Life Course Determinants of Muscle Weakness: The Role of Stress and Trauma

Kate Duchowny[1, 2], Margaret Hicken[3], Philippa Clarke[1, 3]

[1] Department of Epidemiology, University of Michigan School of Public Health, Ann Arbor, MI

[2] Department of Epidemiology and Biostatistics, University of California, San Francisco, CA

[3] Institute for Social Research, University of Michigan, Ann Arbor, MI

Tables: 2 / Figures: 5

Corresponding Author:

Kate Duchowny, PhD, MPH

University of California, San Francisco

Department of Epidemiology & Biostatistics

550 16th Street, 2nd Floor

San Francisco, CA 94158

kate.duchowny@ucsf.edu

Abstract

Word Count: 149/150

Background: Muscle weakness, as measured by handgrip strength, is associated with disability and mortality; however, the extent to which muscle strength trajectories are shaped by social adversity experienced across the life course is unknown.

Methods: Using data from the Health and Retirement Study (N= 20,472, Mean Age= 63.8 years), we employed gender-stratified growth curve models to investigate whether life course stress and trauma experienced at distinct life stages were associated with trajectories of grip strength in a nationally-representative sample of older adults.

Results: We found that life course trauma and stress experienced during emerging/early adulthood (18-42 years) was associated with both mean grip strength at age 50 and trajectories of grip strength.

Discussion: Results shed light on the importance of considering how one's social environment shapes grip strength trajectories among older adults and may drive racial/ethnic disparities in muscle weakness in later life, particularly among Black Men and Women.

Introduction

Muscle weakness, as measured by handgrip strength, is associated with a host of negative health outcomes, including physical functioning limitations, [1,2] disability,[3–6] multimorbidity,[7–9] and both cardiovascular[7,10] and all cause-mortality.[1,10–15] In the United States, it is estimated that 55% of older men and 45% of older women have muscle weakness.[16] Racial disparities in muscle weakness have also been uncovered by recent research showing that 55% of Black men and 88% of Black women meet criteria for clinical muscle weakness compare to 37 % of White men and 48% of White women.[16] The implications of compromised muscle strength in later age may be especially consequential since older Black adults also have a higher prevalence of mobility limitations compared to Whites.[17] Thus, a "dual burden" of muscle weakness combined with greater mobility limitations may exacerbate physical health disparities in later age and lead to greater challenges associated with the recovery process.

While physical activity[18], gender[19], chronic disease status[20] and nutrition[21] in older age are important determinants of muscle weakness, significant unexplained variability remains in identifying which individuals become weak in older age. One of the primary reasons for this may be that research has largely focused on proximal determinants of muscle weakness among older adults and less on early and midlife risk factors. It is possible that a better grasp of the risk factors earlier in the life course would not only help identify those who are both most at risk for muscle weakness in older age but also who would benefit most from early intervention.

An enhanced understanding of the upstream social factors that drive differential vulnerability to muscle weakness in later life is of critical public health importance. There is a well-established body of evidence documenting how social stress and trauma "gets under the skin" to impact physical health in older age.[22–24] However, to date, few studies have investigated

the role social stress and trauma plays in the development of muscle weakness in later age, and whether previously observed disparities in muscle weakness may be exacerbated due to differential exposure to social stress and trauma. Therefore, this study addresses a major gap in the literature by explicitly testing in a longitudinal setting whether exposure to stressful and traumatic events experienced across the life course influence trajectories of muscle weakness in older age within a nationally-representative, diverse group of Americans.

This article will begin by first reviewing several related bodies of literature integral to our understanding of the relationship between life course risk factors and muscle weakness in middle and older aged adults. We will first review life course epidemiology, followed by stress and trauma as independent risk factors for physical and mental health, and conclude with a brief review of how these factors may shape racial/ethnic disparities in health.

Life Course Epidemiology: Theoretical underpinnings and conceptual models

Life course epidemiology has been used to elucidate how seemingly unrelated physical and social exposures experienced during gestation, childhood, adolescence, young adulthood and middle age drive disease outcomes in later life.[25] From a life course perspective, aging is seen from a developmental lens in which distinct phases of adulthood are marked by specific life events and role transitions where certain stressors/protective factors may be more or less likely to occur.[25,26] For example, childhood is often defined by gains in education while adolescence is an important window of development when young people begin to assert their independence, make life style choices and establishes health behaviors that will often persist into adulthood.[27] The emerging/early period of adulthood (typically occurring in the 20's to late 30's and early 40's) is typically characterized by the establishment of one's career, marriage, parenthood and asset acquisition that has a lasting effects on health and SES in later life.[28–30] Lastly, the midlife period

(mid 40s to early 60s) is often typified by changes in health status as a result of early life health behaviors and life chances.

Two general conceptual models within life course theory have been proposed to understand how early life antecedent events drive health outcomes in older age: the critical period model and the accumulation of risk model.[25] The critical period model suggests that there are important life stages in which an individual experiences adverse events and exposures that may have crucial consequences on their health in later life. This conceptual model is largely rooted in the fetal origins hypothesis, which linked poor maternal nutrition in utero to increased risk of coronary heart disease and diabetes in later life.[31] Similarly, childhood SES has been found to be directly associated with cardiovascular disease,[32] stroke,[33,34] physical functioning[35,36] and lower levels of grip strength[37] in older adults.

The accumulation of risk model posits that negative exposures gradually accumulate across the life course, ultimately influencing health status in later life.[38] This model has been used to explain why socioeconomic differentials in health exist across a wide range of diseases.[25] For example, early childhood conditions may set individuals on risk trajectories of cumulative advantage/disadvantage with those from lower SES backgrounds experiencing a faster decline in health compared to those from higher SES backgrounds, ultimately leading to widening health disparities in later life.[39,40] The accumulation of risk model has been applied to examine physical health outcomes. For example, physical inactivity, smoking, heavy drinking, social isolation, fair/poor perceived health and prevalence of chronic symptoms and conditions across a 30-year period of emerging and midlife adulthood was associated with increased risk of frailty in a community dwelling sample of older adults.[41]

Life Course Epidemiology & Muscle Weakness

There is growing interest in the role early and midlife factors play in the preservation of muscle strength in later life. However, the majority of research has almost exclusively focused on early life anthropometric indicators showing higher birth weight to be associated with greater muscle strength adulthood.[42] In the Hertfordshire Ageing Study, lower birth weight and weight in the first year of life were significantly associated with lower grip strength 60-70 years later. This relationship, while somewhat attenuated, remained significant after adjusting for body size, indicating that one's early environment may be of critical underlying importance.[43] Pre-pubertal growth has also been found to be associated with midlife grip strength.[44]

More recently, several studies have demonstrated that socioeconomic conditions experienced across the life course may also be linked to muscle health in later life. A recent systematic review found modest, positive associations between childhood SES and later life grip strength, even after adjusting for adult SES and current body size.[36] Wealth in later life was found to be inversely associated with grip strength in a sample of older Europeans, while education, income and occupation were not, suggesting that earnings accrued across the life course may be important in maintaining grip strength in later life.[45] Results from a British birth cohort study indicated that higher levels of material deprivation (i.e., not having a car, not owning one's home) were inversely related to grip strength in later life.[37] Low income and low education were found to be significantly associated with decreased grip strength among an elderly sample of Korean men.[46] More recently, childhood misfortune was found to be related to lower handgrip strength in men, but not in women. [47]

Stress, Trauma and the Life Course

A substantial body of literature has demonstrated that one's social context is consequential for health. Previous studies have found social and economic hardships

experienced both in childhood[48] and throughout the life course are associated with mental and physical health outcomes in later life.[49,50] There is evidence to suggest that exposure to stress and trauma throughout one's life may be linked to poorer health outcomes in later life.

Previous research investigating the downstream cascade that emerges after experiencing stress and trauma early in the life course suggests there are several important mediators on the causal pathway between stress, trauma and muscle weakness in later life. Indeed, experiencing stressful and traumatic events earlier in life may lead to maladaptive coping[51], which in turn may lead to higher levels of BMI since previous research has shown that victims of trauma may use food to "anaesthetize" themselves from unpleasant feelings and memories.[52] Research also shows that individuals who experience greater levels of stress and trauma are more likely to smoke.[53] As a result, individuals who experience higher levels of stress and trauma may be less likely to engage in physical activity which may lead to a higher prevalence of chronic conditions.[54]

Social stress has been found to be associated with mental health status and depression among older adults.[22,55] Traumatic events have been shown to have a strong relationship on both immediate and long-term health outcomes. Trauma in particular may be especially consequential for health. Pearlin (2005) noted that trauma may be the most potent form of stress, characterized by the "magnitude of their onerousness…and by their sudden and violent character" (pg. 210) that have negative consequences for health in later life.[24] Despite the known links between stress and trauma with later life physical health, no studies have directly examined whether stress and trauma experienced throughout the life course, and specifically among distinct critical life periods, are associated with muscle health in later life.

Racial/ethnic health disparities

Racial/ethnic disparities in health are pervasive and persistent in the United States.[56,57] Non-Hispanic Black Americans have a higher prevalence of several chronic conditions[58], live more years with chronic health problems[59] and have higher rates of disability[60,61] compared to Non-Hispanic White Americans. Similarly, among sub-groups of Hispanics, Hispanic Americans have been found to have higher rates of chronic disease and have worse functional health.[62,63] However, mortality rates, particularly among Mexican Americans, appear to be comparable and in some cases exceed all-cause mortality for Non-Hispanic Whites.[64] Racial/ethnic disparities in physical functioning, mobility and disability are also well documented.[59,61,65,66]

In seeking to understand why these disparities persist, many studies have examined SES as a key explanatory contributor. Indeed, several studies have shown that after accounting for SES, disparities in functional health between Blacks and Whites become partially attenuated, and in some cases, disappear[61,67]. However, the evidence regarding the association between SES and functional health remains equivocal. Other studies investigating this relationship have found that even after accounting for SES differences, disparities in disability and physical functioning persist, [68] suggesting that there may be other explanatory factors.

Social adversity and racial/ethnic disparities in health

While several studies have shown racial/ethnic minorities to have a higher prevalence of lifetime stress and trauma[69], this evidence is largely mixed. Individuals in more advantaged social positions have better access to resources and opportunities in early life, which can offset or reduce exposure to negative life events, while those in more disadvantaged social positions are at greater risk of negative life events on account of reduced access and opportunity.[70] Moreover,

since the root of disadvantage is structural and often experienced in all aspects of one's life, persistent advantage or disadvantage can become compounded over time, ultimately leading to a widening in racial/ethnic health disparities across populations.[71] As a result, it can be hypothesized that disparities in muscle strength between Whites, Blacks and Hispanics may be indirectly related to differential exposure to stress and trauma across the life course, a view that is consistent with the accumulation of risk theory.

Based on the above, the primary objectives of this study are twofold: (1) To identify whether life course stress and trauma are associated with grip strength trajectories in a nationally representative sample older Americans followed across an 8-year period, and; (2) To examine whether the timing of when these stressful and traumatic events across the life course and at distinct life stages is associated with changes in grip strength in racially and ethnically diverse, longitudinal study of Americans aged 50 years and older.

Methods

Study Design and Sample Population

Data came from the Health and Retirement Study (HRS), a nationally representative, multistage area probability survey of non-institutionalized, community dwelling Americans aged 51 years and older. Study details have been previously described.[72] Briefly, HRS is the longest running longitudinal study of older Americans in the United States, with consistent response rates of ~85%.[72] Sampled persons have been re-interviewed biannually since 1992, and new cohorts have been added to the original sample to maintain the nationally-representative nature of the survey over time.[72]

In 2006, half the sample of HRS participants was randomly selected for an enhanced face-to-face interview that included physical measurements, and the other random one-half completed the same interview in 2008.[73] Additionally, in the same 2006 survey wave, HRS began collecting data on psychological and social well-being that was left behind after the enhanced face-to-face interview.[74] Participants completed these questions and then mailed in their responses. For this analysis, we used 5 waves of longitudinal data from the 2006-2014 Health and Retirement Study.

Our initial population included 26,163 individuals who were 50+ years old and community-dwelling. Individuals who had died (n=1,429), reported "other" for their race/ethnicity (n=745), or were missing on grip strength across all waves (n=3,517) were excluded, yielding a final analytic sample of 20,472 Black, White, Hispanic men and women who were 50 years and older at the time they received their first grip strength measurement (baseline).

Measures

Hand grip strength

Hand grip strength, our primary outcome of interest, was assessed using a Smedley spring-type hand dynamometer (Scandidact, Denmark). Participants were instructed to squeeze the device with the dominant hand as hard as they could and then let go. Grip strength assessments were administered while participants were standing with their arm at their side, and with the elbow flexed at a 90 degree angle.[73] After one practice trial, two measurements were taken with each hand, alternating hands. The maximum measurement in kilograms (kg) from the four trials was used for the analysis.

Life Course Cumulative Trauma and Stress

As part of the leave behind self-administered questionnaire, participants were asked to answer a series of questions pertaining to traumatic and stressful life events experienced across the life course (yes/no). Example of trauma indicators included: "Has a child of yours ever died?", "Did you ever have a life-threatening illness or accident?", and; "Have you ever been in a major fire, flood, earthquake, or other natural disaster?" Life course cumulative trauma was defined as the sum of all traumatic events at any wave based on whether a respondent answered "yes" to a series of 11 questions (Range: 0-11). The full list of questions pertaining to traumatic life events are presented in Supplementary Table 1A.

Participants were also asked about stressful life events. These indicators inquired about stressful life events (yes/no) experienced across the life course. Examples of stressful life events questions included: "At any time in your life, have you ever been unfairly denied a bank loan", "Before you were 18 years old, did you ever have to do a year of school over again?", and, "Have you involuntarily lost a job for reasons other than retirement at any point in the past five years?". Life course cumulative stress was defined as the sum of all stressful life events reported in the series of 11 questions (Range: 0-11). The full list of questions pertaining to stressful life events are presented in Supplementary Table 1B.

Life Stage Trauma and Stress

If a respondent answered "yes" to any of the traumatic and/or stressful life event indictors, they were then asked to record the year it occurred. In order to calculate the age at which the respondent experienced the stressful or traumatic event, we subtracted the respondent's birth year from the year they experienced the event. Summary stress and trauma

variables were then created for three critical life stages: Early Childhood (age 0-17 years), Emerging/early adulthood (age 18-42 years) and Midlife (age 43-67 years). Since the stressful life event questions focused on events pertaining to job and financial security, there were no stressful life events recorded in the childhood period. This resulted in five primary exposure variables (2 stressful life event summaries in emerging/early adulthood and midlife, and 3 trauma event summaries in childhood, emerging/early adulthood and midlife) that capture the total number of stressful and traumatic events experienced during these distinct life stages and across the life course.

Stress and trauma variables were missing for 3,182 individuals in the leave behind survey and were excluded from analyses with any of the exposure variables. These individuals were not significantly different from those who did complete the questions with respect to age, number of chronic conditions or BMI. However, individuals who were missing on the stress/trauma questions were more likely to report more difficulty with activities of daily living (ADL) than those who answered the stress/trauma questions (mean number of ADL limitations = .42 vs. .29, respectively, $p<.0001$).

Sociodemographic variables

The following time invariant covariates were included in the analysis: (1) Age was defined continuously in number of years; (2) Race/Ethnicity was self-reported and 3 dummy indicators were created for Non-Hispanic Black, Non-Hispanic White (referent) and Hispanic individuals; (3) Gender was treated as dummy variable coded 1 for women and 0 for men; (4) Education was modeled as a binary dummy variable contrasting those with greater than or equal to 12 years of education compared to those with less than 12 years of education. Since

educational attainment is a known risk factor for stress and trauma[75] and is also related to muscle weakness,[76] it was included as a confounder variable and was adjusted for in the statistical models.

The following time-varying covariates were included as hypothesized mediators in the causal pathway between early life stress/trauma and muscle strength in later age: (1) Smoking, categorized as current, former and never (referent) smoker based on self-report; (2) Physical activity was assessed based on whether an individual reported taking part in sports or activities that were "moderately energetic" (i.e., gardening, cleaning the car, walking at a moderate pace). Individuals who reported hardly ever or never were classified as "inactive" while those who engaged in moderate activity more than once a week, once a week, one to three times a month were considered "active"; (3) Body mass index (BMI) defined as weight in kilograms/(height in meters)^2; (4) Number of chronic health conditions was assessed based on the sum of eight self-reported medically diagnosed chronic health conditions (high blood pressure, diabetes, cancer, lung disease, heart disease, stroke, psychiatric problems and arthritis).

Analytic Approach

Growth curve models were used to examine trajectories of grip strength over mid to late-adulthood. Due to the established gender differences in grip strength, separate models were estimated for men and women. Growth curve models are a type of mixed model that account for correlations and clustering between and within individuals over time.[77] A two-level model was specified using 5 waves of HRS data across an 8 year time period (2006-2014). Age in years was used as the primary time indicator from age 50 to 99, which was centered at age 50 to aid in parameter interpretation (setting age 50 to 0). The functional form of age was tested as linear,

quadratic and cubic terms in order to capture potential non-linearity in trajectories of grip strength with aging. However, only the linear and quadratic terms were significant, and were retained in all models.

The structure of this model can be expressed by equations at each level. At level 1 (within-person model), maximum grip strength scores are nested with individuals (*i*) as defined by the following statement:

$$GS_{ti} = \pi_{0i} + \pi_{1i}(age - 50)_{ti} + \pi_{2i}(age - 50)^2 + r_{ti} \quad (1)$$

where π_{0i} is the expected maximum grip strength score for person *i* at age 50 (centered age), π_{1i} captures the linear rate of change in grip strength with age, π_{2i} captures the quadratic rate of change in grip strength, and r_{ti} captures the within-person residual (the part of an individual's grip strength at time *t* that cannot be explained by time/age) and is assumed to have a normally distributed mean of 0 and variance of σ^2.

The level-1 parameters are then modeled as a function of the individual characteristics at level-two. The level-2 between person sub-model assumes that grip strength intercepts and slopes vary across individuals, and we explicitly model these difference based on the following equations using race/ethnicity as a working example:

$$\pi_{0i} = \beta_{00} + \beta_{01}(black) + \beta_{02}(hispanic) + e_{0i} \quad (2.1)$$

$$\pi_{1i} = \beta_{10} + \beta_{11}(black) + \beta_{12}(hispanic) \quad (2.2)$$

$$\pi_{2i} = \beta_{20} + \beta_{21}(black) + \beta_{22}(hispanic) \quad (2.3)$$

In the equations above, the intercept and age slopes from equation 1 are modeled as a function of race/ethnicity, where β_{01} represents the difference in grip strength (intercept) for Blacks compared to Whites at age 50, β_{11} represents the difference in the rate of change (linear slope) of grip strength for Blacks compared to Whites and β_{21} represents the difference in the rate of change (quadratic slope) of grip strength for Blacks compared to Whites. Similarly, β_{20} represents the difference in grip strength (intercept) for Hispanics compared to Whites at age 50, β_{12} represents the difference in the rate of change (linear slope) of grip strength for Hispanics compared to Whites and β_{22} represents the difference in the rate of change (quadratic slope) of grip strength for Hispanics compared to Whites. The residual error (e_{0i}) captures the random error in the intercept across individuals. Random variance around the slope coefficients were not estimated due to problems with model convergence. Substituting equations 2.1 - 2.3 into equation (1) yields the full composite model:

$$\begin{aligned} Grip\ Strength_{ti=}\ & \beta_{00} + \beta_{01}(black) + \beta_{02}(hispanic) + \beta_{11}(black)(age-50) \\ & + \beta_{12}(hispanic)(age-50) + \beta_{21}(black)(age-50)^2 \\ & + \beta_{22}(hispanic)(age-50)^2 + e_{0i} + r_{ti} \end{aligned}$$

We used the MIXED procedure in SAS 9.4 to estimate the linear mixed models using full information maximum likelihood. The distribution of the residuals showed a good approximation

to normality with little deviation from the diagonal in the normal probability plots, justifying the linear model. Nested models were compared using the following goodness-of-fit indices: (1) Change in the -2log likelihood, which follows a χ^2distribution where the degrees of freedom as the same between nested models, (2) Bayesian Information Criterion (BIC), where models with a lower BIC indicate better model fit, and; (3) Proportion of variance in grip strength that is explained by a model (pseudo R^2), which is calculated by squaring the correlation between the observed and predicted grip strength values. We also tested for mediation by adding each hypothesized mediator individually to assess change in the estimate of our primary exposure.

Results

We first present descriptive statistics by gender and race/ethnicity in separate tables for men (Table 1A) and women (Table 1B) and proceed in discussing the model results for men (Table 2A) and women (Table 2B) separately below.

Results for Men

Descriptive Statistics

Among the 8,847 men included in this analysis, 17% were Black, 70% were White and 13% were Hispanic (Table 1A). White men were slightly older (63.5 years) compared to Black (61.1 years) and Hispanic (61.1 years) men. White men had the highest mean grip strength at 43.6 kg while Hispanic men had the lowest at 39.8 kg. Black men had a mean grip strength of

42.1 kg. The average number of chronic conditions was relatively similar across all three race/ethnic groups (range= 1.7-1.9 conditions). The average body mass index was also comparable across Black, White and Hispanic men (mean BMI range= 28.5-29.2 kg/m^2). While physical activity and smoking levels were similar across all groups, there were notable differences in educational attainment. Fifty-nine percent of White men had 12 or more years of education compared to 42% of Black men and only 28% of Hispanic men.

When examining the distribution of trauma across the life course, roughly one in 4 men reported no traumatic event from birth through age 67 (Table 1A). On average, Black men experienced slightly higher levels of trauma (mean= 1.9 events) compared to Whites (1.7 events) and Hispanics (1.8 events). The distribution of the number of traumatic events by race/ethnicity was similar, although Black and Hispanic men were somewhat more likely to report 3 or more traumatic events over the life course compared to White men. However, there were notable race/ethnic differences as to when these events occurred in the life course. In early childhood (0-17 years old), half of Black men and 46% of White men reported experiencing 1 or more traumatic events compared to 37% percent of Hispanic men. The number of traumatic events experienced during emerging/early adulthood (18-42 years) and midlife (43-67 years) were relatively comparable across race/ethnic groups.

There were also noticeable race/ethnic differences in the number of stressful life events experienced over the life course. Black men experienced more stressful life events (mean= 1.7 events) across the life course compared to Whites (1.2) and Hispanics (1.3). Thirty-two percent of Black men reported 3 or more stressful life events compared to 19% of White men and 22% of Hispanic men. The life stage as to when these events occurred also varied by race/ethnicity. Black men were more likely to report one or more stressful life event in emerging/early

adulthood (30%) compared to White (20%) and Hispanic (17%) men. This was also the case for stressful life events experienced during midlife with 40% of Black men reporting one or more event compared to 32% of White men and 36% of Hispanic men.

---- Table 1A ----

Growth Curve Models

Unconditional Growth Model

Results for the growth curve model for men are presented in Table 2A. In the unconditional growth model (Model A), the mean grip strength for men at age 50 is 48.6 kg and there is a significant negative linear and quadratic time effect indicating that grip strength declines with age. For each additional year of age, men lose, on average, .31 kg per year ($p< .0001$) and this decline accelerates with age (significant quadratic term of -.007 kg per year^2).

---- Table 2A about here ----

Race/Ethnicity

When adding race/ethnicity to the model (Model B, Table 2A), White men at age 50 have a mean grip strength of 50.3 kg (the intercept, $p< .0001$) while both Black and Hispanic men have statistically significant lower average grip strengths of 46.7 kg ($\beta= -3.6$, $p< .0001$) and 45.4 kg ($\beta= -4.9$, $p<.0001$), respectively, at age 50. However, there were no significant differences in the rate of decline in grip strength with age by race/ethnicity (coefficients for rate of change by race/ethnicity, Model B). Predicted grip strength trajectories based on this model are plotted in Figure 1.

---- Figure 1 about here ----

Life Course and Life Stage Trauma

Model C (Table 2A) adds the traumatic life event variables to the race adjusted models. The total number of traumatic events experienced cumulatively across the life course was not associated with either mean grip strength at age 50 or rates of change in grip strength for Black, White or Hispanic men (results not shown). However, we found traumatic life events experienced at the critical life stage of emerging/early adulthood were associated with differences in trajectories of grip strength by race. Experiencing trauma during childhood or midlife was not associated with grip strength trajectories for any race/ethnic group (results not shown). After adjusting for education (Model D, Table 2A) Black men who experienced one additional trauma in emerging/early adulthood had higher mean grip strength at age 50 (β= 1.66, $p<.001$) but faster rates of decline in grip strength with age (β= -.08, $p< .001$) than Black men who did not experience a traumatic event during this life stage. In contrast, the experience of traumatic events was not associated with differences in grip strength trajectories for either White or Hispanic men.

Despite starting out with a higher mean grip strength at age 50, Black men with one additional trauma underwent a steeper decline in grip strength with age. Specifically, Black men who experienced one additional traumatic event in emerging/early adulthood lost, on average, an additional .08 kg in their grip strength each year (β= -.08, $p< .001$; Model D Table 2A). This means that, at age 80, for example, Black men who did not experience any traumatic event have a predicted grip strength of 33.7 kg while Black men who experienced two traumatic events have a predicted grip strength of 27.4 kg—over a 6 kg difference, as shown in Figure 2.

---- Figure 2 ----

Racial/ethnic differences in the effects of trauma on trajectories of grip strength have notable consequences for the observed disparities in later life grip strength by race. For example, at age 80, the predicted grip strength for a White man who experienced two traumatic events during emerging/early adulthood is comparable to a Black men who experienced no traumatic events (34.7 kg vs. 33.7 kg, respectively), indicating that even Black men who are free from the experience of trauma during emerging/early adulthood have similar hand grip strength to White men who have experienced two traumatic events during this life stage.

Life course and Life Stage Stress

Results for models including the measures of stressful life events are presented in Models E and F (Table A). We found no association between the total number of stressful life events and either mean hand grip strength or rates of change in grip strength over time (results not shown). However, we did find that experiencing stressful life events during emerging/early adulthood was significantly associated with trajectories of grip strength, and these effects varied by race. (Stressful life events experienced during midlife were not associated with grip strength trajectories.) After adjusting for education (Model F, Table 2A), White men who experienced one stressful life event during emerging/early adulthood had lower mean grip strength at age 50 than White men who experienced no stressful life events ($\beta = -.78$, $p < .01$). However, similar to the findings for traumatic life events (above), Black men who reported one additional stressful life event during emerging/early adulthood had a higher mean grip strength at age 50 ($\beta = 2.4$, $p < .0001$) but faster rates of decline in grip strength with age ($\beta = -.06$, $p < .05$) than Black men reporting no stressful life events during this life stage. Extrapolating these results to age 80, Black men who experience 2 stressful life events in emerging/early adulthood have a predicted grip strength at age 80 that is 3 kg lower than Black men who do not report experiencing any

stressful life events (30.3 kg vs. 33.5, respectively) and fully 4 kg lower than White men who do not report any stressful life events (34.5 kg). Predicted trajectories by race and stressful life events are plotted in Figure 3.

---- Figure 3 ----

Testing Potential Mediating Pathways

As a final step in the modeling process, we included the hypothesized mediators in the pathway between traumatic/stressful life events and grip strength, including time-varying chronic conditions, BMI, smoking status, and physical activity. Since these variables are both potential mediators and potential confounders in this longitudinal model, we report these results with caution. After entering each hypothesized mediator into both the emerging/early adulthood trauma (Model D) and stress (Model F) models (Table 2), we found no meaningful change in the relationship between stress and trauma on the grip strength intercept and trajectories by race/ethnicity. Specifically, the intercept and slope differences found for Black men did not change even after including these mediating/confounding variables, indicating that trauma and stress in emerging/early adulthood has a net direct effect on grip strength for Black men in later life. This also indicates that the observed association between emerging/early adulthood stress, trauma and muscle strength is not operating through the time-varying, health behaviors that were hypothesized to be on the causal pathway.

Results for Women

Descriptive Statistics

The sample characteristics for Black, White and Hispanic women are presented in Table 1B. Out of the 11,624 women included in the sample, 20% were Black, 67% were White and 13% were Hispanic. The average age at baseline for White women was slightly older (65.2 years) compared to Black (62.4 years) and Hispanic (62.2 years) women. Black women had higher mean grip strength (27.1 kg) compared to White women (25.7 kg) and Hispanic women (24.1 kg). Black women and Hispanic women had a higher mean BMI (31.5 and 29.6 kg/m^2, respectively) compared to White women (27.8 $kg/m^{2)}$ and Black women had a greater prevalence of chronic health conditions at baseline (mean 2.2 conditions) compared to White and Hispanic women (mean=1.8 conditions for both groups). There were notable racial inequalities in attained education with 51% of White women having a high-school education or higher, compared to only 43% of Black women and 23% of Hispanic women. White women were also more likely to report engaging in moderate physical activity 3 times per week (80.2%) compared to 73.1% of Black women and 77% of Hispanic women. Current smoking status was roughly comparable across all three groups.

---- Table 1B ----

When examining the distribution of lifetime trauma, Black women reported a slightly higher mean number of traumas (mean= 1.7 events) compared to White (1.6 events) and Hispanic (1.6 events) women. Black women were more likely to report 3 or more traumatic life events (30.8%) compared to White women (25.8%) and Hispanic women (28.4% 3). Black (33.6%), White (36.4%) and Hispanic women (39.8%) were more likely to report experiencing one or more traumatic event during childhood than in emerging/early adulthood or in the midlife period. Black women also reported a higher mean number of stressful life events (mean= 1.3 events) compared to White (.85 events) and Hispanic (.96 events) women. Black women were

more likely to report experiencing 3 or more stressful life events across the life course (23.4%) compared to White (12%) and Hispanic (14.3%) women ($p<.05$). When examining the timing of when these events occurred, Black (34.6%), White (25.2%) and Hispanic (25.2%) women were more likely to report experiencing stressful life events during midlife than in emerging/early adulthood.

Growth Curve Models

Results for the growth curve models for women are presented in Table 2B.

---- Table 2B ----

Unconditional Growth Model

In the unconditional growth model (Model A), the mean grip strength for women at age 50 is 29.8 kg (the intercept, $p< .0001$) and there is a significant, negative linear and quadratic time effect indicating that grip strength declines over time. Specifically, for each additional year of age, women lose, on average .2 kg of grip strength per year ($\beta=-.196$, $p<.0001$) and this decline accelerates over time (significant quadratic effect for age).

Race/Ethnicity

Model B (Table 2B) presents the results after adjusting for race/ethnicity. Hispanic women have significantly lower average grip strength at age 50 than White women (27.1 kg vs. 30.5 kg, respectively ($\beta= -3.4$, $p< .0001$) but experience a slower rate of decline in grip strength with age ($\beta = .094$, $p<.001$). Black women have a slightly lower mean grip strength at age 50 than White women (vs. 30.0kg vs. 30.5kg), respectively, although this difference was not statistically significant ($\beta= -.443$, $p= .27$) However, as seen from the predicted trajectories in

Figure 4, Black women experience a slower rate of decline in grip strength with age compared to White women (β =.110, p<.001, Model B, Table 2B).

---- Figure 4 ----

Life Course and Life Stage Trauma

We found no association between the total accumulation of traumatic events over the life course and women's grip strength in later life (results not shown). However, we did find that traumatic events experienced in emerging/early adulthood proved to be a critical window of exposure and varied by race. While traumatic events had no effect on grip strength for either White or Hispanic women, Black women who experienced a traumatic life event over emerging/early adulthood had significantly lower levels of grip strength in later adulthood. After adjusting for education (Model D, Table 2B), Black women who experienced one additional traumatic event had significantly lower mean grip strength than Black women who did not experience a traumatic event (β= -.69, p < .05). We also tested whether lifetime and life stage stressors were associated with grip strength in women but found no significant associations.

---- Figure 5 ----

Testing Potential Mediating Pathways

While the association between trauma in emerging/early adulthood and mean grip strength at age 50 remained significant after adding time-varying chronic health conditions, smoking status and physical activity to the model, time-varying BMI significantly attenuated the coefficient representing the effect of trauma for Black women (Model D, Table 2B). After adjusting for time varying BMI, the intercept for Black women who had experienced traumatic

life events in emerging/early adulthood was reduced (-.69 to -.63) and was no longer significant. This suggest that BMI is a partial explanatory factor in the relationship between early adult traumatic events and later life grip strength for Black compared to White women. However, we present these results with caution, because these variables are both mediators and confounders in the longitudinal relationship between life events and grip strength. Further work should test these complex relationships with other analytic methods (i.e., marginal structural models) that are better equipped to deal with simultaneous mediating and confounding in longitudinal models.

Discussion

There is growing interest in the life course determinants of muscle strength in older age. While a few studies have investigated the role of early life anthropometry and socioeconomic status in differential vulnerability to muscle weakness,[44,78,79] less is known about how one's lived social experience unfolds over the life course to influence trajectories of grip strength in later life. This study is an important contribution to the literature because it not only examined longitudinal changes in grip strength over time by race/ethnicity but also considered to what extent earlier negative life events impacted grip strength trajectories in later life.

There are several key findings from this study. First, we found that life course trauma and stress experienced during emerging/early adulthood were associated with differences in levels of grip strength and rates of change in grip strength over mid to late adulthood.

Specifically, among Black men, stress and trauma experienced during emerging/early adulthood were not only related to higher mean grip strength at age 50, but also associated with steeper declines as individuals aged over time compare to White men. Second, for Black women,

traumatic events during emerging/early adulthood were associated with lower mean grip strength at age 50. Third, the accumulation of traumatic and stressful events across the life course was not associated with grip strength in later life for any group. This finding supports the critical period hypothesis, whereby experiencing stressful events experienced during emerging/early adulthood may have disproportionate negative consequences for maintaining and preserving muscle strength in later age, particularly for Black men and women. Lastly, contrary to our hypothesis, no differences in grip strength were observed for White and Hispanic men and women even after accounting for stress and trauma.

To the best of our knowledge, no studies have directly examined the relationship between life course social stress and trauma and muscle strength in later age. After considering the type and timing of the exposure, our study suggests that one's lived experience, particularly during emerging/early adulthood, is consequential for muscle health in older age. Findings from this study are consistent with previous work documenting a strong association between stress, trauma and other physical and mental health. Indeed, there is a well-established literature that has found stress and trauma experienced earlier in the life course to be associated with a host of negative health outcomes, including depression,[80] cardiovascular disease [81] and impaired immune function.[82]

The mechanism by which social stress and trauma could affect muscle strength is not well studied. However, the distinct physiologic cascade the takes place following exposure to stressful events is well documented.[82] Furthermore, exposure to chronic stress, such as those negative events that persist over time (i.e., taking care of a sick family member) or experiencing an acute, traumatic event (i.e., being the victim of a crime) are believed to be the most potent forms of stress.[83] When a stress response is activated, cortisol is released by the hypothalamic-

pituitary-adrenocortical (HPA) axis. While the initial release of cortisol and other hormones is viewed as adaptive by slowly digestion and breaking down metabolic compounds in order to quickly produce energy, cortisol remains elevated the longest amount of time in the body.[83] This has been replicated over decades of research demonstrating that repeated activation of the HPA pathway is harmful to health. The proposed mechanism, increased inflammation, has grave implications for multiple bodily systems, including, but not limited to, the skeletal muscle system.[82,83] Indeed, higher levels of interleukin-6 (IL-6), interleukin-1 receptor (IL-1R) and tumor necrosis (TNF) and C-reactive protein (CRP), all primary markers of an elevated inflammatory state, have been found to be associated with reduced muscle strength.[84,85] Based on the disproportionate burden of stressful life events experienced by Black men and women relative to Whites and Hispanics in our study, we would anticipate that the physiologic wear and tear or "weathering"[86] could be a salient mechanism leading to impaired muscle strength in later life.

While considering the individual-level, physiologic mechanisms by which stressful events "get under the skin" and leads to steeper declines in muscle strength, this is only a partial explanation of the findings observed in this study. Indeed, previous scholars have noted that while accounting for non-social factors is valuable, doing so "should not preclude consideration of the integral, often antecedent ways racialization may condition disease and distributions".[87,88] Previous research on the social determinants of health, coupled with recent calls to incorporate Critical Race Theory into the realm of health disparity research,[89,90] provide a clear rationale for looking at macro, upstream factors to understand the structural contributors to the racial/ethnic disparities in muscle strength observed in this study.

One of the primary structural drivers of the racial and ethnic disparities observed in health operates through structural racism. Structural racism, defined as "the macro-level systems, social forces, institutions, ideologies, and processes that interact with another to generate and reinforce inequities among racial and ethnic group"[91] has insidious consequences for health.[88] A growing body of research has documented how the consequences of structural racism shape social and economic inequities that are largely produced along racial and ethnic lines.[57,92,93] The insidious effects of structural racism on health are multidimensional and far reaching by simultaneously restricting access to a myriad of domains that include, but are not limited to, health-promoting resources such was wealth, income, safe neighborhoods, quality education and healthcare, as well as maintaining a system where socially marginalized groups lack the basic and essential resources needed to prevent and treat diseases.[94–96]

In this study, Black men and women were more likely to positively endorse items pertaining to experiences of major lifetime discrimination, a pervasive symptom of structural racism. For example, Black men were more likely to experience being denied a bank loan (20% compared to 6% of White and 10% of Hispanic men), prevented from moving into a neighborhood because the landlord or realtor refused to sell or rent you a house or apartment (12% compared to 1% of White and 2% Hispanic men) and unfairly stopped, searched, questioned physically threatened or abused by the police (34% compared to 10% of Whites and 19% of Hispanic men). These differences were also observed in Black women with 14% reporting being denied a loan (5% of White and 6% of Hispanic women), 9% reporting not being able to move into a certain neighborhood (1% of Whites and 2% of Hispanic women) and 11 percent endorsing unfair treatment by the police (3% of Whites and 4% of Hispanic women). We did not find differences in the grip strength trajectories by stress for White men or women. This

may be due to the fact that when Whites experience unfair treatment, they are more likely to interpret the unfair treatment as an individual and not due to their particular group membership.[97]

In connecting the distal and proximal pathways stated above, we believe that the disparities observed in this study are the result of a larger structural-physiologic pathway whereby entrenched macro-level forces of structural racism that operate through stressful experiences of discrimination, stress and trauma, lead to chronic activation of the HPA axis, which in turn lead to a wear and tear on the body, that produce declines in muscle strength for Black men and women in later life.

Consistent with a life course approach, we sought to examine whether the timing of when stressful and traumatic events occurred matters in preserving muscle strength in older age. We found that when trauma and stress were experienced during the emerging/early adulthood period, a life stage rooted in distinct transitions and the establishment of key social roles,[29,49] muscle strength was compromised in later life. In other words, trauma and stress experienced during emerging/early adulthood was associated with a faster decline in muscle strength compared to those who did not experience any traumatic or stressful events during this same period. Therefore, our results suggest that emerging/early adulthood may prove to be "critical period" in which excess exposure to stress and trauma may have far reaching and adverse consequences for muscle strength compared to other time periods, particularly for Black men and women. Our findings are consistent with past work that has found emerging/early adulthood to be a critical period for health outcomes in later life. For example, Clarke & Wheaton found that consequences of neighborhood poverty and unemployment experienced during the developmental period of adulthood (23-38 years of age), compared to other life stages, was linked to higher levels of depression in later life.[98]

A major finding in this study is that the consequences of trauma and stress were experienced differentially with regard to muscle strength in later life. Specifically, Black men and women were disproportionately impacted as steeper declines in grip strength were observed for both men and women on account of earlier negative events compared to those did not experience stressful and traumatic life events during emerging/early adulthood. Although men who experienced one traumatic or stressful event during emerging/early adulthood had higher grip strength by the time they reached age 50, this reserve quickly eroded over time such these same Black men and women who had experienced stress and trauma earlier in the life course had markedly lower grip strength in later life compared to their non-exposed peers. Moreover, the grip strength declines observed in this study among Black men were also notable relative to the longitudinal changes in White men. In extrapolating our findings, we found that by age 80, the grip strength profile of a Black men who had experienced no stressful/traumatic events during emerging/early adulthood looked similar to White men who had experienced 2 or more stressful/traumatic events, opposite of what we could expect.

The question as to why experiencing stress and trauma would be especially consequential for Black men during emerging/early adulthood with respect to their later life grip strength is not fully understood. However, research suggests that racial disparities in health are rarely the result of sudden changes in health in later life but rather the byproduct of a long-standing, cumulative process subject to larger structural systems of racialization.[39,70] In other words, the differential vulnerability observed in this study is not due to biological differences, but rather a consequence of one's social context. Through this lens, being exposed to major life stress and trauma during emerging/early adulthood, the time in which the establishment of one's career, marriage, and parenting becomes of critical importance to future income, earnings and health status may lead to

a particularly devastating consequences for Black men. That is, Black men who lack the resources and opportunities to rebound and recover due to structural factors may experience far reaching effects due to stress and trauma.[70] It would follow that the stress Black men experience associated with trauma has the potential to derail and limit future opportunities, above and beyond experiencing the same events at a different point later in the life course and it is this heightened vulnerability that may compromise health in later life, and in this case, muscle strength.

This study has several strengths. First, to the best of our knowledge, this is the first study to investigate the association between stress and trauma and its consequences of muscle strength in older age in a racially/ethnically diverse sample of older adults. Second, the results of were obtained in a nationally representative sample of adults and can therefore be generalized to community-dwelling Black, White and Hispanic adults aged 50 years and older living in the United States. Third, we used data that considered not only what type of stressor was experienced but at what point in the life course it occurred. This enabled us to apply a life course approach in our inquiry of how stress and trauma impacts later life muscle strength. Previous studies documenting how early life exposures impact later life health have been largely been relegated to examining childhood exposures (i.e., maternal education) due to limits in the assessment of life course social experiences. Lastly, a major strength of this study was our ability to examine whether muscle strength trajectories differ by race/ethnicity and gender. Past work examining longitudinal changes in grip strength have largely focused on White populations.[1,7] Given the rapidly changing demographic makeup of older adults in the United States,[99] understanding how muscle strength changes over time across a variety of groups is essential in

delaying or preventing the onset of disability, physical functioning limitations in order to maximize independence in older age.

Despite these strengths, this study is not without limitations. First, participants were asked to retrospectively recall their exposure to stressful and traumatic events throughout the life course. Thus, participants had to rely on their memory of when certain events took place, which may be subject to recall bias especially if events that occurred earlier in one's life history may be more difficult to recall. Despite this potential limitation, previous research has found that when individuals are asked to recall the timing of past traumatic events, they do so with reasonable accuracy.[100] For example, in one study, participants were prospectively assessed via self-report as to when they experienced childhood communicable diseases, accident, hospitalizations, surgeries and other illnesses, and by age 50, 85% of the these events were correctly recalled.[101]

Second, as with any longitudinal study of older adults, we cannot overlook the potential for selective survival bias in our sample, particularly among older Black and Hispanic men. Previous research estimates that in the HRS, only 40 percent of Black men born between 1931 and 1941 live to age 60.[102] Additionally, because this study did not include those whom are homeless or incarcerated, the results presented in this study a likely an underestimate of the true association since those who were not enrolled/died before age 50 are likely to be the most disadvantaged. Lastly, we were unable to adequately adjust for both mediators and confounders as many of the hypothesized mediators in this study could also be considered time-varying confounders. Future work in this area should consider other analytic techniques that can accommodate both mediator-confounders in order to obtain controlled estimates that are able to tease apart the independent effects of mediator and confounding in a longitudinal setting.

The results of this study underscore the importance of considering how structural systems of inequality, as experienced through life course exposure to stress and trauma, lead to steeper declines in muscle strength, particularly among older Black men and women. Moreover, we believe these findings are a call to action for future research in this area by focusing less on individual-level risk factors of muscle strength in older life and begin placing greater emphasis in the inquiry of how one's social context shapes trajectories of muscle strength as adults age over time.

Table 1A Baseline descriptive statistics for Men in the Health and Retirement Study, N=8,847 (2006-2014).

	Black Men (n=1506)	**White Men (n=6200)**	**Hispanic Men (n=1127)**
Variable	**Mean* (SD)**	**Mean* (SD)**	**Mean* (SD)**
Age (in years) (range 46-99)	61.1 (9.0)	63.5 (10.3)	61.1 (8.9)
Grip Strength (kg)	42.1 (10.1)	43.6 (9.8)	39.8 (9.2)
Chronic Conditions (Range: 0-8)	1.9 (1.5)	1.8 (1.5)	1.7 (1.4)
Body Mass Index (kg/m^2)	28.6 (5.5)	28.5 (5.1)	29.2 (5.1)
	%*	**%***	**%***
Education			
<HS	57.7	41	71.8
≥ HS	42.3	59	28.2
Physical Activity			
Inactive/Sedentary	16.9	14.7	15
Active	83.1	85.3	85
Smoking			
Current	19.1	13.5	14.6
Former	46	48.7	49.1
Never	34.8	37.8	36.4
Traumatic Events Across Life Course (range 0-11)			
0	24.5	22.3	24
1	21.3	26.8	25.2
2	21.2	21.4	18
3	13.2	14.8	13.4
4	11.2	7.9	8
5+	8.6	6.8	10.8
Stressful Events Across the Life Course (range 0-11)			
0	30	44	40.5
1	22	23.2	23.5
2	15.7	13.6	14.1
3	10.5	9.2	8.6
4+	21.8	10	13.4
Traumatic Events Across Life Stages			
Early childhood trauma (0-17 years)			
0	50.3	53.2	49.6
1	30.3	29.9	29.8
2	14	12.2	13,8
3+	5.5	4.8	6.8
Emerging adulthood trauma (18-42 years)			

0	69.3	69.3	69.4
1	21.4	21.8	22.8
2	6.9	6.9	6.5
3+	2.5	2.1	1.3
Midlife trauma (43-67 years)			
0	68	65.8	68.1
1	21.2	24.4	19.5
2	7.2	7.4	9.1
3+	3.6	2.4	3.3
Stressful Events Across Life Stages			
Emerging adulthood stress (18-42 years)			
0	70.4	80.4	82.8
1	17.7	14.2	9.6
2	7.7	4.4	6.2
3+	4.2	1	1.4
Midlife stress (43-67 years)			
0	60.7	68	63.5
1	20.6	17.2	19.2
2	9.6	7.3	8.5
3+	9	7.4	8.7

*Weighted mean and percentages

Table 2A Growth curve models for hand grip strength in Men in the Health and Retirement Study (N=8,847), 2006-2014.

	Unconditional Growth Model	**+Race/ Ethnicity**	**+ Trauma in Emerging/Early Adulthood**	**+Trauma and Education**	**Stress in Emerging/Early Adulthood**	**+ Stress and Education**
	Model A	Model B	Model C	Model D	Model E	Model F
Intercept	48.58***	50.27***	50.39***	50.63***	50.64***	50.89***
Race/Ethnicity						
Blacks		-3.56***	-3.39***	-3.26***	-3.89***	-3.38***
Hispanics		-4.89***	-4.67***	-4.43***	-5.13***	-4.88***
Education						
≤HS[a]				-0.71***		-0.701***
Traumatic Events			-0.013	-0.024		
Trauma*Black			1.7**	1.66**		
Trauma*Hispanic			-4.67***	-0.412		
Stressful Events					-.764**	-0.779***
Stress*Black					2.42***	2.40***
Stress*Hispanic					1.09	1.04
Rate of Change						
Age	-0.308***	-0.339***	-.34***	-.336***	-.347***	-.342***
Age2	-.007***	-.007***	-0.007***	-.007***	-.007***	-.007***
Race/Ethnicity						
Blacks*Age		0.024	-0.004	-0.004	0.009	0.009
Blacks*Age^2		0.002	0.002	0.003	0.002	0.002
Hispanics*Age		-0.09	-0.082	-0.086	-0.061	-0.066
Hispanics*Age^2		0.003	0.032	0.002	0.002	0.002
Traumatic Events						
Trauma*Age			0.007	0.007		
Stressful Events						
Stress*Age					0.016	-0.014

Trauma & Race/Ethnicity						
Trauma*Black*Age			-.08**	-.081**		
Trauma*Hispanic*Age			0.032	0.031		
Stress & Race/Ethnicity						
Stress*Black*Age					-.063*	-.062*
Stress*Hispanic*Age					-0.023	-0.021
Goodness-of-Fit Statistics						
BIC	167264.4	166857.7	145419.7	14515.1	14.5549.7	145545.2
Within Person Variance	13.04	13.01	13.25	13.25	13.25	13.26
Pseudo R2		0.23	0.02	0.02	0.02	0.02

* p<.05

** p<.01

*** p<.001

[a] Reference is High School degree or higher

Figure 1. Grip strength growth curve trajectories for Men by Race/ethnicity in the Health and Retirement Study (N=8,847), 2006-2014.

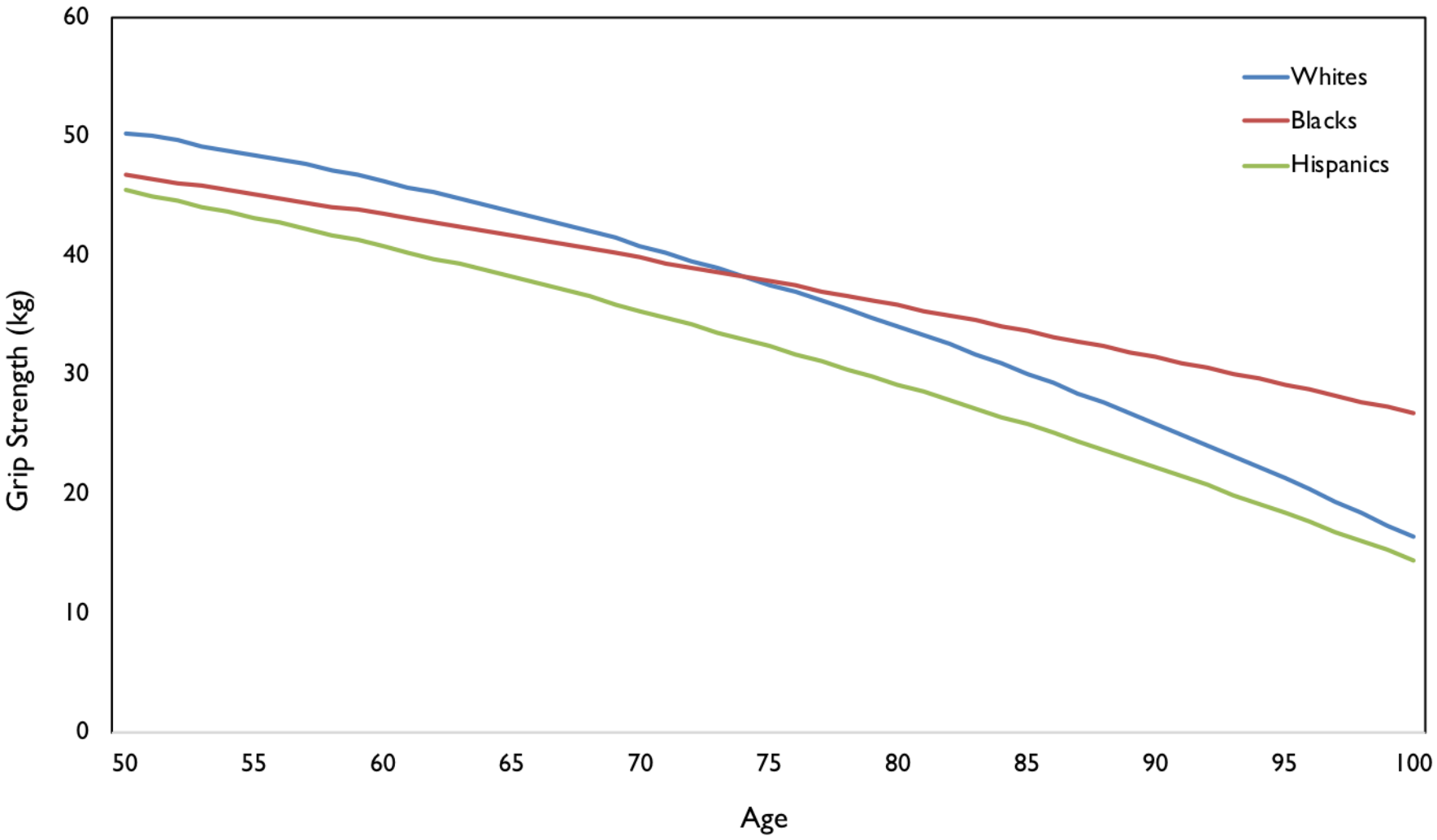

60
50
40
30
20
10
0
Grip Strength (kg)
50
55
60
65
70
75
80
85
90
95
100
Age
Whites
Blacks
Hispanics

Figure 1. Grip strength growth curve trajectories for Men by Race/ethnicity and Levels of Traumatic Events in the Health and Retirement Study (N=8,847), 2006-2014.

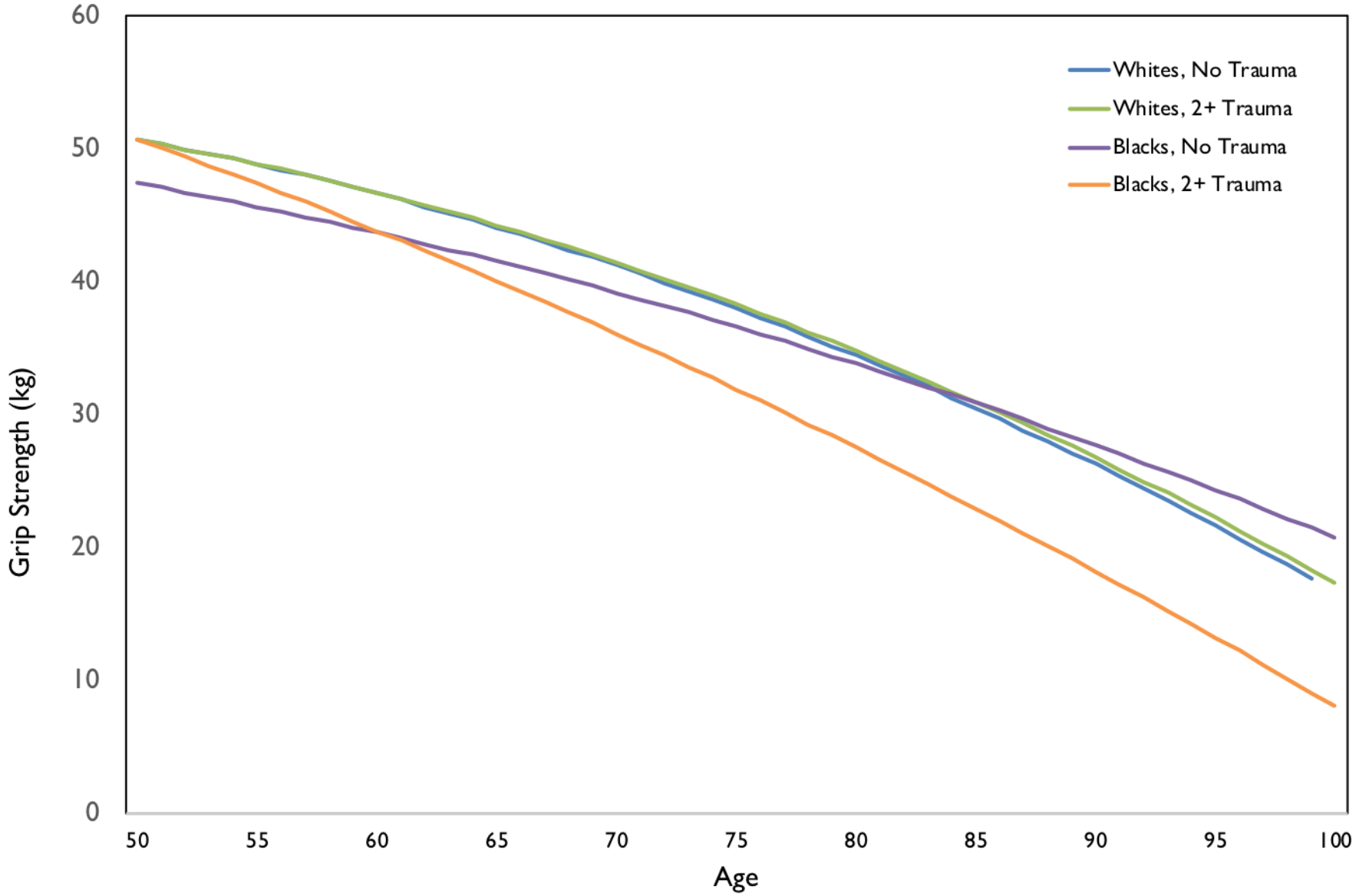


Figure 2. Grip strength growth curve trajectories for Men by Race/ethnicity and Levels of Stressful Events in the Health and Retirement Study (N=8,847), 2006-2014.

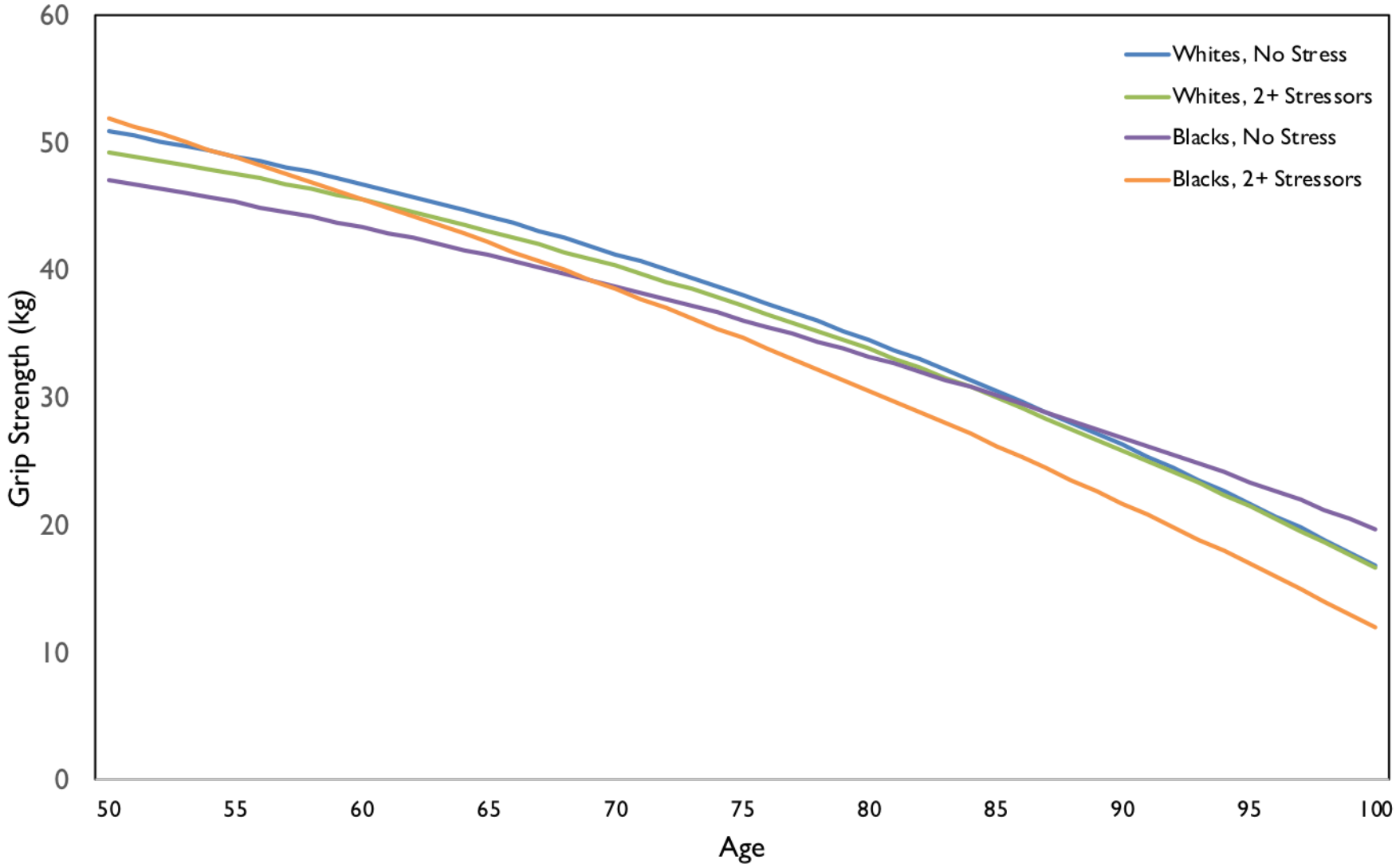


Table 1B Baseline descriptive statistics for Women in the Health and Retirement Study (N=11,624), 2006-2014.

Variable	Black Women (n=2,354) Mean* (SD)	White Women (n=7,797) Mean* (SD)	Hispanic Women (n=1,458) Mean* (SD)
Age (in years) (range 46-99)	62.4 (9.6)	65.2 (10.7)	62.2 (9.4)
Grip Strength (kg)	27.1 (6.9)	25.7 (6.5)	24.1 (5.9)
Chronic Conditions (Range: 0-8)	2.2 (1.4)	1.8 (1.4)	1.8 (1.4)
Body Mass Index (kg/m^2)	31.5 (7.3)	27.8 (6.2)	29.6 (6.4)
	%*	%*	%*
Education			
<HS	57.3	48.6	77
≥ HS	42.8	51.4	23
Physical Activity			
Inactive/Sedentary	26.9	19.8	23.4
Active	73.1	80.2	76.6
Smoking			
Current	14.2	12.5	9.1
Former	36.8	37.6	35.2
Never	49	49.9	55.7
Traumatic Events Across Life Course (range 0-11)			
0	28.2	26	29.5
1	22.6	28	21.7
2	18.4	20.2	20.5
3	15.8	13.1	15
4	7.3	7.4	6.6
5+	7.7	5.3	6.8
Stressful Events Across the Life Course (range 0-11)			
0	40.3	55	51.5
1	22.2	21.5	22.1
2	14.2	11.5	12.2
3	10.2	6.4	7.3
4+	13.2	5.6	7
Traumatic Events Across Life Stages			
Early childhood trauma (0-17 years)			
0	66.4	63.6	60.2
1	23.5	25.6	27.9
2	8.1	7.9	9.3
3+	2	2.9	2.6
Emerging adulthood trauma (18-42 years)			
0	73.2	74.5	64.4

1	19	18.4	24.2
2	6.5	5.2	8.7
3+	1.3	1.8	2.8
Midlife trauma (43-67 years)			
0	66	64.4	70.3
1	24.7	24.1	20.2
2	7.2	8.7	6.1
3+	2	2.8	3.3
Stressful Events Across Life Stages			
Emerging adulthood stress (18-42 years)			
0	82.2	87.8	90.8
1	12.7	9.3	7.6
2	3.3	2.1	1.1
3+	1.8	0.8	0.5
Midlife stress (43-67 years)			
0	65.4	74.8	74.8
1	18.7	13.7	11.5
2	8.4	5.9	8
3+	7.5	5.6	5.7

*Weighted percentages

Table 2B Growth curve models for handgrip strength in Women in the Health and Retirement Study (N=11,624), 2006-2014.

	Unconditional Growth Model	**+Race/Ethnicity**	**+ Trauma in Emerging/Early Adulthood**	**+Trauma and Education**
	Model A	Model B	Model C	Model D
Intercept	29.84***	30.47***	30.68***	31.91***
Race/Ethnicity				
Blacks		-0.443	-0.131	-0.072
Hispanics		-3.38***	-3.59***	-3.42***
Education				
≤HS[a]				-.566***
Trauma During Emerging Adulthood			-0.077	0.108
Trauma*Black			-0.661*	-0.689*
Trauma*Hispanic			0.009	0.001
Rate of Change				
Age	-0.196***	-0.238***	-.246	-.247***
Age2	-.004***	-.003***	-.003	-.003***
Race/Ethnicity				
Blacks*Age		.110***	.117***	.113***
Blacks*Age^2		.002**	-.002**	-0.002*
Hispanics*Age		0.094**	.139***	.129**
Hispanics*Age^2		-0.001	-0.003**	-.003*
Trauma Events				
Trauma*Age			-0.077	0.001
Trauma & Race/Ethnicity				
Trauma*Black*Age			0.026	-.027
Trauma*Hispanic*Age			-0.013	-0.013

Goodness-of-Fit Statistics				
BIC	199489.7	199196.4	179686.7	179688.6
Residual	6.354	6.352	6.47	6.48
Pseudo R2		0.00	0.02	0.02

* p<.05
** p<.01
*** p<.001
[a] Reference is High School degree or higher

Figure 3. Grip strength growth curve trajectories for Women by Race/ethnicity in the Health and Retirement Study (N=11,624), 2006-2014.

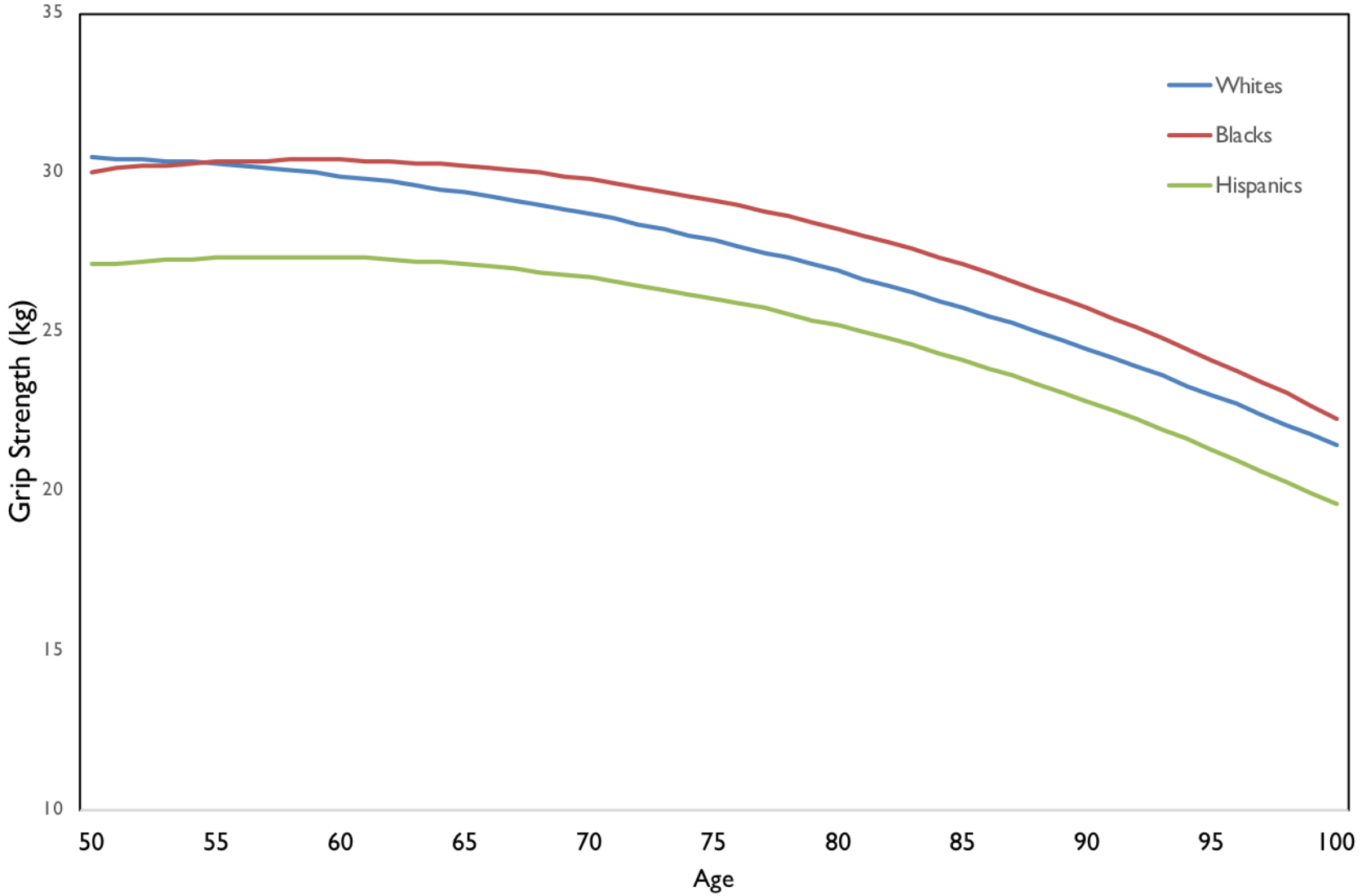
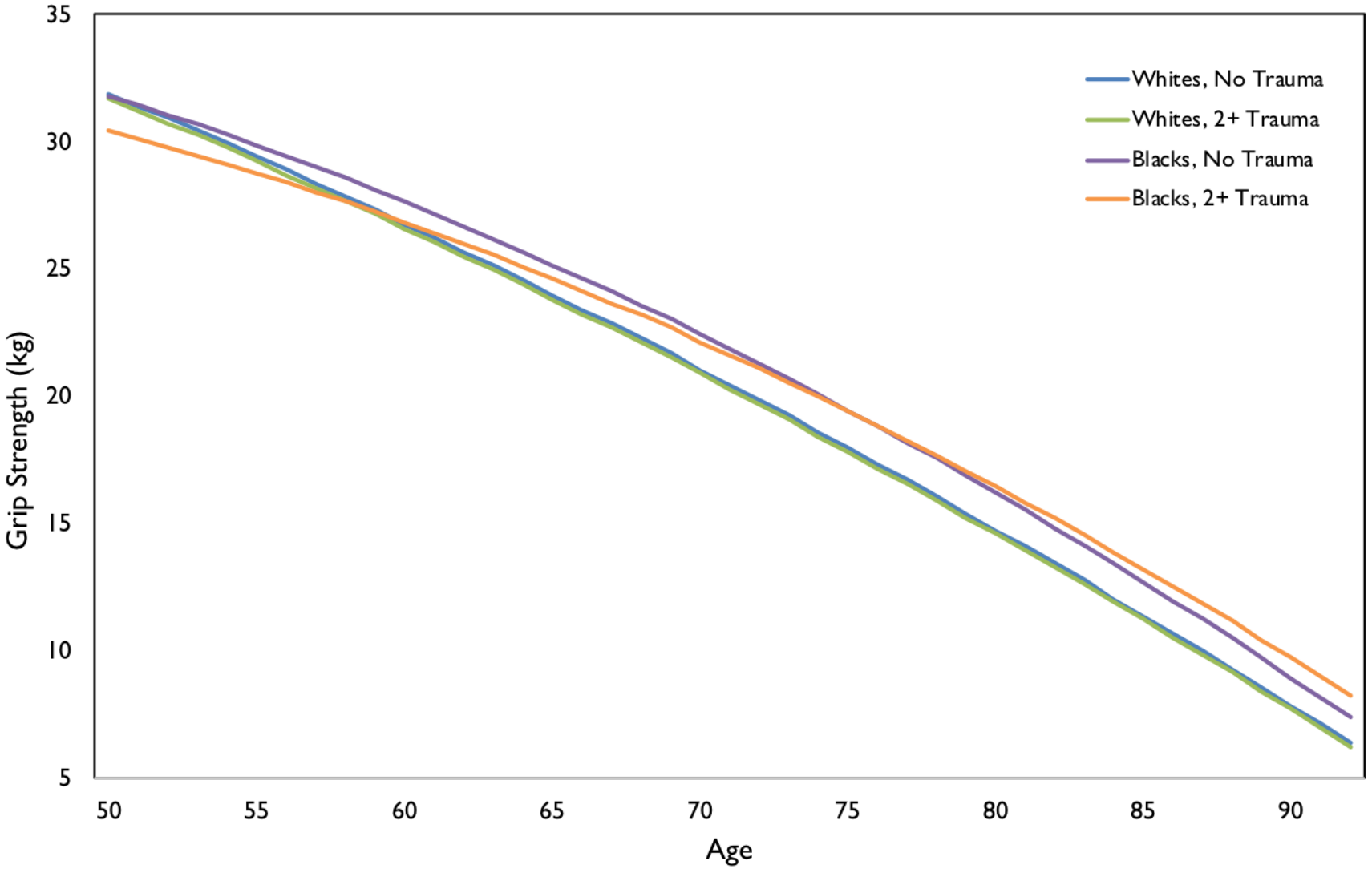


Figure 4. Grip strength growth curve trajectories for Women by Race/ethnicity and Levels of Stressful Events in the Health and Retirement Study (N=11,624), 2006-2014.


35
30
25
20
15
10
5
Grip Strength (kg)
50
55
60
65
70
75
80
85
90
Age
Whites, No Trauma
Whites, 2+ Trauma
Blacks, No Trauma
Blacks, 2+ Trauma

Supplemental Table 1A. Traumatic Life Event Questions from the HRS Participant Leave-Behind Questionnaire

For each of the following events, please indicate whether the event occurred AT ANY POINT IN YOUR LIFE. If the event did happen, please indicate the year in which it happened MOST RECENTLY. (Mark (X) one box for each line. If "Yes", indicate which year.)

1. Has a child of yours ever died?
2. Have you ever fired a weapon in combat or been fired upon in combat?
3. Has your spouse, partner, or child ever been addicted to drugs or alcohol?
4. Have you ever been in a major fire, flood, earthquake, or other natural disaster?
5. Did you ever have a life-threatening illness or accident?
6. Were you the victim of a serious physical attack or assault?
7. Did your spouse or a child of yours ever have a life-threatening illness or accident?

For this next set of events, please think about your childhood growing up, BEFORE YOU WERE 18 YEARS OLD. (Mark (X) one box for each line.)

8. Before you were 18 years old, did you have to do a year of school over again?
9. Before you were 18 years old, did either of your parents drink or use drugs so often that it caused problems in the family?
10. Before you were 18 years old, were you ever physically abused by either of your parents?
11. Before you were 18 years old, were you ever in trouble with the police?

Supplemental Table 1B. Stressful Life Event Questions from the HRS Participant Leave-Behind Questionnaire.

For each of the following events, please indicate whether the event occurred AT ANY POINT IN YOUR LIFE. If the event did happen, please indicate the year in which it happened MOST RECENTLY. (Mark (X) one box for each line. If "Yes", indicate which year.)

1. At any time in your life, have you ever been unfairly dismissed from a job?
2. Have you ever been unfairly denied a promotion?
3. Have you ever been unfairly prevented from moving into a neighborhood because the landlord or a realtor refused to sell or rent you a house or apartment?
4. For unfair reasons, have you ever not been hired for a job?
5. Have you ever been unfairly stopped, searched, questioned, physically threatened, or abused by the police?
6. Have you ever been unfairly denied a bank loan?

Now please think about the LAST 5 YEARS and indicate whether each of the events below occurred. If the event did happen, please indicate the year in which it happened MOST RECENTLY. (Mark (X) one box for each line. If "Yes", indicate year.)

7. Have you involuntarily lost a job for reasons other than retirement at any point in the past five years?
8. Was anyone else in your household unemployed and looking for work for longer than 3 months in the past five years?
9. Have you moved to a worse residence or neighborhood in the past five years?
10. Have you been unemployed and looking for work for longer than 3 months at some point in the past five years?

11. Were you robbed or did you have your home burglarized in the past five years?

References

1. McLean RR, Shardell MD, Alley DE, et al. Criteria for clinically relevant weakness and low lean mass and their longitudinal association with incident mobility impairment and mortality: the foundation for the National Institutes of Health (FNIH) sarcopenia project. *J Gerontol A Biol Sci Med Sci*. 2014;69(5):576-583. doi:10.1093/gerona/glu012

2. Sallinen J, Stenholm S, Rantanen T, Heliövaara M, Sainio P, Koskinen S. Hand-grip strength cut points to screen older persons at risk for mobility limitation. *J Am Geriatr Soc*. 2010;58(9):1721-1726. doi:10.1111/j.1532-5415.2010.03035.x

3. Rantanen T, Guralnik JM, Foley D, et al. Midlife Hand Grip Strength as a Predictor of Old Age Disability. *JAMA*. 1999;281(6):558. doi:10.1001/jama.281.6.558

4. Rantanen T. Muscle strength, disability and mortality. *Scand J Med Sci Sport*. 2003;13(1):3-8. doi:10.1034/j.1600-0838.2003.00298.x

5. Duchowny KA, Clarke PJ, Peterson MD. Muscle weakness and physical disability in older Americans: Longitudinal findings from the U.S. Health and Retirement Study. *J Nutr Health Aging*. 2017. doi:10.1007/s12603-017-0951-y

6. Snih S Al, Markides KS, Ottenbacher KJ, Raji MA. Hand grip strength and incident ADL disability in elderly Mexican Americans over a seven-year period. *Aging Clin Exp Res*. 2004;16(6):481-486. doi:10.1007/BF03327406

7. Gale CR, Martyn CN, Cooper C, Sayer AA. Grip strength, body composition, and

mortality. *Int J Epidemiol*. 2007;36(1):228-235. doi:10.1093/ije/dyl224

8. Cheung C-L, Nguyen U-SDT, Au E, Tan KCB, Kung AWC. Association of handgrip strength with chronic diseases and multimorbidity. *Age (Omaha)*. 2013;35(3):929-941. doi:10.1007/s11357-012-9385-y

9. Sasaki H, Kasagi F, Yamada M, Fujita S. Grip Strength Predicts Cause-Specific Mortality in Middle-Aged and Elderly Persons. *Am J Med*. 2007;120(4):337-342. doi:10.1016/j.amjmed.2006.04.018

10. Leong DP, Teo KK, Rangarajan S, et al. Prognostic value of grip strength: findings from the Prospective Urban Rural Epidemiology (PURE) study. *Lancet*. 2015;386(9990):266-273. doi:10.1016/S0140-6736(14)62000-6

11. Rantanen T, Harris T, Leveille SG, et al. Muscle Strength and Body Mass Index as Long-Term Predictors of Mortality in Initially Healthy Men. *Journals Gerontol Ser A Biol Sci Med Sci*. 2000;55(3):M168-M173. doi:10.1093/gerona/55.3.M168

12. Al Snih S, Markides KS, Ray L, Ostir G V., Goodwin JS. Handgrip Strength and Mortality in Older Mexican Americans. *J Am Geriatr Soc*. 2002;50(7):1250-1256. doi:10.1046/j.1532-5415.2002.50312.x

13. Newman AB, Kupelian V, Visser M, et al. Strength, But Not Muscle Mass, Is Associated With Mortality in the Health, Aging and Body Composition Study Cohort. *Journals Gerontol Ser A Biol Sci Med Sci*. 2006;61(1):72-77. doi:10.1093/gerona/61.1.72

14. Peterson MD, Zhang P, Duchowny KA, Markides KS, Ottenbacher KJ, Al Snih S.

Declines in strength and mortality risk among older mexican americans: Joint modeling of survival and longitudinal data. *Journals Gerontol - Ser A Biol Sci Med Sci*. 2016;71(12). doi:10.1093/gerona/glw051

15. Ruiz JR, Sui X, Lobelo F, et al. Association between muscular strength and mortality in men: prospective cohort study. *BMJ*. 2008;337. http://www.bmj.com/content/337/bmj.a439. Accessed September 7, 2017.

16. Duchowny KA, Peterson MD, Clarke PJ. Cut Points for Clinical Muscle Weakness Among Older Americans. *Am J Prev Med*. 2017;53(1):63-69. doi:10.1016/J.AMEPRE.2016.12.022

17. Freedman VA, Martin LG. Understanding trends in functional limitations among older Americans. *Am J Public Health*. 1998;88(10):1457-1462. doi:10.2105/AJPH.88.10.1457

18. Davis JW, Ross PD, Preston SD, Nevitt MC, Wasnich RD. Strength, physical activity, and body mass index: relationship to performance-based measures and activities of daily living among older Japanese women in Hawaii. *J Am Geriatr Soc*. 1998;46(3):274-279. http://www.ncbi.nlm.nih.gov/pubmed/9514371. Accessed December 15, 2015.

19. Rantanen T, Volpato S, Ferrucci L, et al. Handgrip strength and cause-specific and total mortality in older disabled women: exploring the mechanism. *J Am Geriatr Soc*. 2003;51(5):636-641. doi:10.1034/j.1600-0579.2003.00207.x

20. Peterson MD, Duchowny K, Meng Q, Wang Y, Chen X, Zhao Y. Low Normalized

Grip Strength is a Biomarker for Cardiometabolic Disease and Physical Disabilities Among U.S. and Chinese Adults. *J Gerontol A Biol Sci Med Sci*. 2017;72(11). doi:10.1093/gerona/glx031

21. Wang AYM, Sea MMM, Ho ZSY, Lui SF, Li PKT, Woo J. Evaluation of handgrip strength as a nutritional marker and prognostic indicator in peritoneal dialysis patients. 2005;81(1):79-86. https://www.scopus.com/record/display.uri?eid=2-s2.0-13744257736&origin=inward&txGid=ae9b853210c5851461aee20d092fd1f2. Accessed September 21, 2017.

22. Turner RJ, Lloyd DA. Lifetime Traumas and Mental Health: The Significance of Cumulative Adversity. *J Health Soc Behav*. 1995;36(4):360. doi:10.2307/2137325

23. Mcleod JD, Shanahan MJ. Trajectories of Poverty and Children's Mental Health Trajectories of Poverty and Children's Mental Health*. *Source J Heal Soc Behav J Heal Soc Behav*. 1996;37(37). http://www.jstor.org/stable/2137292. Accessed April 2, 2018.

24. Pearlin LI, Schieman S, Fazio EM, Meersman SC. Stress, Health, and the Life Course: Some Conceptual Perspectives. *J Health Soc Behav*. 2005;46(2):205-219. http://journals.sagepub.com/doi/10.1177/002214650504600206. Accessed April 2, 2018.

25. Kuh D, Ben-Shlomo Y, Lynch J, Hallqvist J, Power C. Life course epidemiology. *J Epidemiol Community Health*. 2003;57(10):778-783. doi:10.1136/JECH.57.10.778

26. ELDER Jr MONICA KIRKPATRICK JOHNSON ROBERT CROSNOE GH, Elder GH, KIRKPATRICK JoHNSON M. The Emergence and Development of Life Course Theory. https://biblio.csusm.edu/sites/default/files/reserves/ch1_handbook_of_the_life_course_p.3-19.pdf. Accessed April 2, 2018.

27. Kane JB, Harris KM, Morgan SP, Guilkey DK. Pathways of Health and Human Capital from Adolescence into Young Adulthood. *Soc Forces*. 2018;96(3):949-976. doi:10.1093/sf/sox079

28. Clarke P, Marshall V, House J, Lantz P. The Social Structuring of Mental Health over the Adult Life Course: Advancing Theory in the Sociology of Aging. *Soc Forces*. 2011;89(4):1287-1313. doi:10.1353/sof.2011.0036

29. SCHULENBERG JE, SAMEROFF AJ, CICCHETTI D. The transition to adulthood as a critical juncture in the course of psychopathology and mental health. *Dev Psychopathol*. 2004;16(04):799-806. doi:10.1017/S0954579404040015

30. Arnett JJ. Emerging Adulthood: What Is It, and What Is It Good For? *Child Dev Perspect*. 2007;1(2):68-73. doi:10.1111/j.1750-8606.2007.00016.x

31. Barker DJ. Fetal origins of coronary heart disease. *BMJ*. 1995;311(6998):171-174. http://www.ncbi.nlm.nih.gov/pubmed/7613432. Accessed April 2, 2018.

32. Galobardes B, Smith GD, Lynch JW, et al. Systematic Review of the Influence of Childhood Socioeconomic Circumstances on Risk for Cardiovascular Disease in

Adulthood. *Ann Epidemiol*. 2006;16(2):91-104. doi:10.1016/j.annepidem.2005.06.053

33. Glymour MM, Avendaño M, Haas S, Berkman LF. Lifecourse social conditions and racial disparities in incidence of first stroke. *Ann Epidemiol*. 2008;18(12):904-912.

34. Nandi A, Glymour MM, Kawachi I, VanderWeele TJ. Using marginal structural models to estimate the direct effect of adverse childhood social conditions on onset of heart disease, diabetes, and stroke. *Epidemiology*. 2012;23(2):223-232. doi:10.1097/EDE.0b013e31824570bd

35. Clarke P, Latham K. Life course health and socioeconomic profiles of Americans aging with disability. *Disabil Health J*. 2014;7(1 Suppl):S15-23. doi:10.1016/j.dhjo.2013.08.008

36. Birnie K, Cooper R, Martin RM, et al. Childhood Socioeconomic Position and Objectively Measured Physical Capability Levels in Adulthood: A Systematic Review and Meta-Analysis. Vitzthum V, ed. *PLoS One*. 2011;6(1):e15564. doi:10.1371/journal.pone.0015564

37. Syddall H, Evandrou M, Cooper C, Aihie Sayer A. Social Inequalities in Grip Strength, Physical Function, and Falls Among Community Dwelling Older Men and Women. *J Aging Health*. 2009;21(6):913-939. doi:10.1177/0898264309340793

38. Ben-Shlomo Y, Kuh D. A life course approach to chronic disease epidemiology:

conceptual models, empirical challenges and interdisciplinary perspectives. *Int J Epidemiol*. 2002;31(2):285-293. doi:10.1093/intjepid/31.2.285

39. Dannefer D. Cumulative Advantage/Disadvantage and the Life Course: Cross-Fertilizing Age and Social Science Theory. *Journals Gerontol Ser B Psychol Sci Soc Sci*. 2003;58(6):S327-S337. doi:10.1093/geronb/58.6.S327

40. Wickrama KAS, Noh S, Elder GH. An investigation of family SES-based inequalities in depressive symptoms from early adolescence to emerging adulthood. *Adv Life Course Res*. 2009;14(3). doi:10.1016/j.alcr.2010.04.001

41. Strawbridge WJ, Shema SJ, Balfour JL, Higby HR, Kaplan GA. Antecedents of Frailty Over Three Decades in an Older Cohort. *Journals Gerontol Ser B Psychol Sci Soc Sci*. 1998;53B(1):S9-S16. doi:10.1093/geronb/53B.1.S9

42. Dodds RM, Syddall HE, Cooper R, Kuh D, Cooper C, Sayer AA. Global variation in grip strength: a systematic review and meta-analysis of normative data. *Age Ageing*. 2016;45(2):209-216. doi:10.1093/ageing/afv192

43. Sayer AA, Syddall HE, Gilbody HJ, Dennison EM, Cooper C. Does Sarcopenia Originate in Early Life? Findings From the Hertfordshire Cohort Study. *Journals Gerontol Ser A Biol Sci Med Sci*. 2004;59(9):M930-M934. doi:10.1093/gerona/59.9.M930

44. Kuh D, Hardy R, Butterworth S, et al. Developmental Origins of Midlife Grip Strength: Findings From a Birth Cohort Study. *Journals Gerontol Ser A Biol Sci Med Sci*. 2006;61(7):702-706. doi:10.1093/gerona/61.7.702

45. Mohd Hairi F, Mackenbach JP, Andersen-Ranberg K, Avendano M. Does socio-economic status predict grip strength in older Europeans? Results from the SHARE study in non-institutionalised men and women aged 50+. *J Epidemiol Community Heal*. 2010;64(9):829-837. doi:10.1136/jech.2009.088476

46. Quan S, Jeong J-Y, Kim D-H. The Relationship between Smoking, Socioeconomic Status and Grip Strength among Community-dwelling Elderly Men in Korea: Hallym Aging Study. *Epidemiol Health*. 2013;35:e2013001. doi:10.4178/epih/e2013001

47. Smith NR, Ferraro KF, Kemp BR, Morton PM, Mustillo SA, Angel JL. Childhood Misfortune and Handgrip Strength Among Black, White, and Hispanic Americans. *Journals Gerontol Ser B Psychol Sci Soc Sci*. December 2016:gbw147. doi:10.1093/geronb/gbw147

48. O'Rand AM, Hamil-Luker J. Processes of cumulative adversity: Childhood disadvantage and increased risk of heart attack across the life course. In: Vol 60. Gerontological Society of America; 2005:117-124. https://www.scopus.com/record/display.uri?eid=2-s2.0-27644590839&origin=inward&txGid=e1390c3bca5504441a1d0ff49735422f. Accessed April 3, 2018.

49. Mirowsky J, Ross CE. Age and Depression. *J Health Soc Behav*. 1992;33(3):187. doi:10.2307/2137349

50. Turner RJ, Thomas CS, Brown TH. Childhood adversity and adult health: Evaluating intervening mechanisms. *Soc Sci Med*. 2016;156:114-124.

doi:10.1016/J.SOCSCIMED.2016.02.026

51. Mayo D, Corey S, Kelly LH, et al. The Role of Trauma and Stressful Life Events among Individuals at Clinical High Risk for Psychosis: A Review. *Front Psychiatry*. 2017;8:55. doi:10.3389/fpsyt.2017.00055

52. Brewerton TD. Food addiction as a proxy for eating disorder and obesity severity, trauma history, PTSD symptoms, and comorbidity. *Eat Weight Disord - Stud Anorexia, Bulim Obes*. 2017;22(2):241-247. doi:10.1007/s40519-016-0355-8

53. Hapke U, Schumann A, Rumpf H-J, John U, Konerding U, Meyer C. Association of Smoking and Nicotine Dependence With Trauma and Posttraumatic Stress Disorder in a General Population Sample. *J Nerv Ment Dis*. 2005;193(12):843-846. doi:10.1097/01.nmd.0000188964.83476.e0

54. Lang AJ, Rodgers CS, Laffaye C, Satz LE, Dresselhaus TR, Stein MB. Sexual Trauma, Posttraumatic Stress Disorder, and Health Behavior. https://www.tandfonline.com/doi/pdf/10.1080/08964280309596053. Accessed April 12, 2018.

55. Turner RJ, Wheaton B, Lloyd DA. The Epidemiology of Social Stress. *Am Sociol Rev*. 1995;60(1):104. doi:10.2307/2096348

56. Sondik EJ, Huang DT, Klein RJ, Satcher D. Progress Toward the Healthy People 2010 Goals and Objectives. *Annu Rev Public Health*. 2010;31(1):271-281. doi:10.1146/annurev.publhealth.012809.103613

57. Williams DR. Race and health: Basic questions, emerging directions. *Ann*

Epidemiol. 1997;7(5):322-333. doi:10.1016/S1047-2797(97)00051-3

58. Blackwell DL, Collins JG, Coles R. Summary health statistics for U.S. adults: National Health Interview Survey, 1997. *Vital Health Stat 10*. 2002;(205):1-109. http://www.ncbi.nlm.nih.gov/pubmed/15786607. Accessed April 3, 2018.

59. Hayward MD, Heron M. Racial Inequality in Active Life among Adult Americans. *Demography*. 1999;36(1):77. doi:10.2307/2648135

60. Fuller-Thomson E, Nuru-Jeter A, Minkler M, Guralnik JM. Black-White disparities in disability among older Americans: further untangling the role of race and socioeconomic status. *J Aging Health*. 2009;21(5):677-698. doi:10.1177/0898264309338296

61. Kelley-Moore JA, Ferraro KF. The Black/White Disability Gap: Persistent Inequality in Later Life? *Journals Gerontol Ser B Psychol Sci Soc Sci*. 2004;59(1):S34-S43. doi:10.1093/geronb/59.1.S34

62. Markides KS, Eschbach K. Aging, migration, and mortality: current status of research on the Hispanic paradox. *J Gerontol B Psychol Sci Soc Sci*. 2005;60 Spec No 2:68-75. http://www.ncbi.nlm.nih.gov/pubmed/16251594. Accessed April 3, 2018.

63. Markides KS, Rote S. Immigrant Health Paradox. https://onlinelibrary.wiley.com/doi/pdf/10.1002/9781118900772.etrds0174. Accessed April 3, 2018.

64. Hummer RA, Rogers RG, Amir SH, Forbes D, Frisbie WP. Adult mortality

differentials among Hispanic subgroups and non-Hispanic whites. 2000;81(1):459-476. https://www.scopus.com/record/display.uri?eid=2-s2.0-0040188013&origin=inward&txGid=bcea90848bdb6c02435aee5e9c6adf0d. Accessed April 3, 2018.

65. Ostchega Y, Harris TB, Hirsch R, Parsons VL, Kington R. The prevalence of functional limitations and disability in older persons in the US: data from the National Health and Nutrition Examination Survey III. *J Am Geriatr Soc*. 2000;48(9):1132-1135. http://www.ncbi.nlm.nih.gov/pubmed/10983915. Accessed April 3, 2018.

66. Kelly-Hayes M, Jette a. M, Wolf P a., D'Agostino RB, Odell PM. Functional limitations and disability among elders in the Framingham study. *Am J Public Health*. 1992;82(6):841-845. doi:10.2105/AJPH.82.6.841

67. Kington RS, Smith JP. Socioeconomic status and racial and ethnic differences in functional status associated with chronic diseases. *Am J Public Health*. 1997;87(5):805-810. doi:10.2105/AJPH.87.5.805

68. Clark DO, Maddox GL, Steinhauser K. Race, Aging, and Functional Health. *J Aging Health*. 1993;5(4):536-553. doi:10.1177/089826439300500407

69. Roberts AL, Gilman SE, Breslau J, Breslau N, Koenen KC. Race/ethnic differences in exposure to traumatic events, development of post-traumatic stress disorder, and treatment-seeking for post-traumatic stress disorder in the United States. *Psychol Med*. 2011;41(1):71-83. doi:10.1017/S0033291710000401

70. Shuey KM, Willson AE. Cumulative Disadvantage and Black-White Disparities in Life-Course Health Trajectories. *Gibson Hayward Heron Res Aging*. 1997;30(2):200-225. doi:10.1177/0164027507311151

71. Ferraro KF, Shippee TP. Aging and Cumulative Inequality: How Does Inequality Get Under the Skin? *Gerontologist*. 2009;49(3):333-343. doi:10.1093/geront/gnp034

72. Growing Older in America: The Health and Retirement Study. http://hrsonline.isr.umich.edu/index.php?p=dbook. Accessed December 15, 2015.

73. Crimmins EM, Guyer H, Langa KM, Ofstedal MB, Wallace RB, Weir DR. Documentation of Physical Measures, Anthropometrics and Blood Pressure in the Health and Retirement Study. *Hrs*. 2008;14(February).

74. Smith J, Ryan L, Sonnega A, Weir D. Psychosocial and Lifestyle Questionnaire Documentation Report Core Section LB. 2006. https://hrs.isr.umich.edu/sites/default/files/biblio/HRS 2006-2016 SAQ Documentation_07.06.17.pdf. Accessed April 11, 2018.

75. American Psychological Association. BAJDV. *Journal of Consulting and Clinical Psychology*. Vol 68. American Psychological Association; 2000. https://insights.ovid.com/consulting-clinical-psychology/jccpy/2000/10/000/meta-analysis-risk-factors-posttraumatic-stress/1/00004730. Accessed April 12, 2018.

76. Stenholm S, Tiainen K, Rantanen T, et al. Long-Term Determinants of Muscle Strength Decline: Prospective Evidence from the 22-Year Mini-Finland Follow-Up

Survey. *J Am Geriatr Soc*. 2012;60(1):77-85. doi:10.1111/j.1532-5415.2011.03779.x

77. Singer JD, Willett JB. *Applied Longitudinal Data Analysis : Modeling Change and Event Occurrence*. Oxford University Press; 2003.

78. Oh C, Jho S, No J-K, Kim H-S. Body composition changes were related to nutrient intakes in elderly men but elderly women had a higher prevalence of sarcopenic obesity in a population of Korean adults. *Nutr Res*. 2015;35(1):1-6. doi:10.1016/j.nutres.2014.07.018

79. Dodds R, Denison HJ, Ntani G, et al. Birth weight and muscle strength: A systematic review and meta-analysis. *J Nutr Health Aging*. 2012;16(7):609-615. doi:10.1007/s12603-012-0053-9

80. Pace TWW, Mletzko TC, Alagbe O, et al. Increased stress-induced inflammatory responses in male patients with major depression and increased early life stress. *Am J Psychiatry*. 2006;163(9):1630-1633. doi:10.1176/ajp.2006.163.9.1630

81. Rozanski A, Blumenthal JA, Kaplan J. Impact of psychological factors on the pathogenesis of cardiovascular disease and implications for therapy. *Circulation*. 1999;99(16):2192-2217. http://www.ncbi.nlm.nih.gov/pubmed/10217662. Accessed April 5, 2018.

82. MCEWEN BS. Protection and Damage from Acute and Chronic Stress: Allostasis and Allostatic Overload and Relevance to the Pathophysiology of Psychiatric Disorders. *Ann N Y Acad Sci*. 2004;1032(1):1-7. doi:10.1196/annals.1314.001

83. Cohen S, Janicki-Deverts D, Miller GE. Psychological Stress and Disease. *JAMA*. 2007;298(14):1685. doi:10.1001/jama.298.14.1685

84. Cesari M, Penninx BWJH, Pahor M, et al. Inflammatory Markers and Physical Performance in Older Persons: The InCHIANTI Study. *Journals Gerontol Ser A Biol Sci Med Sci*. 2004;59(3):M242-M248. doi:10.1093/gerona/59.3.M242

85. Cesari M, Kritchevsky SB, Baumgartner RN, et al. Sarcopenia, obesity, and inflammation--results from the Trial of Angiotensin Converting Enzyme Inhibition and Novel Cardiovascular Risk Factors study. *Am J Clin Nutr*. 2005;82(2):428-434. http://ajcn.nutrition.org/cgi/content/long/82/2/428. Accessed April 5, 2015.

86. Geronimus AT, Hicken M, Keene D, Bound J. "Weathering" and Age Patterns of Allostatic Load Scores Among Blacks and Whites in the United States. *Am J Public Health*. 2006;96(5):826-833. doi:10.2105/AJPH.2004.060749

87. Brown MK. *Whitewashing Race : The Myth of a Color-Blind Society*. University of California Press; 2005. https://www.ucpress.edu/book.php?isbn=9780520244757. Accessed April 6, 2018.

88. Gee GC, Ford CL. STRUCTURAL RACISM AND HEALTH INEQUITIES: Old Issues, New Directions. *Du Bois Rev*. 2011;8(1):115-132. doi:10.1017/S1742058X11000130

89. Ford CL, Airhihenbuwa CO. Critical Race Theory, race equity, and public health: toward antiracism praxis. *Am J Public Health*. 2010;100 Suppl 1(Suppl 1):S30-5. doi:10.2105/AJPH.2009.171058

90. Hicken MT, Kravitz-Wirtz N, Jackson JS. Racial inequalities in health: Framing future research. *Soc Sci Med*. 2018;199:11-18. doi:10.1016/J.SOCSCIMED.2017.12.027

91. Powell J. Structural Racism: Building upon the Insights of John Calmore. *North Carol Law Rev*. January 2007. https://scholarship.law.berkeley.edu/facpubs/1637. Accessed April 5, 2018.

92. Viruell-Fuentes EA, Miranda PY, Abdulrahim S. More than culture: Structural racism, intersectionality theory, and immigrant health. *Soc Sci Med*. 2012;75(12):2099-2106. doi:10.1016/J.SOCSCIMED.2011.12.037

93. Lewis TT, Cogburn CD, Williams DR. *Self-Reported Experiences of Discrimination and Health: Scientific Advances, Ongoing Controversies, and Emerging Issues*. Vol 11.; 2014. doi:10.1146/annurev-clinpsy-032814-112728

94. Phelan JC, Link BG. Is Racism a Fundamental Cause of Inequalities in Health? 2015. doi:10.1146/annurev-soc-073014-112305

95. Riley AR. Neighborhood Disadvantage, Residential Segregation, and Beyond—Lessons for Studying Structural Racism and Health. *J Racial Ethn Heal Disparities*. 2018;5(2):357-365. doi:10.1007/s40615-017-0378-5

96. Wallace M, Crear-Perry J, Richardson L, Tarver M, Theall K. Separate and unequal: Structural racism and infant mortality in the US. *Health Place*. 2017;45:140-144. doi:10.1016/J.HEALTHPLACE.2017.03.012

97. Hicken MT, Lee H, Hing AK. The weight of racism: Vigilance and racial

inequalities in weight-related measures. *Soc Sci Med*. 2018;199:157-166. doi:10.1016/J.SOCSCIMED.2017.03.058

98. Clarke P, Wheaton B. Mapping Social Context on Mental Health Trajectories Through Adulthood. *Adv Life Course Res*. 2005;9:269-301. doi:10.1016/S1040-2608(04)09010-0

99. Ortman JM, Velkoff VA, Hogan H. An Aging Nation: The Older Population in the United States Current Population Reports. 2014. http://bowchair.com/uploads/9/8/4/9/98495722/agingcensus.pdf. Accessed August 1, 2016.

100. Haas S. Trajectories of functional health: The "long arm" of childhood health and socioeconomic factors. 2007. doi:10.1016/j.socscimed.2007.11.004

101. Krall EA, Valadian I, Dwyer JT, Gardner J. Recall of childhood illnesses. *J Clin Epidemiol*. 1988;41(11):1059-1064. doi:10.1016/0895-4356(88)90075-3

102. Hayward MD, Miles TP, Crimmins EM, Yang Y. The Significance of Socioeconomic Status in Explaining the Racial Gap in Chronic Health Conditions. *Am Sociol Rev*. 2000;65(6):910. doi:10.2307/2657519