial disparities in longevity and disability exist between race, sex, and educational groups in the US. However, little research to date has taken an intersectional approach to simultaneously consider inequalities at the intersection of race, sex, and education. It also remains unclear whether and how these intersectional inequalities have changed across successive birth cohorts. Utilizing data from the US Health and Retirement Study (HRS) from 1998 to 2020, we estimate 22 years of partial cohort life expectancy (LE) and disability-free/disabled life expectancy (DFLE/DLE) by education, race, and sex. We then decompose disparities in DFLE/DLE by education across race-sex groups and examine whether the educational disparities in later-life disability are primarily due to unequal levels of functional impairment at the baseline age, or if they stem from divergent patterns of functional decline across age. Our findings indicate these disparities are primarily driven by differences in the transitions between disability states and mortality. By decomposing educational levels, we highlight key factors contributing to gaps in life expectancy (LE) and disability-free life expectancy (DFLE) between college graduates and those without a high school diploma. The impact of education varies significantly by race and sex across U.S. birth cohorts, advancing the debate on how early-life education affects health disparities in later life.

Keywords: health, education, racial inequality, mortality

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Introduction

Social inequalities in health, disability, and longevity in the US are staggering and pervasive. These inequalities exist along multiple dimensions of stratification, including sex, race, and education. Women typically live longer than men but live a higher proportion of their remaining years in poor health and with disabling conditions (Read & Gorman 2010). White adults generally live longer and healthier lives compared to Black adults, who experience higher risks of premature disability, morbidity and mortality (Hayward & Heron 1999; Phelan & Link 2015; Solé-Auró et al. 2015). There are also educational gradients in life expectancy (LE), disability, and health, with substantial gaps in longevity and healthy life expectancy between individuals with high and low levels of education (Chiu et al. 2016; Chiu et al. 2019; Crimmins & Saito 2001; Meara et al. 2008; Molla et al. 2004; Shen & Payne 2023). In general, research finds that these sex, race, and educational inequalities in health and longevity have widened over historical time (Freedman et al. 2016; Hayward & Heron 1999; Hendi 2015; Phelan & Link 2015; Sasson 2016; Solé-Auró et al. 2015), highlighting the pressing need to identify the determinants of these patterns in order to better inform policy and intervention efforts aimed at reducing inequality.

Despite considerable research on patterns of healthy longevity among sex, racial, and educational groups, two critical gaps remain. First, previous research generally examines sex, race, and educational inequalities separately or in isolation, with little empirical research investigating intersectional inequalities in LE and healthy LE (Shannon et al. 2022). As a result, it remains unclear how sex, racial, and educational stratification intersect to shape patterns of health and longevity. In particular, relatively little research has explored how educational inequalities in healthy longevity may differ by race and sex. Educational inequalities in healthy and total life expectancy may operate differently by sex, and/or within different racial groups. Indeed, research shows that the links between education and health and longevity are not uniform but vary across subpopulations (Boen 2016; DeAngelis et al. 2022; Hayward et al. 2015), suggesting that more research taking an intersectional approach is needed.

Second, research in this area has relied largely on cross-sectional data or assessed period-level changes in subgroup inequalities with less attention to how sex, race, and educational gradients in LE and healthy LE have changed across successive birth cohorts in the US. These period-based approaches make interpreting results challenging as they conflate age and cohort effects (Luy et al. 2020). This period-based approach can produce misleading findings and mask substantial heterogeneity in patterns across cohorts, in particular. In fact, period and cohort approaches have often revealed distinct patterns in life and health expectancies, particularly by race-ethnicity. For example, Case and Deaton (2021) used a period analysis to show that racial gaps in life expectancy between ages 25 and 75 have narrowed over the past three decades. In contrast, Payne (2022) employed a cohort-based approach and found no evidence of narrowing racial/ethnic disparities in life expectancy, diverging from other period-based studies.

In this study, we use data from the US Health and Retirement Study ([HRS] 2024) and an intersectional approach (Bowleg 2012; Shannon et al. 2022) to estimate cohort life expectancy (LE) and disability-free/disabled life expectancy (DFLE/DLE) by educational groups for Black and White adults by sex using an intersectional approach. We argue that focusing on education as a core dimension of stratification is crucial, as the educational landscape in the U.S. has shifted significantly in recent years, with striking changes across birth cohorts. A much larger share of older adults now holds a bachelor's degree or higher than in the past, yet a persistent racial gap remains. Between 2010 and 2020, the percentage of White adults over 45 with a bachelor's degree rose from 28% to 35%, while the proportion of Black adults in the same age group increased from 18% to 26% (US Census Bureau 2010, 2020). Notably, these estimates are further stratified by sex. Among the older white population, males tend to be more educated with about 37% holding a bachelor's degree in 2020, while the proportion of Black females with a bachelor's degree at these ages is slightly higher than Black males, reaching 28% in 2020. While the links between education and health and longevity are well studied (Lynch & von Hippel 2016; Montez & Berkman 2014; Ross & Wu 1995; Shkolnikov et al. 2006), how these links may vary across racial and sex groups, and different birth cohorts, is less well established.

To better understand how these inequalities emerge, shift, and potentially grow over the life course, it is crucial to investigate whether social inequalities in healthy longevity are derived from less advantaged populations reaching older ages with worse health and greater impairment, or result from differences in patterns of onset and recovery from poor health and impairment. Previous studies on health expectancy inequalities have not been able to identify the relative importance of these two factors in producing inequalities in later life health expectancies. Recent advances in multistate decomposition now offer greater insight into the role these components play in shaping inequalities. This methodological progress allows us to identify the relative importance of these factors in producing inequalities in later life health expectancies, a capability that has been lacking in previous studies on health expectancy inequalities across education and racial groups.

Our study focuses on 4 overarching research questions, taking an intersectional view towards investigating educational gradients in health and longevity gaps between Blacks and whites:

1) How do cohort measures of LE and DFLE/DLE compare between Black and white older adults?
2) How do patterns of healthy longevity by sex compare across older cohorts of Black and white adults?
3) How do patterns of healthy longevity by educational groups compare between cohorts of Black and white older adults?
4) How does the educational gradient in healthy longevity compare between older Black and white individuals, and how does this gradient differ by sex?

Investigating these research questions, we find that the impact of higher education on disability and longevity differs substantially by race and cohort. The benefits of higher education for healthy longevity were smaller for older cohorts, especially for Black individuals, but have grown in more recent cohorts. Among older cohorts of Black individuals, having some post-high school education was associated with a substantial increase in total and disability-free life but a completed Bachelors' degree was not. Having a completed bachelor's degree was associated with longer life expectancy among both Black and White individuals in more recently born cohorts. However, the health composition of these additional years differed—among Whites, life expectancy gains from attaining a bachelor's degree were driven by increases in disability-free life, while among Blacks they resulted largely from an increase in life spent disabled. Although higher educational attainment among Black individuals was associated with a longer LE and more lifetime spent disability-free, schooling attainment did not act to close the Black-white gap in longevity, with the largest Black-white gaps in LE arising among those with a bachelor's degree. By exploring LE and DFLE/DLE using a cohort perspective, our research provides a more nuanced understanding of the lived experience of disability and longevity inequalities in the US, potentially informing more effective policies and interventions to promote health equity across diverse populations.

Background

Educational inequalities in health, disability, and longevity

Educational attainment is one of the most important socioeconomic predictors of disability, health and life expectancy, including disability-free life expectancy (DFLE) and disabled life expectancy (DLE) (Hayward & Farina 2023; Link & Phelan 1995; Masters et al. 2015). Research consistently shows that individuals with higher levels of education in the U.S. tend to live longer and spend more of their lives in good health and with fewer impairments than those with lower levels of education (Cantu et al. 2021; Hendi 2015; Montez et al. 2019; Payne 2022). By contrast, lower-educated populations have not only experienced little improvement in DFLE over time, but they have also spent an increasing proportion of years lived with disability, driven by the increased burden of chronic diseases such as diabetes and cardiovascular conditions (Khan et al. 2023; Lam et al. 2024; Shen & Payne 2023).

Historical trends reveal a widening educational gradient in life expectancy (LE) and disability-free life expectancy (DFLE). These disparities both reflect and reinforce structural conditions and inequalities, as education shapes access to resources, employment opportunities, health literacy, and other social determinants of health (Mirowsky & Ross 2003; Ross & Wu 1995). As societies undergo shifts in educational composition and more individuals attain higher levels of education, the factors influencing these inequities may have become more pronounced, contributing to an increase in educational inequalities in life expectancy, health, and disability (Montez & Zajacova 2014).

Education shapes mortality, disability, and health risks through several interconnected channels. Importantly, education is a pathway to secure, well-paying employment (Elias & Purcell 2004). In contrast, individuals with lower levels of education often find themselves in physically demanding jobs that carry higher levels of job insecurity and occupational hazards (Burgard et al. 2009). Beyond direct effects from the employment conditions, more highly educated people typically have access to jobs with higher incomes, which improves health and well-being through a variety of pathways (Hout 2012; Marmot & Wilkinson 2001). Education can also shape life expectancy, health, and disability through social networks (Cohen 2004; House et al. 1988). These networks provide emotional and practical support, reducing stressors and promoting well-being throughout life. Importantly, individuals with higher education are more likely to form partnerships with similarly educated peers through schools or workplaces (Hirschl et al. 2024), which may contribute to educational disparities in health. Finally, education improves access to health promoting information. Despite the accessibility of information in the digital age, navigating and utilizing knowledge effectively often depends on one's social network and cognitive skills (Baker et al. 2011; Hout 2012; Mirowsky & Ross 2003). Individuals with higher education are more adept at finding, analyzing, and applying information to benefit their own health (Saeed & Masters 2021). This informational and cognitive advantage further exacerbates health inequalities, as those with less education face greater challenges in accessing and benefiting from innovations and social welfare.

Heterogeneous educational gradients in health, disability, and longevity by sex and race

Research provides convincing evidence of strong educational gradients in LE and DFLE. However, whether these educational disparities vary within and across sex and racial groups remains less clear. In this study, then, we first consider how sex and racial disparities manifest *within* educational strata. We then assess how educational disparities manifest differently *across* sex and racial groups. While these perspectives are inherently interconnected, each yields distinct insights into educational inequalities in LE and DFLE: the first examines the gradient in subgroup differences controlling for education attainment, while the second considers how educational gradients vary across gender and race groups.

Women tend to live longer and but generally experience higher levels of disease and disability than men (Case & Paxson 2005; Luy & Minagawa 2014; Rieker & Bird 2008). The underlying mechanisms of this paradox are not entirely clear but are believed to reflect a combination of biological and social factors (Luy 2003; Rieker & Bird 2005; Short et al. 2013). Socioeconomic inequalities—including disparities in educational attainment—between men and women are critical pathways underlying sex differences in health (Read and Gorman 2010). While sex differentials in educational attainment have narrowed and even reversed in more recent birth cohorts in the U.S., higher education was relatively rare—and highly selective—among women in older birth cohorts (Goldin 2006), which likely played a key role in producing women's health disadvantage.

Research also suggests that the relationship between education, health, and mortality may also vary by sex. Under the resource substitution and human capital frameworks, education should play a more significant role in women's health because women have fewer socioeconomic resources than men and can therefore benefit more from increases in educational attainment (Mirowsky & Ross 1998; Ross & Mirowsky 2010). However, studies in this area yield mixed results, depending on the specific health outcomes and populations examined (Hamad et al. 2018; Montazeri et al. 2008). Some research indicates that women's health is less sensitive to socioeconomic status (Phillips & Hamberg 2015) producing a less steep educational gradient among women compared to men (Montez et al. 2009). Other findings suggest that the educational gap of women's mortality has widened due to increasing mortality of women without high school education, rather than from substantial declines in mortality among more educated groups (Hummer & Hernandez 2013). Altogether, while research provides clear evidence of educational benefits for both sexes, educational gradients may vary by sex, context, and outcome.

There is also evidence that educational gradients in health and longevity vary by race. Racial disparities in health, disability, and mortality are well documented (Hummer and Gutin 2018). Compared to White individuals, Black people in the U.S. live shorter lives, characterized by higher rates of many chronic and disabling conditions. The social forces underlying these patterns are multifaceted, though racial disparities in socioeconomic resources play a major role (Boen 2016; Boen et al. 2023; Brown et al. 2023; Hayward et al. 2000; Phelan and Link 2015). Relative to White people, Black people have fewer socioeconomic resources, including lower levels of educational attainment (Everett et al. 2011; Kao and Thompson 2003). These disparities are rooted in structural inequalities, including structural racism, and play a central role in generating and maintaining racialized patterns of disease, disability, and death (Geruso 2012; Phelan and Link 2015).

Still, while racial disparities in educational attainment certainly contribute to racialized health, disability, and mortality gaps, growing evidence also indicates that the health and life expectancy gains associated with increases in education vary by race. Evidence of the "diminishing returns hypothesis" shows that the reduction in health and mortality risks associated with increased education are dampened for Black compared to White people, such that racial gaps in health and mortality tend to be widest among highly educated people (Assari 2018; Boen 2016; Brown et al. 2023; Colen et al. 2018; DeAngelis 2022; Gaydosh et al. 2018). There are many possible explanations for this. Because of racism, Black people report higher levels of exposure to stress and discrimination (DeAngelis 2022) and contextual deprivation (Hargrove, Gaydosh, and Dennis 2022) compared to their White counterparts. Further, for much of U.S. history Black people attended segregated and disinvested schools (Walsemann et al. 2023) and faced du jure discrimination in the housing, lending, and labor markets, which restricted the ability of Black people to "translate" increases in education to improvements in income, wealth, and health (Walsemann et al. 2022). Black adults who completed their schooling before the desegregation of schools in the U.S. may have experienced especially low returns to education compared to White people in the same cohorts given stark racial differences in educational quality during these earlier periods (Walsemann et al. 2023). By contrast, educational gradients among more recent cohorts of Black adults—who came of age during an era of educational expansion—may be quite distinct, though these cohort differences are rarely examined empirically. In many ways, the social and educational experiences of Black and White individuals with the same levels of educational attainment were—and continue to be—markedly different, which likely produces racial heterogeneity in the links between education, health, disability, and longevity.

A cohort perspective on inequalities

In this study, we take a cohort-based approach to understanding inequalities in LE and DFLE. Demographic research has long cautioned against the challenges of interpreting period life expectancy (Luy et al. 2020). However, due to data limitations and the relative simplicity of period-based estimations, most studies focus on period results. The key issue with period estimates is that they do not reflect actual individual experiences over time. Lauderdale (2001) suggests that, from a period perspective, the effect of education on survival decreases slightly with age. In contrast, a cohort perspective reveals a clear increase in this effect over time. Similarly, Masters et al. (2012) use an age-period-cohort model to demonstrate that changes in educational inequality stem mostly from cohort effects. Their findings further emphasize that educational expansion is best understood as a cohort-driven process.

The difficulty in interpreting period life expectancy estimates by educational groupings largely derives from the substantially different processes of selection into educational groupings that occurred across successive cohorts during educational expansion. This expansion occurred at different times for different cohorts, meaning that the accessibility, and significance, of higher levels of educational attainment varies sharply over cohorts. For older cohorts in the U.S., high-school completion was seen as sufficient schooling for most occupations when they were in early life, and access to college education was limited. As norms and expectations around schooling changed in the later part of the 20th century, a much greater proportion of more recently born cohorts went on to complete at least some tertiary schooling (Thelin 2004). Given that schooling is generally completed by early adulthood, this means that period estimates of life expectancy by level of education group older individuals, for whom higher education was quite rare and selective, with younger individuals where a much larger fraction went on to complete higher education. These same processes, in reverse, play out among those who did not attain their high-school diploma, as share of the population dropping out of high school has declined markedly over cohorts (McFarland et al. 2020). These issues with interpreting period-based educational inequalities in life expectancy are further complicated when also considering sex and race differences. As described, educational expansion not only occurred at different times for different cohorts, but also varied within cohorts by sex and race, further highlighting the need for a cohort-based, intersectional approach to understanding inequalities in LE and DFLE.

Data and Method

Data

Data for this study is drawn from the US Health and Retirement Survey (HRS), a biennial national longitudinal survey (Sonnega et al. 2014). The HRS is a longitudinal survey of older adults in the US. Our analysis utilized the RAND HRS Longitudinal File 2020 (V2) (HRS 2024). We focused on data from 1998 to 2020 to estimate cohort life expectancy across different educational groups for three birth cohorts—1938-1947, 1928-1937, and 1918-1927—who were, on average, 55, 65, and 75 years old in 1998, respectively. The estimated cohort life expectancy should not exceed 22 years given the time range of the observation period.

Measures

Educational attainment was classified into four distinct levels: less than a high school diploma (<HS), high school graduate or equivalent (HS, including GED), some college experience (Col), and a bachelor's degree or higher (Bac). The analysis focused on two primary racial groups: non-Hispanic White and non-Hispanic Black individuals, as small sample sizes for other racial and ethnic groups prevented their inclusion in the study. Detailed information on gender, education, and race for each cohort is provided in Supplementary Table A. Typically, each individual is observed across multiple waves; however, the sample size is relatively small for the oldest cohorts (1918-1927), particularly among Black men with higher levels of education. Individuals missing data on gender, race, or education were excluded from the analysis, with fewer than 10 individuals missing any demographic information in each cohort.

Disability is defined as difficulty in performing basic daily activities as measured by the Activities of Daily Living (ADL) scale (Katz et al. 1963), including tasks such as bathing, dressing, eating, transferring in and out of bed, and walking across a room. Individuals with no limitations were classified as "disability-free (DF)," while those with one or more limitations were classified as "disabled (D)." Mortality is captured by the register linkage provided by the HRS.

Multistate modelling

We use a discrete multistate model with multinomial regression to estimate population-based partial cohort life expectancy (LE), as well as disability-free and disabled life expectancies (DFLE/DLE) by educational attainment for four subpopulations (non-Hispanic White males, non-Hispanic Black males, non-Hispanic White females, and non-Hispanic Black females) across three birth cohorts. Given that some subgroups in the oldest birth cohort have smaller samples, we pool all cohorts together in the multinomial regression to borrow strength. The regression includes several covariates, including age, age-squared, sex, birth cohorts, educational attainment, race, and interaction terms among these factors. All coefficients within the models are statistically significant. The sample weight used is the person-level analysis weight available in the HRS dataset at each individual's first wave of observation. To address potential bias from differential attrition over time, we generate an individual-level attrition weight at each wave, which uses inverse probability weighting to adjust for individuals who do not drop out, considering their age, race, education, and disability status. The final analysis weight used is the product of these two weights (Dugoff et al. 2014; Payne 2022).

The modeled coefficients are then used to generate transition probabilities for each demographic group by age, which serve as inputs for a microsimulation-based multistate life table model (Cai et al. 2010; Shen & Payne 2023). 95% confidence intervals (CIs) are derived through 500 bootstrap resamples from the original dataset. The final point estimates presented in the results are based on the complete dataset. All analyses are conducted using R software (R Core Team 2023).

Decomposition

As discussed above, we calculate life expectancy (LE), disability-free life expectancy (DFLE), and disabled life expectancy (DLE) by educational attainment for four subpopulations across three birth cohorts. We then decompose the gaps between adjoining educational groups, as well as the total gap between the most educated (those with a bachelor's degree) and the least educated (those without a high school diploma), stratified by sex, race, and birth cohort. This process measures the role of two components in generating a difference in LE and DFLE between educational groups (Shen et al. 2023). The first component, which we denote as the **I-effect**, represents the portion of the gap in health expectancies that results from differences in the initial health status between educational groups (i.e., the proportion of each cohort initially disability-free, or disabled). This component can be interpreted as the effect of a difference in cumulative health before the baseline age. The second component, which we denote as the **H-effect**, represents the proportion of the gap in health expectancies that results from differences in the rates of onset and recovery from disability, and rates of mortality, during the ages each cohort is observed. This component can be interpreted as the effect of differences in health transitions over the period of observation.

Results

Our first research question centers on taking a cohort perspective to understanding how healthy longevity compares between older Black and white adults. Table 1 presents these partial life expectancies and health expectancies by cohort, sex, and race, spanning 22 years from the initial age. These partial life expectancies vary across birth cohorts, reflecting different age ranges of observation. When examining the same race across cohorts, the gender health paradox becomes apparent: females tend to live significantly longer than males, but with a greater proportion of their life spent in disabled life expectancy (DLE). As a result, the gender gap in disability-free life expectancy (DFLE) is less pronounced, with Black individuals showing little evidence of a sex difference and White females having slightly higher DFLE than Black males. Across all cohorts and age ranges, White individuals consistently exhibit significantly higher DFLE and total life expectancy (TLE), along with significantly lower DLE, compared to Black individuals of the same sex. These findings align with racial disparities observed in other studies.

[Figure 1 about here]

Figure 1 disaggregates Table 1 by educational attainment, demonstrating systematic variations in life and health expectancy metrics across racial and educational strata (with corresponding data presented in Supplementary Table B). This approach yields three analytical dimensions, which align with our three intersectional research questions: exploring how gender differential stratify by race and education, investigating racial disparities stratified by gender and education, and understanding educational gradients stratified by gender and race. These dimensions provide unique insights into inequalities in LE and DFLE. We find pronounced and consistent racial differentials, as well as heterogeneity in the gender differentials, across educational categories. Higher educational attainment consistently corresponds to longer DFLE and TLE and decreased disabled life expectancy (DLE). The most striking contrast is observed between White individuals with bachelor's degrees, who consistently have the highest life expectancy, and Black individuals with less than high school education, who generally have the lowest.

Racial differences by level of educational attainment exhibit some substantial variations across birth cohorts. Among the oldest cohorts (those born 1918-1927 and 1928-1937), the largest gaps in TLE and DFLE generally arise between Black and white individuals with a Bachelors' degree or more, and TLE differences in other educational groups are not statistically significant. In the youngest cohort in our study (those born between 1938 and 1947), TLE differences are more consistent across educational groups.

Moreover, the ratio of non-disabled to disabled years demonstrates a positive association with educational attainment, with more educated groups and White populations exhibiting a higher proportion of life spent disability-free, indicating education's dual role in both longevity and disability prevention. However, this association demonstrates notable deviation among Black populations, indicating potential interaction effects. The next step of the analysis examines these differentials systematically and investigates the role of educational attainment as a mediating factor for the life expectancies in different health states.

Sex and educational inequalities

Our exploration of research question 2, focusing on understanding sex and educational inequalities in healthy longevity among older Blacks and whites, is presented in Figure 2. We find that women consistently experiencing longer disabled life expectancy (DLE) and total life expectancy (TLE) than men across all education levels, racial groups, and cohorts—echoing the patterns observed in Table 1. When examining education levels, the gender gap in TLE is generally smallest among individuals with a bachelor's degree, regardless of race or cohort. The gender gap in DLE is most pronounced among the least educated group (<HS), while other education groups show relatively smaller differences. The patterns for disability-free life expectancy (DFLE) are less clear. Among Black individuals, gender differences in DFLE are often non-significant or even slightly negative in the younger cohorts. For White women, however, having a high school diploma or some college education is associated with a longer DFLE compared to their male counterparts.

[Figure 2 about here]

In short, a college degree appears to have a stronger protective effect on mortality for men than for women, leading to the smallest gender gap in TLE. Racial patterns also emerge. Among White women, the mortality advantage of having a high school diploma or some college education comes primarily from longer DFLE. For Black women, however, the gender gap in TLE is largely driven by their longer time spent living with functional disability.

More broadly, the education gradient in the gender gap is not as distinguishable as the education gradient in life expectancy seen in Figure 1. These results suggest that even within the same race and education level, the lived experiences of men and women differ, and their selection into these education groups may also follow different patterns. Furthermore, while the gender gap in mortality by education shares some similarities between Whites and Blacks, there are stark racial differences in how DFLE and DLE contribute to these gender gaps in TLE.

Race and educational inequalities

Figure 3 highlights racial disparities in life expectancy across educational levels, aligning with our third research question. While Whites consistently have higher DFLE and lower DLE compared to Blacks, the magnitude of these racial gaps varies non-monotonically across levels of educational attainment. Among recent cohorts, we find a pronounced educational gradient in racial disparities among women, with higher education associated with diminishing gaps in both DFLE and DLE. The racial gap in TLE is higher among those with bachelor's degrees and typically smaller among those with some college education, a pattern consistent across genders. Notably, the racial gap in DFLE is smallest among men with some college education, while the DLE gap is smallest among those holding bachelor's degrees.

Stratifying by sex introduces an additional layer of complexity to these racial disparities. If we look at gaps in TLE, there is little difference between women and men. However, there is a sharp difference between men and women if we investigate life spent with disability. Among women, racial gaps in both DFLE and DLE maintain statistical significance across all educational categories, with White women consistently experiencing longer disability-free periods and shorter disabled periods. In contrast, men exhibit more modest racial differentials, with gaps in DLE mostly non-significant. This pattern suggests a particular advantage for White women in disability compression – they not only live longer without disability but also experience shorter periods of disability compared to Black women at equivalent educational levels. This finding aligns with the gender differentials observed in Figure 2, which reveal a distinct racial gap by sex: Black women's mortality advantage over Black men manifests primarily through extended periods of disability with minimal DFLE differences across educational strata, whereas White women, particularly those with high school or some college education, live more disability-free years compared to their male counterparts.

In short, the racial gap in DFLE does not diminish with higher education, particularly among older cohorts (born 1928–1937 and 1918–1927). In contrast, racial gaps in DLE tend to be smaller for individuals with a bachelor's degree, suggesting that the university degree may reduce DLE more significantly for Black individuals than for White individuals. Notably, the group with some college education exhibits the smallest racial gap in both DFLE and TLE. The reasons behind this pattern, as well as a more detailed comparison of education gaps, will become clearer in the next section.

Educational inequalities by sex and race

Education demonstrates a consistent positive association with life expectancy across all demographic subgroups (Figure 1). To explore educational inequalities in LE, DFLE, and DLE in line with our fourth research question, Figure 4 presents two key metrics: the incremental gaps between adjacent educational levels and the total educational gap between those with a bachelor's degree and those with less than high school attainment (Bac-<HS). The sum of incremental gaps corresponds to the total educational gap, depicted on the left side of the dashed line. our analysis reveals consistent positive differentials in DFLE and predominantly negative differentials in DLE across educational comparisons, with the educational gradient manifesting most prominently in DFLE.

We find notable patterns across demographic groups. The magnitude of educational effects on DFLE remains relatively consistent across racial and sex categories. However, distinctive patterns emerge in DLE, where the educational gradient among Whites is somewhat smaller than that of Black individuals. This consequently leads to larger educational gaps in TLE between the highest and lowest educated Whites as compared to Blacks. Males exhibit marginally higher gaps in TLE when comparing individuals with the highest and lowest levels of educational attainment. Despite these variations, the total educational gap demonstrates remarkable consistency across racial and gender categories.

Examination of incremental educational gaps reveals more nuanced patterns. The transition from less than high school to high school graduation (<HS to HS) consistently generates the largest contribution to the total educational gap (<HS to Bac). However,

substantial heterogeneity emerges in the second-largest contributor. White populations, particularly males, demonstrate significant gains from bachelor's degree attainment, manifesting in increased DFLE and decreased DLE—suggesting morbidity compression at higher educational levels.

In contrast, Black populations show minimal health advantages from educational attainment beyond some college, with negligible differences in life expectancy metrics between some college and bachelor's degree holders. This finding is particularly strong in older cohorts (1928-1937 and 1918-1927), suggesting divergent patterns of educational returns over cohorts across racial groups. This pattern appears to have shifted in recent cohorts: younger Black males with bachelor's degrees have a higher DFLE compared to their counterparts with some college, with similar but statistically non-significant trends among younger Black females. These findings challenge assumptions about uniform educational returns across demographic groups and highlight the racial disparity of educational effect in health outcomes.

Decomposing educational differences in disability free longevity

Table 2 presents the results from our decomposition analysis, highlighting the proportion of the total gap in LE, DFLE, and DLE between individuals with a bachelor's degree and those with less than a high school education that is attributable to 1) differences in baseline disability conditions and 2) differences in the multistate transition matrix. Overall, the proportion of the life expectancy gap attributable to cumulative health rarely exceeds 30%. Baseline disability rates tend to contribute more to life expectancy gaps in older cohorts, as initial disability status is more likely to persist throughout the remainder of life at older ages. Overall, we find that the initial health distribution has a greater impact on DFLE for Blacks as compared to Whites. This suggests that inequalities in cumulative health may be wider between Black college graduates and Black individuals with less than a high-school education as compared to their White counterparts. This decomposition is further broken down into differences between adjacent educational groupings in Supplemental Figures S1, presenting the contribution of baseline disability conditions, and Supplemental Figure S2, presenting the contribution of the transition matrices.

Discussion

Inequalities in LE by education, race, and sex are well documented. To date, however, most research on inequalities in life expectancy has considered educational, racial, or sex-based inequalities separately using a period-based approach. In this paper, we used an intersectional and cohort-based approach to examine LE and disability-free/disabled life expectancy jointly by education, sex, and race. Three key findings arise from our analyses.

First, while there are certainly educational gradients in LE, DFLE, and DLE, the benefits of higher education for health and longevity varied across race and sex groups and by cohort. The gaps in the outcomes between individuals with less than a high school education and those who completed high school appears to be relatively consistent across all groups. However, the disparities between high school graduates and those with some college, or a bachelor's degree, differ across subpopulations. For white males, achieving a bachelor's degree is associated with significantly higher DFLE, highlighting both an absolute and relative compression of morbidity and disablement. In contrast, for White females, educational attainment beyond high school does not seem to have a major impact on the outcomes of older cohorts but results in improvements for more recent cohorts. Among Black males and females, having some college education is associated with an advantage in DFLE, though a bachelor's degree does not appear to significantly improve survival or health outcomes above those with some college, particularly for older cohorts.

Second, we find the gender health paradox manifested across all groups: women experience longer total life expectancy, but spend more time with disabilities, as compared to men. This pattern varies by education level, with the gender gap in total life expectancy being smallest among those with bachelor's degrees. However, there is no clear education gradient in the gender gap. Comparing the gender gap by race, the pattern of disability-free life expectancy shows distinct racial differences: Black individuals show minimal gender differences in DFLE, while White women with high school or some college education live more disability-free years as compared to their male counterparts. Importantly, we show that Black women's advantage in life expectancy over Black men results largely from additional years spent disabled, not extended disability-free life.

Third, consistent with previous research, our results show striking racial inequities in LE, DFLE, and DLE. Whites consistently have higher DFLE and lower DLE as compared to Blacks across educational levels. The magnitude of these racial gaps varies non-monotonically with education. Among recent cohorts, an educational gradient in racial disparities arises particularly among women, with higher education associated with smaller gaps in both DFLE and DLE. Notably, individuals with some college education exhibit the smallest racial gap in both DFLE and total life expectancy. The gains associated with increases in education were smaller among older Black cohorts, in particular, but have grown in more recently-born cohorts. Among older cohorts of Black individuals, having some post-high school education was associated with a substantial increase in total and disability-free life, but a completed Bachelors' degree was not associated with a substantial increase in healthy longevity beyond those with some post-high school education. This contrasts to our findings among white individuals, where a clear education gradient in healthy longevity is present across the spectrum of educational attainment in all cohorts.

Our findings underscore the need for a deeper exploration of the social factors driving these disparities in health. To further investigate, we employed decomposition techniques to differentiate between the health effects accumulated from younger ages and the transition probabilities in health status observed in older ages. Our decomposition results underscore that initial health conditions play a larger role in shaping healthy longevity among Black individuals than among whites. However, initial health structure contributes less to the educational health gaps, with most of these disparities being driven by patterns of health transitions. The overall patterns of the educational health gap closely mirror those observed in the transition matrix, particularly in older ages.

For Black individuals, and particularly those in older cohorts, achieving higher educational levels led to limited improvements in health outcomes in later life. Potential explanations for this finding are likely rooted the sociohistorical context when these older Black cohorts came of age, went to school, and entered the labor force. Older Black cohorts in the HRS largely attended schools in the Jim Crow South, characterized by extreme disinvestment and disadvantage (Walsemann et al. 2022). While school desegregation by no means resulted in fully equal or integrated schools, that more recent cohorts of Black adults were exposed, at least partially, to some level of school desegregation, which may have contributed to their greater health and longevity returns to increases in education. The Civil Rights Act of 1964, along with other political and policy actions of the 1960s and 1970s aimed at racial equality, may have also reduced discrimination in the labor, housing, and lending markets, which may have allowed Black adults to more readily translate increases in education to improvements in income, wealth, and health.

One of the more striking set of findings arising from our analyses concerns the extent to which attaining a Bachelor's degree, as opposed to a lower level of tertiary schooling, has a much smaller impact on healthy longevity for Black individuals as compared to whites. For whites, those with some post-secondary education, but no degree, had only minimally higher

LE and DFLE as compared to individuals with a high school diploma. This pattern was markedly different for older Black individuals with some college education, where attending some tertiary schooling was associated with markedly increased healthy longevity beyond those with a high school diploma, but a completed Bachelor's degree was associated with only small health benefits. Older cohorts of Black individuals came into the job market during a period of substantial racial barriers in private-sector employment, and racialized barriers to employment meant that Black individuals with a bachelor's degree may not have been able to find jobs that fit with their higher skills. Our results align with previous research demonstrating that the labor market benefits of higher education for Blacks and whites in these cohorts was substantially different. Indeed, prior work has found that the completing some post-secondary education for Black individuals was more strongly linked to employment in sales and managerial classes as compared to their white counterparts. We posit that this differential occupational patterning may in part be driving the racial differences in the patterning of health and longevity gains across the spectrum of educational attainment

We also find a noticeable lag in the effects of education on health outcomes between genders, where males seem to benefit more from a bachelor's degree from earlier cohorts. In more recently born cohorts, particularly among white females, a bachelor's degree is now associated with higher DFLE. This generational shift may be explained by two potential factors: first, education may have less impact on health outcomes at very old ages, particularly for white women; or second, historically, education had a weaker association with health for females than males, with its effects becoming more pronounced only in more recent generations.

However, many of the cohorts in our analyses would have come into working ages in the mid 1960's through the 1970's, a period where state and federal bureaucracies expanded substantially and affirmative action policies emerged mandating non-discriminatory in hiring processes. These public-sector workplaces provided opportunities for stable "middle-class" employment for Black individuals, often with less discrimination and inequality of opportunity as in the public sector. Additionally, many of these positions did not require a bachelor's degree, and these positions presented opportunities for post-secondary training as part of employment.

Conclusions

Our analyses in this paper focused on understanding patterns of healthy longevity in the US at the intersection of race, sex, and educational attainment. We explore these intersectional patterns of LE and DFLE from a cohort perspective, providing results that directly apply to actual groups of individuals living in the US population. We find that there are substantial differences in the role of education both between Black and white individuals, and across successive cohorts. The health and longevity gradient across educational attainment was smaller among older cohorts, especially for Black individuals, but has grown over successive generations. Those with more years of schooling had longer life expectancies regardless of race, but increased educational attainment did not act to shrink the Black-white life expectancy gap, with the largest difference existing among those with a Bachelor's degree. In addition, the additional years lived among those with higher levels of schooling were spent differently. The life expectancy gains associated with attaining a bachelor's degree came from increases in disability-free life for whites, but for Black individuals these additional years were largely spent with disabilities. Our results provide a detailed picture of both inequalities in longevity and the lived experience of disability in older cohorts of Black and white individuals, demonstrating the importance of continued access to educational attainment as a key determinant of improvements in population health.

Table 1. Partial life and health expectancy by cohort, sex and race

Birth Cohort	Age Range	Sex	Race	DFLE	DLE	TLE
1938-1947	55-77	Female	Black	14.2 (13.6, 14.9)	4.6 (4.1, 5.1)	18.8 (18.4, 19.2)
			White	17.5 (17.2, 17.8)	2.4 (2.2, 2.6)	20.0 (19.8, 20.1)
		Male	Black	14.8 (14.1, 15.5)	2.9 (2.5, 3.4)	17.7 (17.1, 18.3)
			White	17.1 (16.8, 17.4)	2.0 (1.9, 2.2)	19.1 (18.8, 19.3)
1928-1937	65-87	Female	Black	11.4 (10.8, 12.0)	5.0 (4.6, 5.5)	16.4 (15.8, 16.9)
			White	14.7 (14.5, 15.0)	2.9 (2.8, 3.1)	17.6 (17.4, 17.8)
		Male	Black	11.3 (10.6, 12.0)	3.0 (2.7, 3.4)	14.4 (13.7, 15.0)
			White	13.4 (13.1, 13.7)	2.3 (2.2, 2.5)	15.7 (15.4, 16.0)
1918-1927	75-97	Female	Black	6.9 (6.2, 7.6)	4.8 (4.3, 5.4)	11.7 (11.0, 12.4)
			White	9.1 (8.8, 9.4)	3.7 (3.5, 3.8)	12.7 (12.5, 13.0)
		Male	Black	6.7 (5.9, 7.5)	2.8 (2.4, 3.3)	9.5 (8.7, 10.4)
			White	8.2 (7.9, 8.5)	2.6 (2.4, 2.8)	10.8 (10.5, 11.1)

Note: 95% confidence interval in the parentheses.

Table 2. Proportional contribution from the disability distribution at the initial age to the life and health expectancy gaps between Bac and <HS (Bac-<HS), by cohort, sex and race

Birth Cohort	Initial age	Sex	Race	DFLE	DLE	TLE
1938-1947	55	Male	White	15%	21%	11%
			Black	22%	26%	19%
		Female	White	13%	18%	9%
			Black	18%	21%	14%
1928-1937	65	Male	White	11%	25%	8%
			Black	25%	30%	23%
		Female	White	12%	23%	8%
			Black	14%	16%	10%
1918-1927	75	Male	White	24%	62%	16%
			Black	42%	30%	57%
		Female	White	19%	56%	11%
			Black	36%	30%	48%

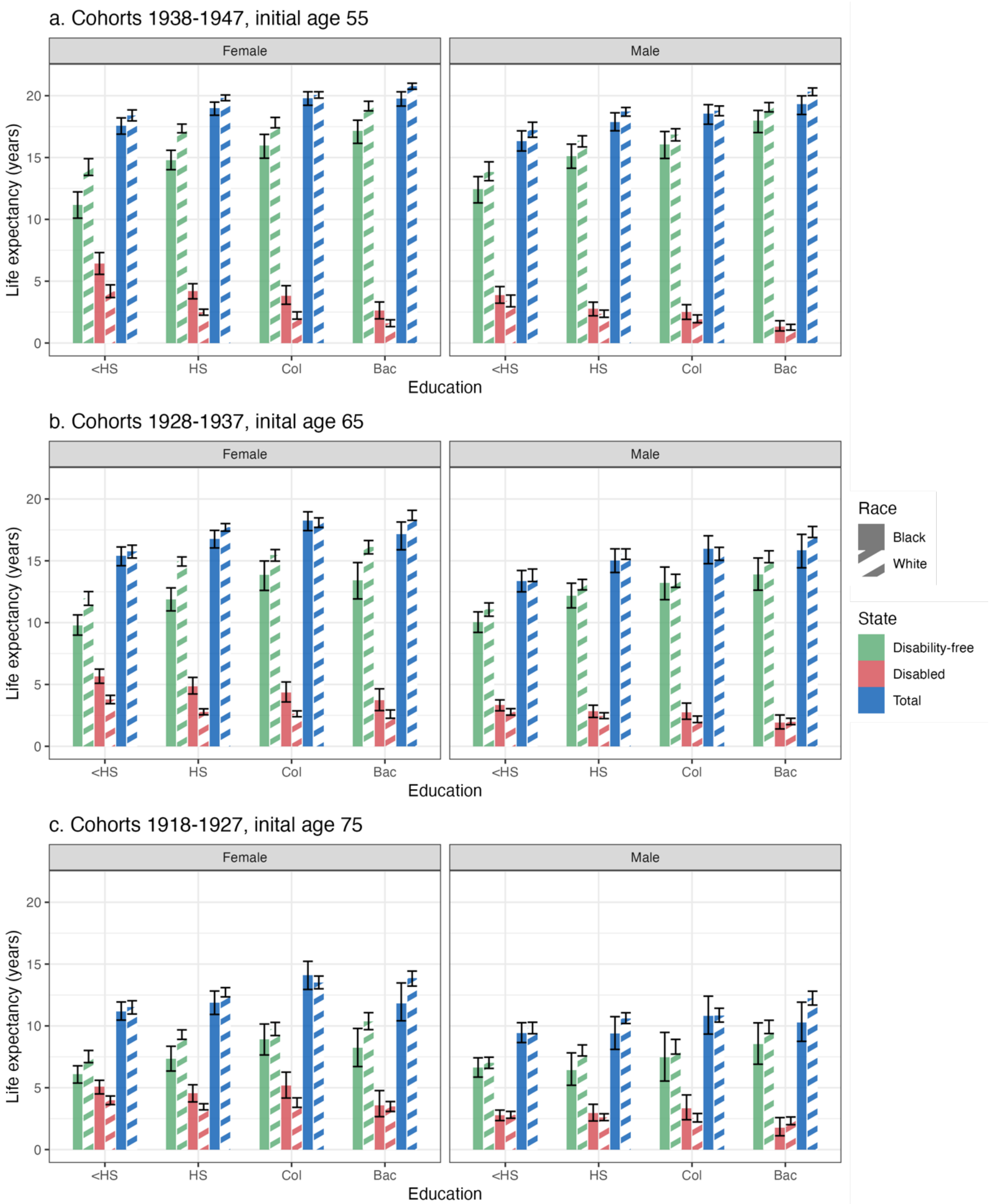

Figure 1. Life expectancies by educational attainment, cohort, sex and race

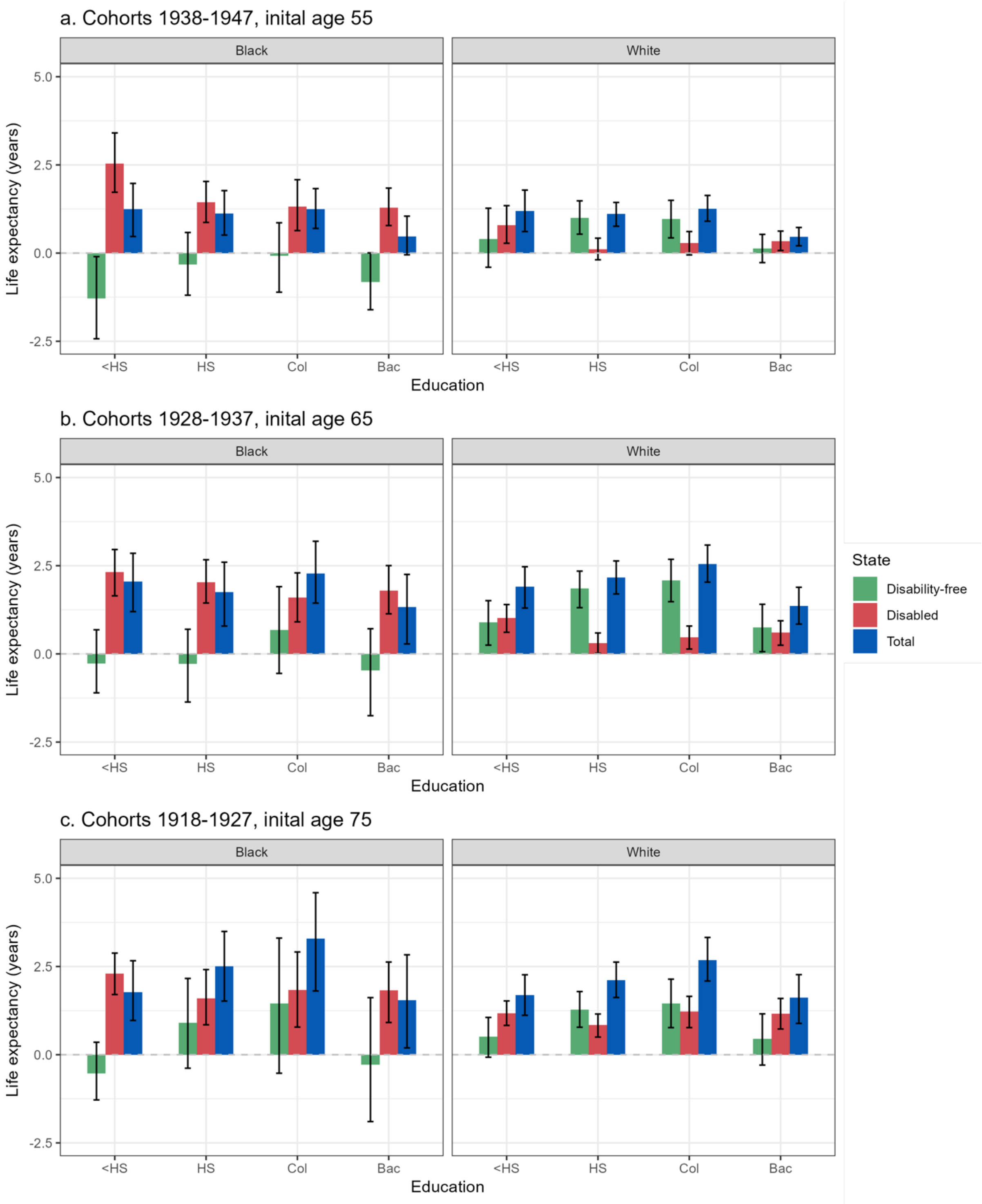

Figure 2. Gender gap (females to males) by educational group, race and birth cohort

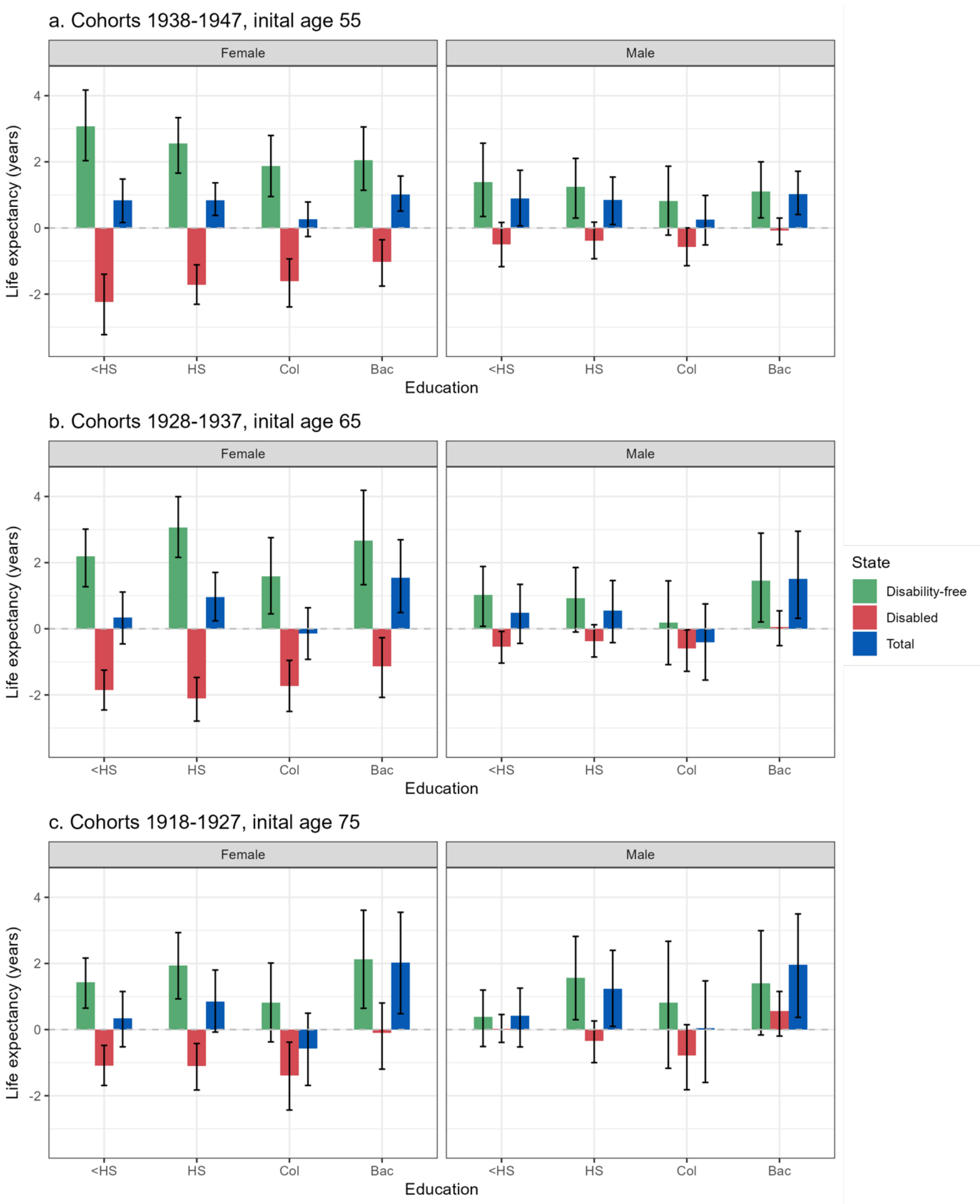

Figure 3. Racial gap (Whites to Blacks) by educational group, gender and birth cohort

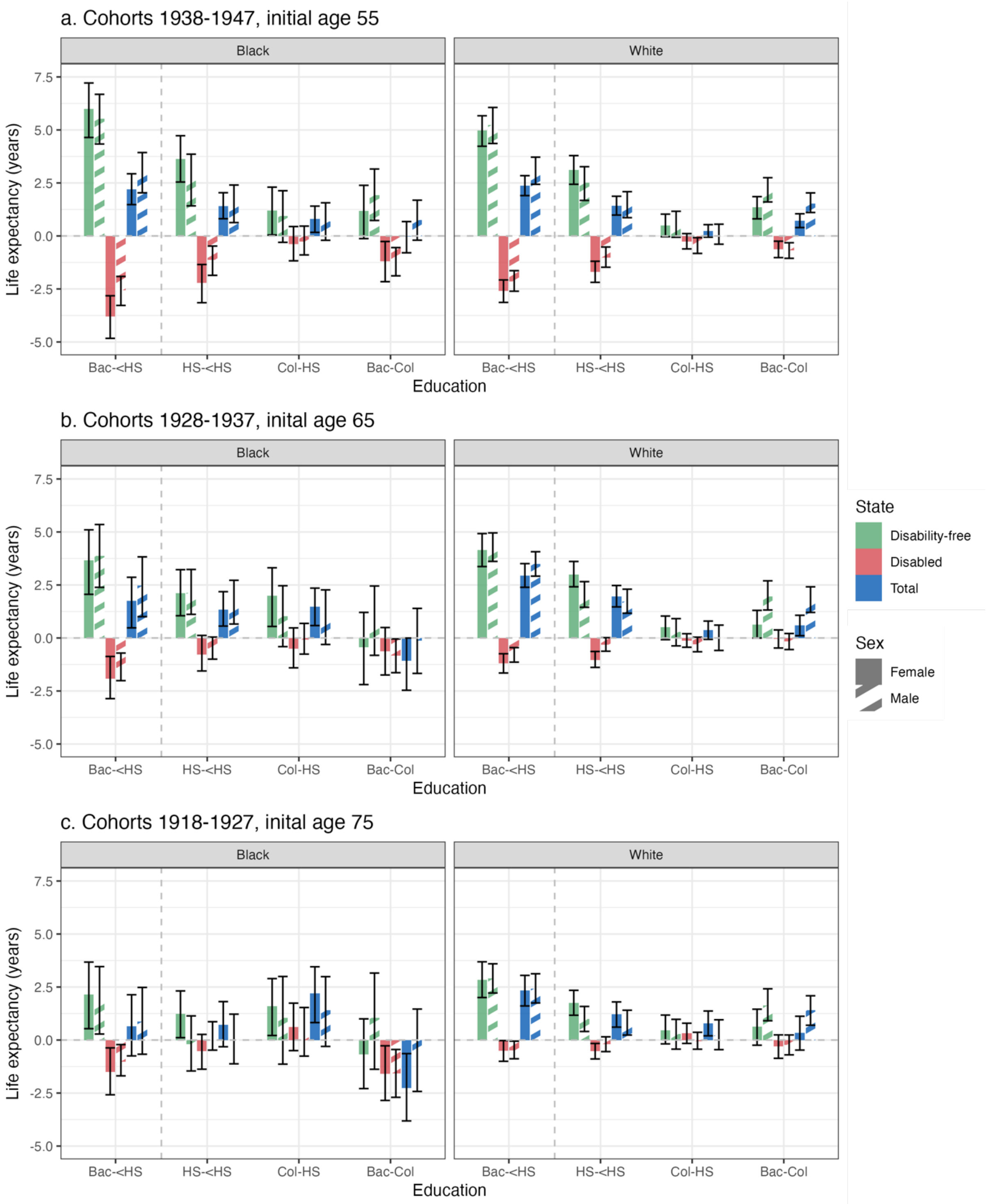

Figure 4. Educational gaps in life expectancies by gender, race and birth cohort

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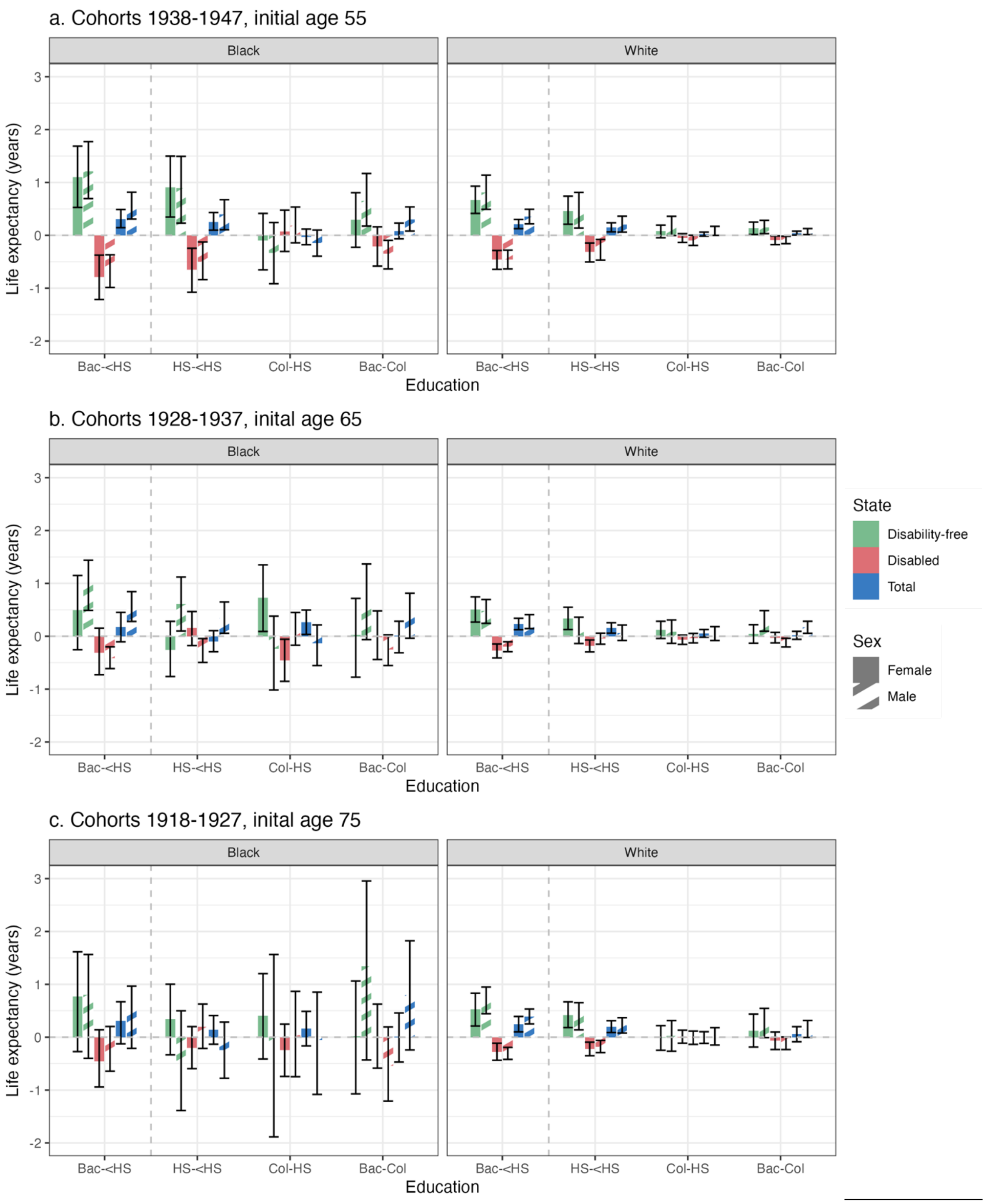
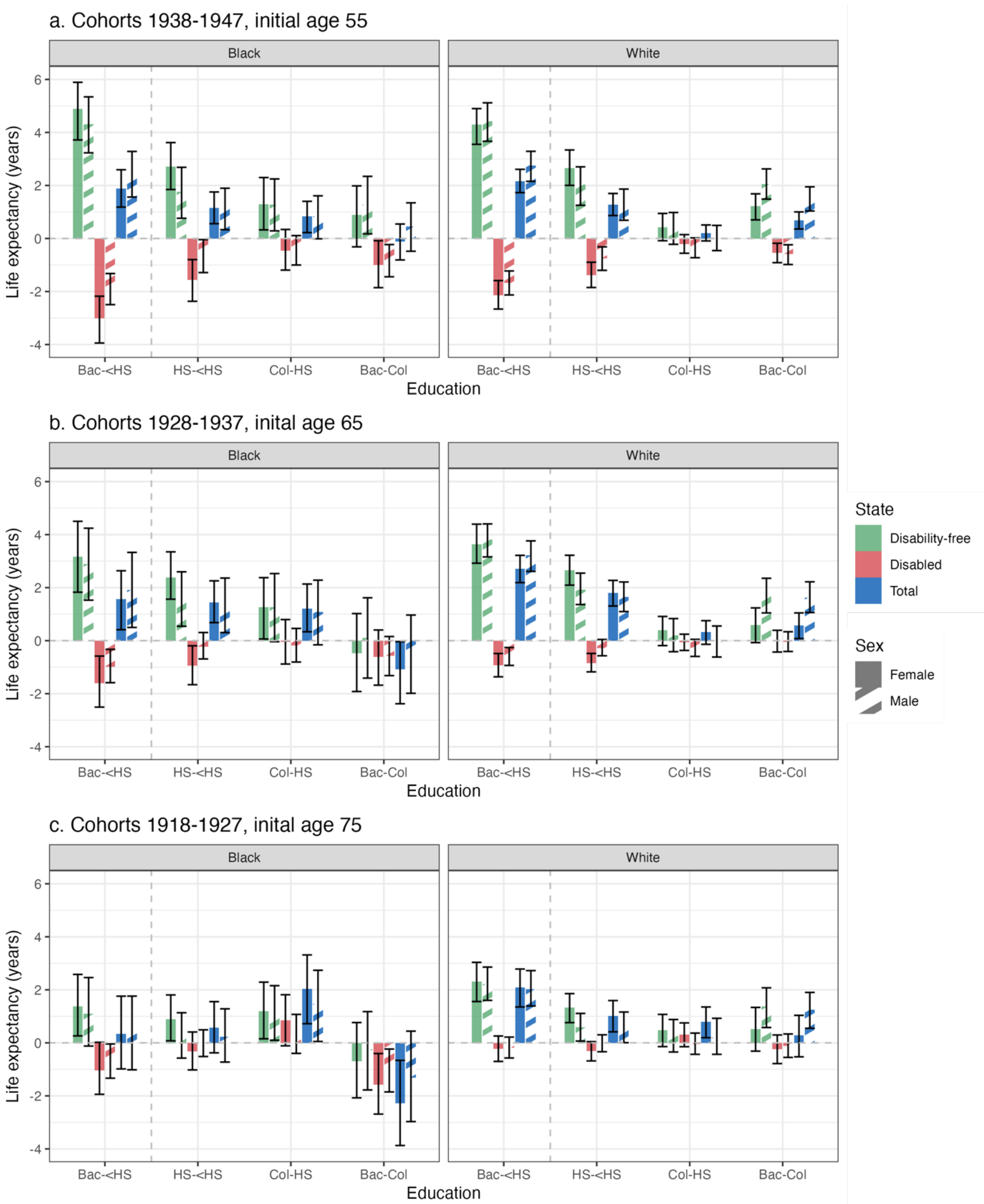


Supplementary Figure 1. Gap in life expectancies between educational groups from the difference in disability distribution at initial age by cohort, sex and race



Supplementary Figure 2. Gap in life expectancies between educational groups from the difference in transition matrix of all ages by cohort, sex and race

Supplementary Table A. Number of individual respondents in each cohort

Sex	Race	Education	Birth Cohort 1918-1927	1928-1937	1938-1947	Total
Male	White	<HS	487	475	278	1,240
		HS	571	898	794	2,263
		Col	320	480	503	1,303
		Bac	390	639	657	1,686
	Black	<HS	166	227	156	549
		HS	44	134	146	324
		Col	19	66	96	181
		Bac	9	33	49	91
Female	White	<HS	544	527	382	1,453
		HS	937	1,232	1,136	3,305
		Col	450	545	703	1,698
		Bac	269	419	538	1,226
	Black	<HS	177	262	213	652
		HS	87	196	230	513
		Col	33	78	144	255
		Bac	22	62	94	178

Supplementary Table B. Life expectancies by cohort, gender and race in Figure 1

Birth Cohort	Age Range	Sex	Education	Black DFLE	Black DLE	Black TLE	White DFLE	White DLE	White TLE
1938-1947	55-77	Female	<HS	11.2 (10.1, 12.2)	6.4 (5.6, 7.3)	17.6 (16.9, 18.2)	14.2 (13.6, 14.9)	4.2 (3.7, 4.7)	18.4 (18.0, 18.9)
			HS	14.8 (14.0, 15.6)	4.2 (3.6, 4.8)	19.0 (18.4, 19.5)	17.3 (17.0, 17.7)	2.5 (2.2, 2.7)	19.8 (19.6, 20.1)
			Col	16.0 (14.9, 16.9)	3.8 (3.1, 4.6)	19.8 (19.2, 20.3)	17.8 (17.4, 18.2)	2.2 (1.9, 2.5)	20.1 (19.8, 20.3)
			Bac	17.2 (16.1, 18.0)	2.6 (2.0, 3.3)	19.8 (19.2, 20.3)	19.2 (18.8, 19.6)	1.6 (1.3, 1.9)	20.8 (20.5, 21.0)
		Male	<HS	12.4 (11.3, 13.5)	3.9 (3.2, 4.6)	16.3 (15.5, 17.2)	13.8 (13.1, 14.7)	3.4 (2.9, 3.9)	17.2 (16.6, 17.9)
			HS	15.1 (14.1, 16.1)	2.8 (2.2, 3.3)	17.9 (17.2, 18.6)	16.4 (15.9, 16.8)	2.4 (2.1, 2.7)	18.7 (18.3, 19.0)
			Col	16.1 (14.9, 17.1)	2.5 (1.9, 3.1)	18.6 (17.7, 19.3)	16.9 (16.3, 17.3)	1.9 (1.6, 2.3)	18.8 (18.4, 19.2)
			Bac	18.0 (17.0, 18.8)	1.3 (1.0, 1.8)	19.3 (18.5, 20.0)	19.1 (18.7, 19.4)	1.3 (1.0, 1.5)	20.3 (20.0, 20.6)

Birth Cohort	Age Range	Sex	Education	Black DFLE	Black DLE	Black TLE	White DFLE	White DLE	White TLE
1928-1937	65-87	Female	<HS	9.8 (9.0, 10.6)	5.6 (5.1, 6.2)	15.4 (14.6, 16.1)	12.0 (11.4, 12.5)	3.8 (3.4, 4.1)	15.8 (15.2, 16.3)
			HS	11.9 (11.0, 12.8)	4.9 (4.2, 5.6)	16.8 (16.0, 17.5)	15.0 (14.6, 15.3)	2.8 (2.5, 3.0)	17.7 (17.4, 18.0)
			Col	13.9 (12.6, 15.0)	4.4 (3.6, 5.2)	18.2 (17.4, 19.0)	15.5 (15.0, 15.9)	2.6 (2.4, 2.9)	18.1 (17.7, 18.5)
			Bac	13.4 (11.9, 14.9)	3.7 (2.9, 4.6)	17.2 (15.9, 18.1)	16.1 (15.6, 16.6)	2.6 (2.3, 2.9)	18.7 (18.3, 19.1)
		Male	<HS	10.0 (9.2, 10.9)	3.3 (2.9, 3.8)	13.4 (12.5, 14.2)	11.1 (10.5, 11.6)	2.8 (2.5, 3.0)	13.8 (13.3, 14.3)
			HS	12.2 (11.2, 13.2)	2.8 (2.3, 3.3)	15.0 (14.1, 16.0)	13.1 (12.6, 13.5)	2.5 (2.2, 2.7)	15.6 (15.1, 16.0)
			Col	13.2 (11.9, 14.5)	2.8 (2.2, 3.5)	16.0 (14.8, 17.0)	13.4 (12.9, 13.9)	2.2 (1.9, 2.4)	15.5 (15.0, 16.1)
			Bac	13.9 (12.6, 15.2)	1.9 (1.4, 2.5)	15.8 (14.4, 17.1)	15.4 (14.8, 15.8)	2.0 (1.8, 2.3)	17.3 (16.9, 17.8)

Birth Cohort	Age Range	Sex	Education	Black			White		
				DFLE	DLE	TLE	DFLE	DLE	TLE
1918-1927	75-97	Female	<HS	6.1 (5.4, 6.8)	5.1 (4.5, 5.6)	11.2 (10.5, 11.9)	7.5 (7.0, 8.0)	4.0 (3.6, 4.3)	11.5 (11.0, 12.0)
			HS	7.3 (6.4, 8.4)	4.6 (3.9, 5.2)	11.9 (10.9, 12.8)	9.3 (8.9, 9.7)	3.5 (3.2, 3.7)	12.7 (12.4, 13.1)
			Col	8.9 (7.7, 10.2)	5.2 (4.2, 6.3)	14.1 (12.9, 15.2)	9.7 (9.2, 10.3)	3.8 (3.4, 4.2)	13.5 (13.0, 14.0)
			Bac	8.2 (6.7, 9.8)	3.6 (2.7, 4.8)	11.8 (10.4, 13.5)	10.4 (9.7, 11.1)	3.5 (3.1, 3.9)	13.9 (13.2, 14.4)
		Male	<HS	6.6 (5.9, 7.4)	2.8 (2.3, 3.2)	9.4 (8.7, 10.3)	7.0 (6.6, 7.5)	2.8 (2.5, 3.1)	9.8 (9.4, 10.3)
			HS	6.4 (5.2, 7.8)	3.0 (2.3, 3.7)	9.4 (8.1, 10.7)	8.0 (7.6, 8.5)	2.6 (2.3, 2.9)	10.6 (10.2, 11.1)
			Col	7.5 (5.5, 9.5)	3.3 (2.4, 4.4)	10.8 (9.3, 12.4)	8.3 (7.7, 8.9)	2.6 (2.2, 2.9)	10.8 (10.3, 11.4)
			Bac	8.5 (6.9, 10.2)	1.8 (1.1, 2.6)	10.3 (8.8, 11.9)	9.9 (9.4, 10.5)	2.3 (2.0, 2.6)	12.2 (11.7, 12.8)