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Article

Life course trauma and muscle weakness in older adults by gender and race/ethnicity: Results from the U.S. health and Retirement Study

Kate A. Duchowny [a,*], Margaret T. Hicken [b], Peggy M. Cawthon [a,c], M. Maria Glymour [a], Philippa Clarke [b,d]

[a] Department of Epidemiology and Biostatistics, University of California, San Francisco, CA, USA
[b] Institute for Social Research, University of Michigan, Ann Arbor, MI, USA
[c] Research Institute, California Pacific Medical Center, San Francisco, CA, USA
[d] Department of Epidemiology, University of Michigan School of Public Health, Ann Arbor, MI, USA

A B S T R A C T

Muscle weakness, as measured by handgrip strength, is a primary determinant of physical functioning and disability. There is a high burden of muscle weakness in the United States with close to 50 percent of older Americans meeting criteria for clinical muscle weakness. While previous racial/ethnic disparities have been documented among older adults, the extent to which lifecourse trauma shapes muscle strength trajectories is unknown. Using U.S. Health and Retirement Study (N = 20,472, Mean Age = 63.8 years) data on grip strength (2006–2014, up to 3 assessments) and retrospectively reported traumatic events, we fit gender-stratified growth curve models to investigate whether traumatic events experienced across the lifecourse or at distinct sensitive periods (childhood, early/emerging adulthood or mid-life) predicted later-life trajectories of grip strength. There was no association between cumulative trauma and trajectories of grip strength and the main effects for the life stage models were largely null. However, among White women, our results suggest that traumatic events experienced during childhood (β = −0.012; 95% CI = −0.024, 0.0004) compared to middle adulthood are associated with faster declines in grip strength in later life. Traumatic events reported during childhood was related to a slower decline in grip strength over time among Hispanic women compared to that for White women (β = 0.086, 95% CI = 0.044, 0.128). Among Black men, the association between traumatic events during early/emerging adulthood and age-related declines in grip strength was stronger for Black men than for White men (interaction β = −0.070; 95% CI = −0.138, 0.001). Traumatic events experienced during distinct life stages may influence later life declines in grip strength and exacerbate racial inequalities in later life. This study addresses an important gap by investigating the life course social determinants of later life muscle strength, which is a key driver of physical functioning and mobility.

Introduction

There is a high burden of muscle weakness among older adults in the United States with close to 50% of older Americans meeting the critieria for clinical muscle weakness (Duchowny, Peterson, & Clarke, 2017). Stark disparities in muscle weakness have also been observed between Black and White adults. Understanding the risk factors that drive muscle weakness in later life is of critical public health importance because low muscle strength is associated with physical functioning limitations, disability, multimorbidity and both cardiovascular and all cause-mortality (Al Snih, Markides, Ray, Ostir, & Goodwin, 2002; Cheung, Nguyen, Au, Tan, & Kung, 2013; Duchowny, Clarke, & Peterson, 2018; Gale, Martyn, Cooper, & Sayer, 2007; Leong et al., 2015; McLean et al., 2014; Newman et al., 2006; Peterson et al., 2016; Rantanen et al., 2000; Ruiz et al., 2008; Sallinen et al., 2010). Although physical activity, chronic diseases, and nutrition in older age are important determinants of muscle weakness, significant unexplained variability remains in identifying which individuals become weak in older age (Davis, Ross, Preston, Nevitt, & Wasnich, 1998; Peterson et al., 2017; Wang et al., 2005). Therefore, employing a life course approach to understanding how early and midlife risk factors predispose individuals to muscle weakness in later life may enhance our understanding of who is most at risk while identifying optimal timing for intervention.

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 (Kuh, Ben-Shlomo, Lynch, Hallqvist, & Power, 2003). Two general conceptual models within life course theory have been proposed to understand how early life antecedent events drive

* Corresponding author. University of California, San FranciscoDepartment of Epidemiology & Biostatistics, 550 16th Street, 2nd Floor, San Francisco, CA, 94158, USA.
E-mail address: kate.duchowny@ucsf.edu (K.A. Duchowny).

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health outcomes in older age: the accumulation of risk model and the sensitive period model. The accumulation of risk model posits that negative expeperiences and exposures accumulate additively across the life course, ultimately influencing health status in later life (Ben-Shlomo & Kuh, 2002). This model has been used to explain why socioeconomic differentials in health exist across a wide range of diseases, and has been applied in the examination of physical health outcomes. For example, the cumulative effects of 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 adulthood and midlife was associated with increased risk of frailty in a community dwelling sample of older adults (Strawbridge, Shema, Balfour, Higby, & Kaplan, 1998).

The sensitive period model suggests there are important life stages in which an individual experiences adverse events and exposures that may have lasting consequences on their health in later life. This 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 (Barker, 1995). However, the sensitive period framework has also been used to demonstrate how exposures during early adulthood, when individuals typically embark on career trajectories and asset accumulation, may be consequential for later health outcomes (Clarke, Marshall, House, & Lantz, 2011). Early life experiences, captured by childhood socioeconomic position, have also been found to be directly associated with cardiovascular disease, stroke, physical functioning and lower levels of grip strength in older adults (Birnie et al., 2011; Clarke & Latham, 2014; Glymour, Avendaño, Haas, & Berkman, 2008; Nandi, Glymour, Kawachi, & VanderWeele, 2012; Syddall, Evandrou, Cooper, & Aihie Sayer, 2009). While there is growing interest in the role that early and midlife factors play in the preservation of muscle strength in later life, the majority of life course research on muscle strength has focused on early life anthropometric indicators showing higher birth weight and pubertal height to be associated with greater muscle strength in adulthood (Dodds et al., 2016; Kuh et al., 2006), with a handful of studies also demonstrating that early life socioeconomic status predicts muscle strength (Quan, Jeong, & Kim, 2013; Syddall et al., 2009).

Gender differences in grip strength

There are well established gender differences in absolute muscle strength. Numerous studies have documented that men have larger muscles compared to women and that these muscles are particularly pronounced in the upper limbs (Miller, MacDougall, Tarnopolsky, & Sale, 1993; Morrow & Hosler, 1981). Several factors may contribute to these known differences, some of which include: the size of type-I muscle fibers, the amount of non-contractive tissue in the muscle, activity of the motor units and potential mechanical advantages as well (Miller et al., 1993). As a result, when seeking to examine grip strength across the life course, gender-stratified models are often appropropiate.

Trauma and muscle health

Traumatic events, such as the death of a spouse or job loss, have a strong relationship with both immediate and long-term health outcomes (Bonanno, 2012; Pearlin, Schieman, Fazio, & Meersman, 2005). Pearlin noted that traumatic events may be the most potent form of stress, due to the "magnitude of their onerousness … and by their sudden and violent character" (pg. 210) (Pearlin et al., 2005).While little is known about life course trauma and later life muscle health, recent work has found a link between social adversity, life course socioeconomic status and muscle health. A systematic review found modest, positive associations between childhood SES and later life grip strength (a measure of muscle weakness), even after adjusting for adult SES and current body size (Birnie et al., 2011). 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 (Syddall et al., 2009). In the only previous population-based study of childhood adversity and later life strength, childhood misfortune was found to be related to lower handgrip strength in men, but not in women (Smith et al., 2016).

Trauma and muscle health across the life course

Despite the known links between traumatic events and later life mental and physical health, no studies have directly examined whether life course trauma is associated with muscle health in later life. Moreover, since the root of disadvantage is structural and often experienced in all aspects of one's life, persistent advantage or disadvantage can alter one's risk of being exposed to traumatic events over the life course, potentially leading to a widening in racial/ethnic health disparities across populations (Ferraro & Shippee, 2009). As a result, it can be hypothesized that previously observed disparities in muscle strength between Whites, Blacks and Hispanics may be indirectly related to differential exposure to trauma across the life course (Roberts, Gilman, Breslau, Breslau, & Koenen, 2011), a view that is consistent with the accumulation of risk theory.

Racial/ethnic disparities and muscle health across the life course

While the life course framework is useful in helping to identify the timing and potential impact of when and how events unfold, historically, life course theory has made assumptions about an "institutional pattern" regarding how individuals transition through different life stages. As a result, viewing the life course as a unified, institutional model has become increasingly controversial as the life course has become more differentiated and heterogeneous over time, particularly with respect to gender and race/ethnicity (Kohli, 2007). Nonetheless, few studies have examined whether traumatic events experienced at distinct sensitive periods or that accumulate across the life course contribute to disparities in muscle weakness in later life, particularly by race/ethnicity. Addressing this gap in the literature is important because it is estimated that 55% of older Black men and 88% of older Black women meet criteria for clinical muscle weakness compared to 37% of older White men and 48% of older White women (Duchowny et al., 2017).

Numerous studies have documented the synergistic effects of adversity across the life course (Dong et al., 2004; Putnam, Harris, & Putnam, 2013; Suliman et al., 2009). Additionally, the timing in which these traumas occur may have differential meaning and consequences at various points in the life course, particularly by race/ethnicity. Experincing traumatic events may also have differential meaning for different racial/ethnic groups. For example, minority stress theory posits there are unique stressful and traumatic experiences among socially disadvantaged indivduals (Pearlin et al., 2005). Based on the above, the primary objectives of this paper are: (Objective 1) To identify whether traumatic events experienced over the life course – both cumulatively and at specific points in the life course – are related to grip strength trajectories in later life, and; (Objective 2) To examine whether there are racial/ethnic differences in this association between life course trauma and grip strength. We hypothesize that life course trauma will be associated with faster declines in grip strength in later life and that this association will be particularly strong for Black men and women compared to White men and women.

Methods

Study design and sample population

The Health and Retirement Study (HRS) is a nationally representative, multistage area probability survey of non-institutionalized, community dwelling Americans aged 51 years and older. Study details have

been previously described (Sonnega et al., 2014) and HRS maintains response rates of ~85%. 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.

In 2006, half of HRS participants were randomly selected for enhanced face-to-face interviews that included physical measurements, and the other half completed the same interview in 2008 (Crimmins et al., 2008). Additionally, in the same 2006 survey wave, HRS began collecting data on psychological and social well-being in a questionnaire that was left behind after the enhanced face-to-face interview (Smith, Ryan, Sonnega, & Weir, 2006). 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 51+ years old and community-dwelling. Individuals who had died (n = 1429), reported "other" for their race/ethnicity (n = 745), or were missing on grip strength across all waves (n = 3517) were excluded, yielding a final analytic sample of 20,472 Black, White, Hispanic men and women who were over 50 years of age at the time they received their first grip strength measurement (baseline).

Measures

Primary outcome: hand grip strength

Hand grip strength, a valid surrogate of total body muscle strength (Bohannon, 2015) and 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° angle(Crimmins et al., 2008). 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. Respondents contributed up to 3 handgrip strength measurements over the course of the analytic study period.

Primary exposure: life course traumatic events

In the self-administered questionnaire that was administed to the random half sample every two years, participants were asked to answer a series of eleven questions pertaining to traumatic life events experienced across the life course (yes/no) and the year at which each of these occurred. Examples of traumatic events 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?" The full list of questions pertaining to traumatic life events are presented in Supplementary Table 1. In order to evaluate the cumulative exposure life course model, we created an exposure variable that was a count of the total traumatic events experienced across all life stages (Range: 0–11). We also created three different life stage variables to test the life course sensitive period model, which was defined as the sum of all traumatic events in childhood (age 0-17 years; range 0-6 traumatic events), emerging/early adulthood (age 18-42 years; range 0-7 traumatic events) and Midlife (age 43-67 years; range 0-6 traumatic events) based on the distribution of when these events occurred in the study sample by age and prior literature (Clarke et al., 2011; Elder, 2004).Overall, we found few adults had experienced more than 5 traumatic events over the life course, and within each life stage, very few respondents reported experiencing more than 3 traumatic events. Therefore, we chose to top code the cumulative number of events at 5+ and the number of events during each sensitive period at 3+ to address the right skewed distribution of events. We modelled all four exposure variables (cumulative, childhood, early/emerging and midlife) as categorical variables.

Due to missing data on traumatic events, 3182 individuals were excluded from the analyses with grip strength. These individuals were not significantly different from those who did complete the trauma questions with respect to age, number of chronic conditions, or BMI or depression status. However, individuals who were missing on the trauma questions were more likely to report difficulty with activities of daily living (ADL) than those who answered the stress/trauma questions (mean number of ADL limitations = .42 vs. 0.29, respectively, $p < .0001$). As a result, since these individuals had greater physical limitations, it is possible that the findings presented below represent a conservative estimate of the trauma-grip strength association.

Covariates

The following covariates were included in the analysis: (1) Age in years; (2) Consistent with how race/ethnicity is captured in the U.S. Census, race/ethnicity was self-reported and categorized as Non-Hispanic Black, Non-Hispanic White (referent) or Hispanic; and (3) Gender. These covariates were specifically chosen since we could be confident they preceded our main exposure and were therefore not on the causal pathway. Other major correlates of declines in grip strength were not included because they are potentially influenced by early life trauma.

Analytic approach

Growth curve models were used to examine trajectories of grip strength over mid to late-adulthood. Separate models were run for men and women due to the established gender differences in grip strength (Bohannon, 2008). 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 51 to 99. To aid in parameter interpretation and avoid interpreting beyond the range of the data, we re-centered age so the intercepts of the model corresponded with age 51. We compared linear, quadratic and cubic age 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. We estimated random intercepts using PROC MIXED in SAS 9.4 with full information maximum likelihood. Due to difficulties with model convergence, random slopes were not estimated. Nested models were compared based on the Bayesian Information Criterion (BIC) where models with a lower BIC indicate better model fit. HRS provides physical measurement sampling weights, which were used in the data analysis to account for non-response and the complex survey sampling design.

Results

Hand grip strength at baseline varied by race/ethnicity with White men showing the highest mean grip strength of 43.6 kg, followed by Black men at 42.1 kg and Hispanic men at 39.8 kg (Table 1; $p < .0001$). The pattern was different among women, with Black women showing the highest mean grip strength of 27.1 kg, followed by White women at 25.7 kg and Hispanic women at 24.1 kg (Table 3; $p < .0001$). Figs. 1 and 2 show the predicted growth curve trajectories in grip strength by race/ethnicity, for men and women, respectively, based on results from the unconditional growth curve model (Supplement, Table 2 for men, Table 3 for women, Model A).White men and women show a steeper age-related decline in their grip strength trajectory compared to Black or Hispanic men ($\beta = -0.44$, SE = 0.02) and women ($\beta = -0.25$, SE = 0.01) (Supplement, Table 2 for men, Table 3 for women, Model B).

Roughly 20-30% of men and women reported no traumatic events over the life course. However, for those that did experience trauma, men tended to report more events during childhood than at other stages of the life course and women tended to report more traumatic events during midlife vs. other stages of the life course (Table 1 for men, Table 3 for women). There were complex racial patterns in these reports. Compared to White men and women, Black and Hispanic men and women were more likely to report having never experienced a traumatic

Table 1
Baseline descriptive statistics for Men in the Health Retirement Study (N = 8847), 2006–2008.

Variable	Black Men (n = 1506)	White Men (n = 6200)	Hispanic Men (n = 1127)	p-value[b]
Baseline Age (in years) (range 46–99)	61.1	63.5	61.1	<.0001
Grip Strength (kg)	42.1	43.6	39.8	<.0001
Chronic Conditions (Range: 0–8)	1.9	1.8	1.7	<.0001
Body Mass Index (kg/m^2)	28.6	28.5	29.2	<.0001
	%[a]	%[a]	%[a]	
Education				
<High School	57.7	41.0	71.8	<.0001
≥ High School	42.3	59.0	28.2	
Physical Activity				
Inactive/Sendentary	16.9	14.7	15.0	<.0001
Active	83.1	85.3	85.0	
Smoking				
Current	19.1	13.5	14.6	
Former	46.0	48.7	49.1	
Never	34.8	37.8	36.4	
Number of Traumatic Events Across the Life Course (Mean: 1.9)				<.0001
0	24.5	22.3	24.0	
1	21.3	26.8	25.2	
2	21.2	21.4	18.0	
3	13.2	14.8	13.4	
4	11.2	7.9	8.0	
5+	8.6	6.8	10.8	
Number of Traumatic Events At Life Stages				
Early childhood trauma (age 0–17 years)				<.0001
0	50.3	53.2	49.6	
1	30.3	29.9	29.8	
2	14.0	12.2	13,8	
3+	5.5	4.8	6.8	
Emerging adulthood trauma (age 18–42 years)				<.0001
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 (age 43–67 years)				
0	68.0	65.8	68.1	<.0001
1	21.2	24.4	19.5	
2	7.2	7.4	9.1	
3+	3.6	2.4	3.3	

[a]Weighted percentages.
[b]T-tests for continuous variables; X^2 tests for categorical variables.

event. However, more Black and Hispanic men and women were more likely to experience 5+ more traumatic events than White men and women who had traumatic experiences (Table 1 for men, Table 3 for women).

Results for Objective 1: Are traumatic events experienced over the life course – both cumulatively and at specific points in the life course –related to grip strength trajectories in later life?

Model A: Cumulative life course trauma and grip strength trajectories in later life.

We first examined whether cumulative life course trauma was associated with trajectories of later life grip strength. For both men and women, there was no association between lifecourse trauma experienced cumulatively over adulthood and either the levels of grip strength at age 51 (Men, Table 2, Model A: β = 0.14; SE = 0.112; Women, Table 4, Model A: β = −0.02, SE = 0.006) or age-related trajectories of grip strength in mid to later life (Men, Table 2, Model A: β = −0.006; SE = 0.005; Women, Table 4, Model A: β = −0.004, SE = 0.003).

Model B: Sensitive life stage trauma and grip strength trajectories in later life.

We then examined whether trauma experienced at distinct life stages was associated with grip strength. Averaging across all race/ethnic groups, the results for men and women were similar in that there was no association between traumatic events experienced at any period of adulthood and trajectories of grip strength over mid to late adulthood (for men, see Table 2, Model B; for women, see Table 4, Model B).

Results for Objective 2: Are there racial/ethnic differences in the association between life course trauma and grip strength trajectories in later life?

Model C: Racial/ethnic differences in cumulative life course trauma and grip strength trajectories.

Turning to the models comparing the association between life course trauma and grip strength across racial/ethnic groups (Models C and D, Tables 2 and 4), we first examined the association between cumulative life course trauma and grip strength. Our results show that there is no association between cumulative life course trauma and trajectories of grip strength over mid to late adulthood for either men or women of any racial ethnic group. (For men, see Table 2, Model C; for women, see Table 4, Model C).

Model D: Racial/ethnic differences in the association between sensitive life stage trauma and grip strength trajectories.

However, when examining specific life course periods, our results suggest that traumatic events experienced during sensitive life periods are related to race/ethnic differences in later life trajectories in grip strength. For White women, a greater number of traumatic events reported during early life (childhood vs. midlife) is associated with significantly faster rates of decline in grip strength in later life (β = −0.012; SE = 0.006; Model D, Table 4). In contrast, there was no association between traumatic events at specific life stages and grip strength for White men, suggesting that childhood trauma is related to age related declines in grip strength for White women but not for White men (a 3-way interaction between trauma, age, and gender, was tested in a combined model and was statistically significant, p < .0001).

As we turn to the results for Black and Hispanic men and women, we will discuss the race/ethnicity modified intercept and slope cofficients in order to examine whether these associations are different from those described for White men and women in the previous paragraph. First, compared to Black men who did not experience a traumatic event during early/emerging adulthood, Black men who experienced trauma during this sensitive life stage have a higher grip strength at age 51 (intercept β = 1.52; Model D, Table 2). In addition, unlike for White men, Black men who experience a greater number of traumatic events in early/emerging adulthood have a faster rate of decline in grip strength over mid to late adulthood compared to Black men who did not experience a trauma during this life stage (slope β = −0.07; Model D, Table 4). These predicted trajectories for Black and White men are illustrated in Fig. 3. For men of all racial/ethnic groups, there was no association between traumatic events experienced during the childhood or midlife stage and the rate of change in grip strength after age 50.

There were no statistically significant differences in the association between childhood trauma and rates of decline in grip strength between Black and White women (Model D, Table 4), indicating that early life traumatic event are equally as consequential for later life muscle health in women of both racial groups. On the other hand, our results suggest a more complex pattern of results for Hispanic women. Among Hispanic women, a greater number of traumatic events reported in childhood is associated with significantly lower levels of grip strength at age 51 (intercept β = −1.30). However, compared to White women, a greater number of childhood traumatic events is related to a slower rate of decline in grip strength over mid to late adulthood for Hispanic women. (Table 4, Model D, Fig. 4). There were no statistically significant differences in the effect of traumatic events experienced at other life stages among Hispanic, Black and White women. For Hispanic men, while there was no association between trauma reported at any life stage and the rate of change in grip strength over mid to late adulthood (Table 2). However, among Hispanic men, childhood trauma was associated with

Table 2
Growth curve models for hand grip strength in men in the health and retirement study (N = 8847), 2006–2014.

	Model A: Cumulative		Model B: Sensitive Period[a]		Model C: Race*Cumulative		Model D: Race*Sensitive Period	
	B	SE	B	SE	B	SE	B	SE
Intercept	50.58***	0.280	50.81***	0.28	51.02***	0.31	51.36***	0.28
Number of Traumatic Events								
Cumulative	0.14	0.112			0.05	0.13		
Childhood Period			−0.20	0.19			−0.31	0.21
Early/Emerging Period			0.09	0.24			−0.07	0.26
Race/Ethnicity[b]								
Black	−2.31***	0.286	−2.3***	0.286	−4.44**	0.75	−4.68***	0.78
Hispanic	−5.07***	0.327	−5.0***	0.328	−6.44***	0.82	−6.46***	0.87
Race/Ethnicity*Traumatic Events								
Black*Cumulative					0.19	0.32		
Hispanic*Cumulative					0.44	0.82		
Black*Childhood Period							0.16	0.55
Black*Early/Emerging Period							1.52*	0.71
Hispanic*Childhood Period							1.26*	0.59
Hispanic*Early/Emerging Period							−0.39	0.82
Rate of Change								
Age	−0.403***	0.021	−0.406***	0.02	−0.41***	0.02	−0.43	0.02
Age[b]	−0.005***	0.001	−0.005***	0.001	-.004***	0.001	−0.004***	0.001
Number of Traumatic Events								
Cumulative Trauma*Age	−0.006	0.005			−0.004	0.005		
Childhood Period*Age			−0.004	0.009			−0.002	0.01
Early/Emerging Period*Age			0.006	0.01			0.013	0.013
Race/Ethnicity*Age								
Black*Age					0.12**	0.08	0.13***	0.08
Hispanic*Age					0.06	0.04	0.06	0.03
Race/Ethnicity*Traumatic Events*Age								
Black*Cumulative*Age					−0.006	0.02		
Hispanic*Cumulative*Age					−0.012	0.02		
Black*Childhood Period*Age							0.008	0.03
Black*Early/Emerging Period*Age							-.070*	0.04
Hispanic*Childhood Period*Age							−0.05	0.03
Hispanic*Early/Emerging Period*Age							0.02	0.04
Goodness-of-Fit								
BIC	146686.3		146,534		146712.3		146576.8	

*p < .05.
**p < .01.
***p < .001.
[a]Reference group is Midlife Period.
[b]Reference group is White.

mean handgrip strength at age 51 (intercept β = 1.26) compared to White men.

Discussion

We sought to examine whether past traumatic events, experienced at any age, in childhood, in early/emerging adulthood, or in middle adulthood, were associated with trajectories of muscle strength in older age. Overall, cumulative life course trauma is largely unimportant for later grip strength level and rates of change in grip strength over time. Our results suggest trauma experienced during the sensitive life stages may have implications for grip strength trajectories among women and Black men. Despite an extensive literature linking trauma experienced earlier in the life course with a host of negative health outcomes, including depression, cardiovascular disease and impaired immune function (McEwen, 2004; Pace et al., 2006; Rozanski, Blumenthal, & Kaplan, 1999), there has been very little research on the relationship between traumatic events and muscle strength. The results of this study address an important gap in the literature since muscle strength is a key driver of physical functioning and mobility disability, outcomes that are highly relevant for the maintenance of physical health in older age (Guralnik, Ferrucci, Simonsick, Salive, & Wallace, 1995; Sternfeld, 2002; Verbrugge, Latham, & Clarke, 2017). Nonetheless, given the many hypotheses examined in this study, we cannot rule out statistical chance and, as a result, interpret our findings with caution. Since this is the first paper to explore the relationship between life course trauma and grip strength, we provide a few substantive explanations.

There are four main findings from our study. First, our results suggest that trauma may be more consequential for grip strength for White women but not for White men. Prior epidemiologic research has consistenly found women are more vulnerable to the effects of trauma and more likely to meet criteria for post-traumatic stress disorders (Tolin & Foa, 2008). As a result, this may translate into differential physiologic consequences. Women who have repeatedly been exposed to trauma are more likely to experience a blunting of the HPA axis (DeSantis et al., 2011) and increased inflammation. This impaired HPA axis-inflammatory stress response may affect muscle strength since higher levels of interleukin-6 (IL-6), interleukin-1 receptor (IL-1R) and tumor necrosis (TNF) and C-reactive protein (CRP) are associated with reduced muscle strength (Cesari et al., 2005, 2004).

Second, our results suggest experiencing traumatic events in childhood may be more consequential for grip strength in later life, particularly for White and Hispanic women. There is conflicting evidence in the literature regarding the link between childhood trauma and grip strength. While Alvarado (2008) found that women who had experienced impoverished childhoods were likely to be frail in older adulthood compared to men, Smith et al. (2016) found childhood misfortune was associated with steeper declines in grip strength for older adult men, but not women using data from the Health and Retirement Study. One potential reason for this discrepancy may be that while the diagnosis of

Table 3
Baseline descriptive statistics for Women in the Health Retirement Study, (N = 11,624), 2006–2008.

Variable	Black Women (n = 2354)	White Women (n = 7797)	Hispanic Women (n = 1458)	p-value
Baseline Age (in years) (range 46–99)	62.4	65.2	62.2	<.0001
Grip Strength (kg)	27.1	25.7	24.1	<.0001
Chronic Conditions (Range: 0–8)	2.2	1.8	1.8	<.0001
Body Mass Index (kg/m^2)	31.5 %*	27.8 %*	29.6 %*	<.0001
Education				
<High School	57.3	48.6	77	<.0001
≥ High School	42.8	51.4	23	
Physical Activity				
Inactive/Sendentary	26.9	19.8	23.4	<.0001
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	
Number of Traumatic Events Across the Life Course (Mean: 1.7)				<.0001
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	
Number Traumatic Events At Life Stages				
Early childhood trauma (age 0–17 years)				<.0001
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 (age 18–42 years)				<.0001
0	55.7	60.8	57.4	
1	31.5	28.4	29.2	
2	10.7	8.1	10.1	
3+	2.2	2.8	3.3	
Midlife trauma (age 43–67 years)				
0	43.8	45.2	46.6	<.0001
1	40.9	37.2	36.4	
2	11.9	13.3	11	
3+	3.4	4.3	6	

**T-tests for continuous variables; X^2 tests for categorical variables.
*Weighted percentages.

frailty includes the presence of muscle weakness, it is a more global outcome comprised of other indicators (i.e, weight loss, exhaustion) compared to the individual measure of handgrip strength. Despite this incongruency, numerous studies desmonstrate that childhood trauma has both direct and indirect negative implications for a range of health outcomes (Baumeister, Akhtar, Ciufolini, Pariante, & Mondelli, 2016; Goodwin & Stein, 2004; Moulton, Newman, Power, Swanson, & Day, 2015), and exposure to childhood trauma may be particularly determental to women's health in later life (Midei, Matthews, Chang, & Bromberger, 2013; Rich-Edwards et al., 2012).

Third, while our findings indicate that trauma experienced during the early/emerging adulthood period is may be less important for White men or women it may be more important for other racial groups. Consistent with Kohli's theory of the institutionalization of the life course (2007), we found that experiencing traumatic events during emerging/early adulthood may have disproportionately negative consequences for maintaining and preserving muscle strength in later age for Black men and Hispanic women. Young adulthood is a life stage rooted in distinct transitions and the establishment of key social roles (Mirowsky & Ross, 1992; Schulenberg, Sameroff, & Cicchetti, 2004). Our findings are consistent with past work that has found emerging/early adulthood to be a sensitive 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 (2005) (Clarke & Wheaton, 2005). Given that unemployment and poverty in the U.S. is higher among Blacks and Hispanics compared to Whites (De Jong, Gordon, & Madamba, 2001), it is possible that our results reflect this differential hardship which may have long-term health effects. For example, using data from the Health and Retirement Study, Haas, Krueger and Rohlfsen found that, compared to US-born Whites, U.S. born Hispanics had lower grip strength in middle and older age (Haas, Krueger, & Rohlfsen, 2012). Moreover, after adjusting for childhood/adult health and SES, foreign born Blacks and Hispanics had poorer physical performance compared to U.S. born Whites.

Lastly, we found that Hispanic women who had experienced traumatic events during childhood had lower grip strength than White women as they entered the midlife stage. These results could partly be explained by the "triple jeopardy" theory, which is rooted in intersectionality and posits that poor health in older age is a function of one's race/ethnicity and gender (Whitfield, Baker, & Abdou, 2013). Specifically, this perspective views multiple forms of oppression (i.e., sexism, racism) as structurally interlocking phenomena that cannot be disentangled. For example, in formally testing these principles, Warner & Brown found that White men had the fewest number of functional limitations while Mexican American women had the highest (2011)(Warner & Brown, 2011). However, we also found that Hispanic women experience a blunted (or slower) decline in their grip strength trajectory through mid to late adulthood. This is consistent with others who have observed paradoxical associations across a wide range of health outcomes among Hispanic women (Keegan, Quach, Shema, Glaser, & Gomez, 2010; Markides & Eschbach, 2005).

This study has several strengths. First, this is the first study to investigate the association between traumatic events experienced over the life course and subsequent muscle strength in older age in a racially/ethnically diverse sample of older Americans. Second, the results were obtained in a nationally representative sample of adults and can therefore be generalized to community-dwelling Black, White and Hispanic adults over the age of 51 living in the United States. Third, we considered not only what role traumatic events played in influencing later life grip strength, but also examined the impact of events experienced at distinct life stages. Lastly, a major strength of this study was our ability to examine whether muscle strength trajectories differ by race/ethnicity. Past work examining longitudinal changes in grip strength have largely focused on White populations (Gale et al., 2007; McLean et al., 2014). Given the rapidly changing demographic makeup of older adults in the United States, 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, there are several limitations to the current study. First, one limitation of this study is the retrospective recall of exposure to traumatic events. Participants' memory may be subject to recall bias especially if events that occurred earlier in life were more difficult to recall. Previous research has found that individuals recall the timing of past traumatic events with reasonable accuracy (Haas, 2007). 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 51, 85% of the these events were correctly recalled (Krall, Valadian, Dwyer, & Gardner, 1988). Second, it is possible that for the midlife stage (43–67), traumatic events may have occurred either before or after one's grip strength measurements were obtained. However, we would expect

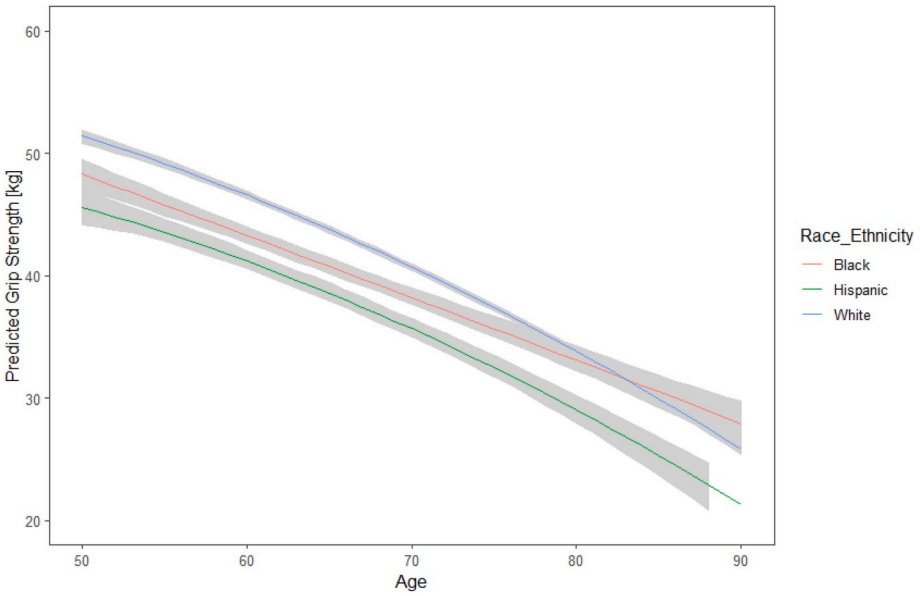

Fig.1. Predicted trajectories of grip strength over mid to late adulthood by race/ethnicity: Men, U.S. Health and retirement study (N = 8847), 2006–2014.

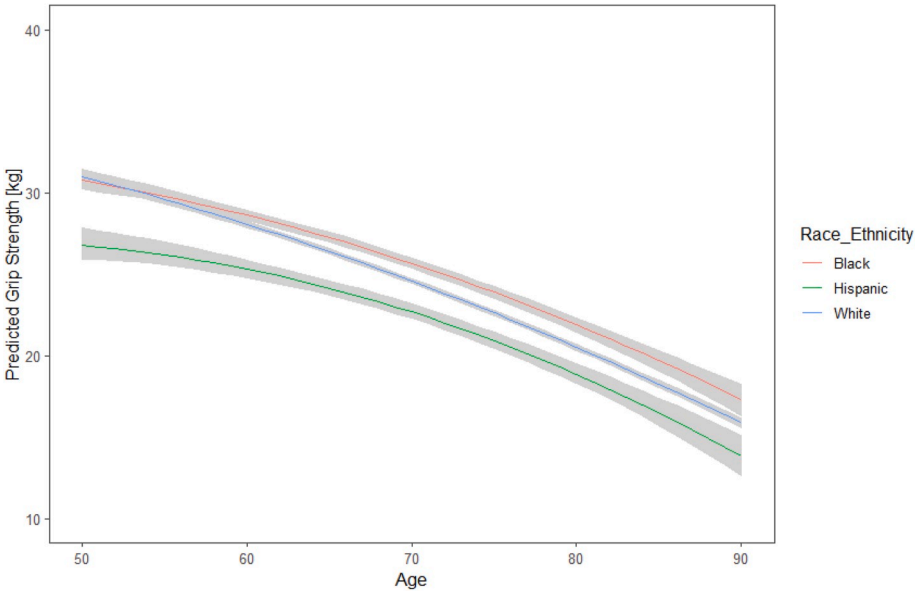

Fig. 2. Predicted trajectories of grip strength over mid to late adulthood by race/ethnicity: Women, U.S. Health and retirement study (N = 11,624), 2006–2014.

that these events would occur at random relative to one's assessment, potentially introducing non-differential bias which may have biased our estimates towards the null. Third, as with any longitudinal study of older adults, selective survival may bias our results, particularly for older Black and Hispanic men. Only about 40 percent of Black men born between 1931 and 1941 lived to age 60 (Hayward, Miles, Crimmins, & Yang, 2000). HRS did not include homeless or incarcerated individuals. Thus, the results presented in this study likely underestimate the true association between traumatic life events and subsequent health if those who died before the age 51 are likely to be the most disadvantaged.

There is growing interest in understanding 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 (Dodds et al., 2012; Kuh et al., 2006; Oh, Jho, No, & Kim, 2015), almost no prior work has evaluated how social experiences unfolding across the entire life course influence trajectories of grip strength in later life. This study is an important contribution to the literature because it evaluated to what extent earlier negative life events shape grip strength trajectories in older age, and evaluated differential effects for Whites, Blacks, and Hispanics. Research on the drivers of musculoskeletal health has primarily focused on individual or medical risk factors, but our results underscore the importance of evaluating other drivers of inequality. To address racial disparities in late life disability, we need richer evidence on how psychosocial experiences and social contexts shape trajectories of muscle strength across the life course.

Ethics statement

Ethics approval was provided by the institution review board of the University California, San Francisco.

Table 4
Growth curve models for hand grip strength in women in the health and retirement study (N = 11,624), 2006–2014.

	Model A: Cumulative		Model B: Sensitive Period[1]		Model C: Race*Cumulative		Model D: Race*Sensitive Period	
	B	SE	B	SE	B	SE	B	SE
Intercept	30.51***	0.165	30.41***	0.166	30.78***	0.186	30.80***	0.163
Number of Traumatic Events								
Cumulative	−0.02	0.065			0.00	0.079		
Childhood Period			−0.13	0.121			−0.01	0.141
Early/Emerging Period			−0.07	0.139			−0.01	0.165
Race/Ethnicity[1]								
Black	0.93***	0.146	0.92[a]**	0.147	−0.10	0.382	0.12	0.307
Hispanic	−2.33***	0.181	−2.34***	0.182	−3.25***	0.458	−2.87***	0.384
Race/Ethnicity*Traumatic Events								
Black*Cumulative					0.03	0.166		
Hispanic*Cumulative					−0.09	0.202		
Black*Childhood Period							0.06	0.324
Black*Early/Emerging Period							−0.50	0.362
Hispanic*Childhood Period							−1.30**	0.385
Hispanic*Early/Emerging Period							0.63	0.43
Rate of Change								
Age	−0.23***	0.0123	−0.22***	0.013	−0.25***	0.012	−0.25***	0.013
Age[2]	−0.003***	0.001	−0.003***	0.001	−0.003***	0.001	−0.003***	0.001
Number of Traumatic Events								
Cumulative Trauma*Age	−0.004	0.003			−0.005	0.003		
Childhood Period*Age			−0.003	0.006			−0.012*	0.006
Early/Emerging Period*Age			−0.001	0.006			−0.002	0.007
Race/Ethnicity*Age								
Black*Age					0.06**	0.019	0.05**	0.014
Hispanic*Age					0.07**	0.023	0.04	0.018
Race/Ethnicity*Traumatic Events*Age								
Black*Cumulative*Age					0.000	0.008		
Hispanic*Cumulative*Age					−0.002	0.010		
Black*Childhood Period*Age							0.012	0.018
Black*Early/Emerging Period*Age							0.016	0.019
Hispanic*Childhood Period*Age							0.086***	0.022
Hispanic*Early/Emerging Period*Age							−0.058	0.024
Goodness-of-Fit								
BIC	177428.6		177178.8		177447.2		177204.2	

*p < .05.
**p < .01.
***p < .001.
[1]Reference group is Midlife Period.
[2]Reference group is White.

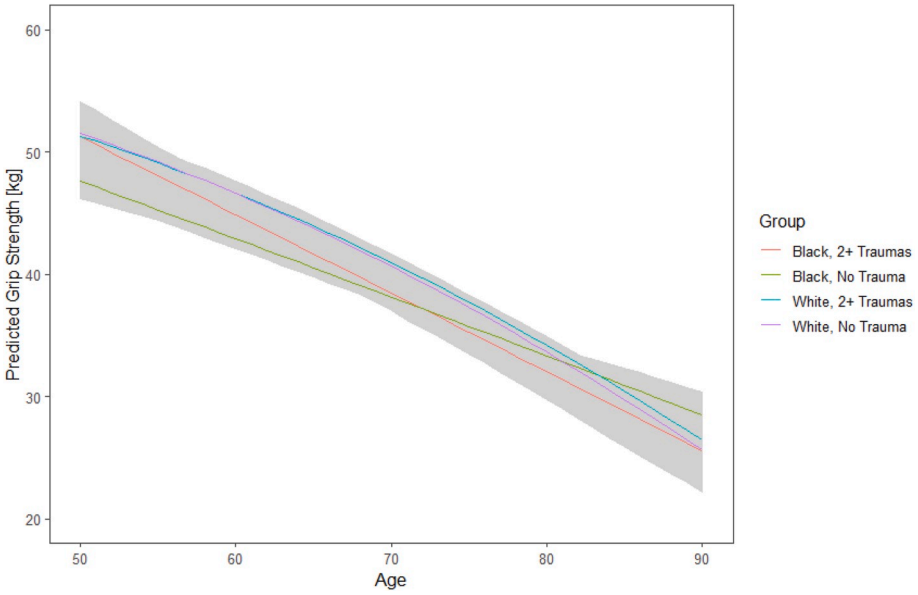

Fig. 3. Predicted Trajectories of Grip strength Over Mid to Late Adulthood by Race/and Number of Traumatic Events Experienced During Early/Emerging Adulthood: Men, U.S. Health and Retirement Study (N = 8847), 2006–2014.

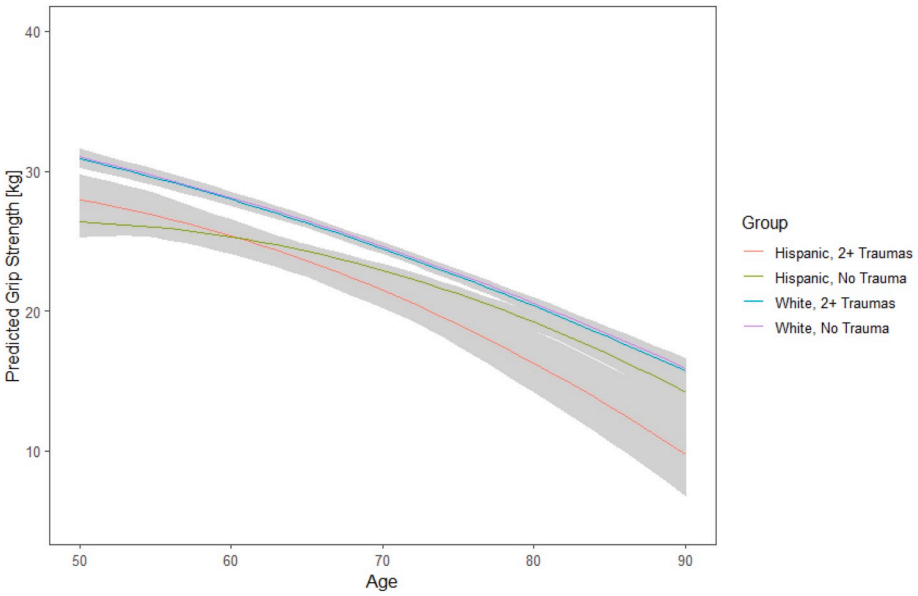

Fig. 4. Predicted trajectories of grip strength by race/ethnicity and number of traumatic events during early/emerging adulthood: Women, US health and retirement study (N = 11,624), 2006–2014.

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CRediT authorship contribution statement

Kate A. Duchowny: Conceptualization, Methodology, Formal analysis, Writing - original draft, Writing - review & editing. **Margaret T. Hicken:** Conceptualization, Methodology, Writing - original draft, Writing - review & editing. **M. Maria Glymour:** Methodology, Writing - review & editing. **Philippa Clarke:** Methodology, Supervision, Conceptualization, Methodology, Writing - original draft, Writing - review & editing.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ssmph.2020.100587.

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