SSM - Population Health 3 (2017) 497–505

Contents lists available at ScienceDirect

SSM - Population Health

journal homepage: www.elsevier.com/locate/ssmph

Article

Explaining racial/ethnic differences in all-cause mortality in the Multi-Ethnic Study of Atherosclerosis (MESA): Substantive complexity and hazardous working conditions as mediating factors

Kaori Fujishiro[a,*], Anjum Hajat[b], Paul A. Landsbergis[c], John D. Meyer[d], Pamela J. Schreiner[e], Joel D. Kaufman[f]

[a] National Institute for Occupational Safety and Health (NIOSH), Centers for Disease Control and Prevention (CDC), 1090 Tusculum Ave, MS R-15, Cincinnati, OH 45226-1998, USA
[b] Department of Epidemiology, University of Washington, Seattle, WA, USA
[c] Department of Environmental and Occupational Health Sciences, State University of New York-Downstate School of Public Health, Brooklyn, NY, USA
[d] Department of Preventive Medicine, Icahn-Mount Sinai School of Medicine, New York, NY, USA
[e] Division of Epidemiology and Community Health, University of Minnesota, Minneapolis, MN, USA
[f] Department of Environmental and Occupational Health Sciences, University of Washington, Seattle, WA, USA

ABSTRACT

Research on racial/ethnic health disparities and socioeconomic position has not fully considered occupation. However, because occupations are racially patterned, certain occupational characteristics may explain racial/ethnic difference in health. This study examines the role of occupational characteristics in racial/ethnic disparities in all-cause mortality. Data are from a U.S. community-based cohort study (n = 6342, median follow-up: 12.2 years), in which 893 deaths (14.1%) occurred. We estimated mortality hazard ratios (HRs) for African Americans, Hispanics, and Chinese Americans compared with whites. We also estimated the proportion of the HR mediated by each of two occupational characteristics, substantive complexity of work (e.g., problem solving, inductive/deductive reasoning on the job) and hazardous conditions (e.g., noise, extreme temperature, chemicals), derived from the Occupational Information Network database (O*NET). Analyses were adjusted for age, sex, nativity, working status at baseline, and study sites. African Americans had a higher rate of all-cause death (HR 1.41; 95% confidence interval [CI]: 1.19–1.66) than whites. Chinese-American ethnicity was protective (HR 0.59, CI: 0.40–0.85); Hispanic ethnicity was not significantly different from whites (HR 0.88; CI: 0.67–1.17). Substantive complexity of work mediated 30% of the higher rate of death for African Americans compared with whites. For other groups, mediation was not significant. Hazardous conditions did not significantly mediate mortality in any racial/ethnic group. Lower levels of substantive complexity of work mediate a substantial part of the health disadvantage in African Americans. This job characteristic may be an important factor in explaining racial health disparities.

Introduction

Racial/ethnic health disparities have been a major focus in public health research for over two decades. In virtually all measures of population health, racial/ethnic minorities, especially African Americans, fare poorly compared with whites (Centers for Disease Control and Prevention, 2013). Investigating the mechanism of these health disparities is challenging because race/ethnicity in the United States is deeply intertwined with socioeconomic position (SEP), another major social determinant of health. Some argue that race/ethnicity is a surrogate for SEP because of the overrepresentation of racial/ethnic minorities in the lower strata of SEP (Isaacs & Schroeder, 2004). However, many prominent scholars emphasize that SEP is a mediator, not a confounder, in the relationship between race/ethnicity and health (Adler & Rehkopf, 2008; Dressler, Oths, & Gravlee, 2005; Kawachi, Daniels, & Robinson, 2005; Williams, Mohammed, Leavell, & Collins, 2010). Most studies have reported that racial/ethnic health disparities seldom disappear, though may diminish, after education and income are accounted for (Adler & Rehkopf, 2008; Williams et al., 2010), which suggests additional mechanisms. Occupation, another indicator of SEP, has been understudied in the context of racial/ethnic health disparities. This study explores the role of occupation in explaining racial/ethnic

* Corresponding author.
E-mail address: Kfujishiro@cdc.gov (K. Fujishiro).

http://dx.doi.org/10.1016/j.ssmph.2017.05.010
Received 27 January 2017; Received in revised form 11 May 2017; Accepted 13 May 2017

differences in all-cause mortality.

Race/ethnicity and socioeconomic position: why consider occupation?

Early studies of health disparities compared mortality and morbidity across occupational groups (Antonovsky, 1967; Marmot, Shipley, & Rose, 1984; Marmot et al., 1991), clearly considering occupation as a marker of SEP. While this tradition continues in Europe, in the United States, studies on SEP and health rarely use occupation. Some researchers assert that occupation is simply a surrogate for education and income (Nam & Boyd, 2004). However, considering SEP as only a function of education and income has limitations when we investigate racial/ethnic health disparities. Citing racial differences in income within the same level of education as well as differential purchasing power of the dollar in racially segregated neighborhoods, Kaufman, Cooper, and McGee (1997) point out that measures of education and income are incommensurate across ethnic groups. This measurement error, they argue, introduces systematic bias toward minimizing impacts of SEP in racial/ethnic health disparities. Kaufman et al. thus advocate for more comprehensive approaches to investigate the role of SEP in creating racial/ethnic disparities.

In this context, the concept of occupation is worth revisiting because it uniquely illuminates racial/ethnic differences in SEP not captured by education or income. The racial/ethnic distribution of workers within occupations varies considerably: minorities are underrepresented in management and professional jobs and overrepresented in service, production, transportation, and material-handling jobs (U.S. Bureau of Labor Statistics, 2015). Some of the uneven distribution may be explained by differences in education; however, even with identical educational credentials, racial/ethnic minorities are less likely to be offered a job (Pager, Western, & Bonikowski, 2009), spend more time looking for a job, accumulate less work experience over their career (Tomaskovic-Devey, Thomas, & Johnson, 2005), and earn less (Hout, 2012). Within the same job, racial/ethnic minorities are more likely to be overqualified than whites (Vaisey, 2006). These findings suggest that the link from education to occupation to income is not the same for whites and racial/ethnic minorities: the latter are more likely to be in jobs incommensurate with their educational attainment, and earn less than their white coworkers in the same job. Only using education and income as SEP indicators will not capture these incongruities.

How to incorporate occupation in race/ethnicity and SEP health disparities

As an SEP indicator, occupation has traditionally been operationalized as hierarchical categories (e.g., high-level non-manual, low-level non-manual, skilled manual, unskilled manual) (e.g., Rosvall et al., 2006). While European studies have reported health gradients by occupational category, the US studies often do not find similar gradients using the US Census categories such as management, professional, service (e.g., Fujishiro, Xu, & Gong, 2010; Johnson, Sorlie, & Backlund, 1999). Braveman et al. (2005) declare that the Census classification categories are "not intended—and do not appear to be meaningful—as SEP measures" (p. 2883). Another traditional approach to occupation in health research is to see it as a source of harmful exposure. Researchers compare distributions of disease across occupations and identify potential causal factors (Boffetta, Jourenkova, & Gustavsson, 1997). Although it has made important discoveries of hazardous materials (e.g., lead, asbestos, and silica), this approach has not explicitly linked occupational exposure to SEP.

We argue that differential occupational exposure is a manifestation of SEP that cannot be captured by education or income, or adequately approximated by occupational categories. Considering occupational exposure as an aspect of SEP is especially important in examining racial/ethnic health disparities because evidence for *occupational* health disparities across race/ethnicity has started to accumulate. Hispanics have higher occupational mortality (Steege, Baron, Marsh, Menéndez, & Myers, 2014), and racial/ethnic minorities are more likely to miss work because of a job-related injury or illness (Strong & Zimmerman, 2005). Workers in occupations with high proportions of African Americans are more likely to report fair or poor health (Chung-Bridges et al., 2008). Given that potentially hazardous jobs are often found in lower strata of SEP (e.g., construction, manufacturing, and transportation) and that these jobs are disproportionally held by racial/ethnic minorities (U.S. Bureau of Labor Statistics, 2015), these occupational health disparities by race/ethnicity suggest that occupational hazard exposure is a dimension of SEP, serving as a mediator between race/ethnicity and health.

Occupation is a source of not only hazardous exposure but also health-protecting resources, which are another manifestation of SEP. The most robust health-protecting characteristic of work is job control, the combination of having decision-making power and opportunities to learn and use new skills (Karasek, 1979). The difference in mortality and morbidity by occupational grade in the seminal Whitehall study (Marmot et al., 1991) were largely attributed to job control (Marmot, Bosma, Hemingway, Brunner, & Stansfeld, 1997), and since then numerous studies have reported significant associations of job control with a wide array of health and well-being (Lang, Ochsmann, Kraus, & Lang, 2012; Theorell et al., 2015). High control jobs are generally found in higher strata of SEP such as management and professional occupations, in which racial/ethnic minorities are underrepresented (U.S. Bureau of Labor Statistics, 2015). The health-protecting effect of job control is thereby disproportionally experienced by white workers overrepresented in high SEP jobs, which may contribute to racial/ethnic health disparities.

In summary, the current US literature on SEP does not incorporate occupation; however, because occupational characteristics are experienced differently by race/ethnicity, examining them can clarify potential mechanisms that create racial/ethnic health disparities. While there is suggestive evidence, explicit examination of occupational characteristics as mediators is needed.

The current study

We examine the role of two occupational characteristics—substantive complexity of work and physically hazardous conditions—in racial/ethnic differences in all-cause mortality. *Substantive complexity*, a construct derived by Kohn and Schooler (1978), expands the concept of job control by incorporating inductive and deductive reasoning, information synthesis, critical thinking, and problem-solving skills to the original dimensions of job control, decision-making and skill utilization. A consistent body of literature has shown the association of high substantive complexity with not only better cognitive functioning (Andel, Vigen, Mack, Clark, & Gatz, 2006; Schooler, Mulatu, & Oates, 1999) but also fewer disabilities (Hayward, Friedman, & Chen, 1998) and lower mortality (Moore and Hayward, 1990). In contrast, a lack of substantive complexity, similar to low job control, is likely to act as a chronic stressor that triggers a prolonged activation of the sympathetic nervous system and hormonal reactions. The chronically activated system then adversely affects a wide range of physiological functions, from the cardiovascular system to immune responses (McEwen, 1998). *Hazardous conditions* in this study indicate the likelihood of being exposed to deleterious environmental factors such as extreme temperatures, distracting levels of noise, and substances that require personal protective equipment. High levels of exposure to these hazardous conditions suggest high risk for injuries (Steege et al., 2014), respiratory diseases (Boschetto et al., 2006), and various types of cancer (Briggs et al., 2003). Moreover, such hazardous conditions can also be chronic psychosocial stressors (Andries, Kompier, & Smulders, 1996; Neupane, Virtanen, Luukkaala, Siukola, & Nygård, 2014) that activate the prolonged stress reaction.

In order to capture the wide-ranging effects of the two occupational characteristics, we examine all-cause mortality as the outcome of

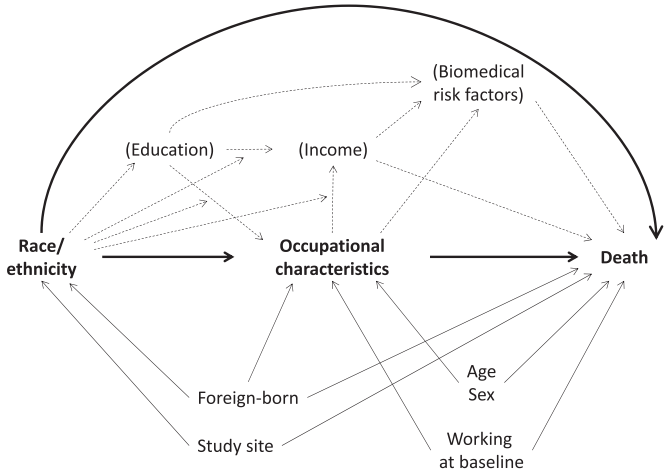

Fig. 1. The directed acyclic graph (DAG) for the study. Solid lines indicate the associations examined in the current analysis, and dotted lines and constructs in parentheses indicate associations we assume to be subsumed in the direct and indirect effects from race/ethnicity to death. Arrows ending on another arrow indicate effect modification (e.g., race/ethnicity modifies the path from education to income).

interest. The causal directed acyclic graph (DAG) for the study is presented in Fig. 1. We adopt Krieger (2005)'s assertion that belonging to a racial/ethnic group embodies a set of health (dis)advantages: that is, racial/ethnic differences in health emerge from "the dynamic social, material, and ecological contexts into which we are born, develop, interact, and endeavor to live meaningful lives" (Krieger, 2005, p. 350). In Fig. 1, the direct arrow from race/ethnicity to death represents the effect of racial/ethnic group membership on mortality not mediated by the occupational characteristics. This path will be mediated by numerous factors (e.g., neighborhood characteristics, discrimination, and access to healthcare), including education and income as shown in parentheses and dotted arrows. In this study, however, we do not distinguish them individually. Similarly, we consider that oft-studied biomedical mortality risk factors (e.g., diabetes, hypertension), which vary by race/ethnicity (Kurian & Cardarelli, 2007), lie on the causal pathway from race/ethnicity to death and also on the path from occupational characteristics to death (Heikkila et al., 2013). Rather than removing their effects as confounders, we conceptualize that the effects of these biomedical mortality risk factors are subsumed in the direct and mediated paths described in Fig. 1. Focusing on the path from race/ethnicity to death through occupational characteristics, our goal is to quantify the proportion of racial/ethnic differences in mortality mediated by the two job characteristics.

Methods

Participants and data collection

This study used data from the Multi-Ethnic Study of Atherosclerosis (MESA), a cohort study of community-residing adults (baseline age: 45–84 years old) initially free of clinical cardiovascular disease (CVD) (Bild et al., 2002). The cohort was formed between 2000 and 2002 (participation rate of 60% among those eligible) with 6814 individuals; of those, five were not followed up for CDV incidence and mortality adjudication because they had experienced a CVD event before enrollment. The cohort included a wide range of occupations and four racial/ethnic groups, with minorities oversampled: whites (38%), Chinese Americans (11%), African Americans (28%), and Hispanics (23%).

Upon enrollment, the participants provided detailed information about health and sociodemographic information when they visited one of six field centers for examinations. This study uses the baseline and mortality data through December 2013 (median follow-up duration: 12.2 years). For this analysis, we excluded 310 participants who never worked outside home, 106 who did not provide occupational information, and 40 whose occupational information was not specific enough to be linked to job characteristic data (see below). Additionally, 11 participants who reported military service as their occupation were excluded because job characteristic data were not available for military personnel. Data from the remaining 6342 participants were analyzed in this study. The MESA study protocol was approved by the Institutional Review Boards of the six field centers and the sponsoring National Heart, Lung, and Blood Institute. This study was approved by the National Institute for Occupational Safety and Health (NIOSH).

Mortality adjudication

After enrollment in MESA, in addition to biennial clinic visits, all participants were contacted by phone every 9–12 months for information about any medical event. If the participant died, the next of kin provided information on the date and cause of death at the time of next contact. In addition, the study staff reviewed the National Death Index to identify or confirm the participant's death. The follow-up time was calculated as the time between enrollment and either death, lost to follow-up, or the end of the study period.

Job characteristics

Occupational information was collected in a self-administered questionnaire at baseline using four open-ended questions from the US Census (i.e., "For whom do you work?" "What type of business or industry is this?" "What kind of work do you do, or what is your job title?" and "What are your most important activities or duties?"). Those who were working at baseline reported their current job. In this cohort of older adults, 43% were no longer working: they were instructed to report their main occupation before they stopped working. The responses to the open-ended questions were coded by NIOSH using the Census 2000 Occupation 3-digit Codes. During the study period, 9.9% of the participants reported at least one job title that was different from the one reported at baseline. Because the impact of occupational exposure to health is likely to be long term, we used the occupation reported at baseline as a time-invariant variable. As a sensitivity analysis, we ran the same models excluding those who reported more than one occupation. There were no racial/ethnic differences in the proportion of participants who changed jobs ($\chi^2 = 2.46$, $df = 3$, $p = 0.48$).

The Census 2000 Occupation Codes were used to derive occupational exposures from the Occupational Resources Network (O*NET) version 21, a database developed by the U.S. Department of Labor. The O*NET provides detailed descriptive information on jobs in the US labor market (Hadden, Kravets, & Muntaner, 2004). Because of its wide range of measured characteristics, O*NET has been used as a job exposure matrix (Cifuentes, Boyer, Lombardi, & Punnett, 2010). For this analysis, we derived two characteristics, substantive complexity and hazardous conditions, using O*NET variables.

Adopting the factor structure of Hadden et al. (2004), we constructed *substantive complexity* scores as the mean score of 11 O*NET items addressing job characteristics such as decision-making, information synthesis, inductive and deductive reasoning, and critical thinking. Cronbach's alpha for the 11 items was 0.96, indicating high internal consistency of the variables composing this construct. Each item had a potential response range from 0 to100. Because these scores do not have intrinsic meaning (i.e., there is no value over which the level of substantive complexity is health-protective), for the ease of interpretation of the regression results, we standardized the score with the mean of zero and the standard deviation of one. Higher scores indicated higher levels of substantive complexity, which was hypothesized to be protective of health.

Hazardous conditions was the mean score of 8 O*NET items addressing traditional occupational hazards: sounds and noise levels that were distracting and uncomfortable, very hot (above 90 F) or very cold

Table 1
Characteristics of the study sample by race/ethnicity (n = 6342). The numbers indicate the percentage within the racial/ethnic group unless otherwise noted.

Baseline characteristic	White N = 2513	African American N = 1791	Hispanic N = 1334	Chinese American N = 704	p-value
Age, years, mean (SD)	62.37(10.20)	62.05 (10.08)	61.00 (10.26)	61.68 (10.00)	0.001
Female	50.7	54.9	47.8	47.3	< 0.0001
Foreign-born	6.6	9.0	67.5	95.9	< 0.0001
Age at migration[a]					< 0.0001
Unknown	22.3	22.4	11.7	6.8	
< 21 years old	23.5	13.0	21.8	4.1	
21–40 years old	47.6	56.5	46.4	41.3	
41–65 years old	6.0	8.1	19.0	40.5	
> 65 years old	0.6	0.0	1.2	7.2	
Education					< 0.0001
Less than high school	4.4	12.0	42.3	22.2	
Completed high school/GED	16.2	18.7	20.4	15.4	
Some college but no degree, technical school certificate, or associate degree	28.5	35.0	26.8	20.1	
Bachelor's degree, graduate or professional school	50.9	34.4	10.6	42.4	
Working at baseline	59.9	56.3	54.7	55.0	0.012
Occupation					< 0.0001
Management	24.1	16.0	7.4	19.7	
Professional	33.2	26.1	12.4	26.3	
Service	6.3	18.9	28.0	14.4	
Sales/Office	24.4	18.2	17.0	19.0	
Blue-collar	12.0	20.8	35.2	20.6	
O*NET Substantive complexity[b]					
25th percentile score	55.4	50.5	44.5	49.0	
Median score	65.7	60.5	50.6	60.7	
75th percentile score	69.3	66.7	61.0	67.4	
O*NET Hazardous conditions[c]					
25th percentile score	12.5	13.0	11.9	12.6	
Median score	19.0	20.6	23.1	20.8	
75th percentile score	24.6	29.8	36.7	28.0	

[a] Calculated for migrants only (n = 1902).
[b] Score can range from 0 to 100, higher scores indicate higher levels of substantive complexity.
[c] Score can range from 0 to 100, higher scores indicate more hazardous conditions.

(under 32 F) temperatures, extremely bright or inadequate lighting, high places (e.g., working on poles, scaffolding, catwalks, or ladders), an environment that was not temperature controlled (i.e., without air conditioning), outdoors under cover, outdoors exposed to all weather conditions, and requirement of personal protective equipment. Cronbach's alpha for the 8 items was 0.95. Similarly to the substantive complexity score, hazardous condition scores do not have intrinsic meaning (i.e., there is no particular value under which the working condition is "safe"). Therefore, we standardized the score with the mean of zero and the standard deviation of one. Higher scores indicated more hazardous conditions. Job titles by the level of the two O*NET measures can be found in Supplemental Table 1.

Race/ethnicity and other covariates

Each participant self-identified his/her race or ethnicity at baseline by answering a set of questions modeled on the 2000 US Census. Additional covariates included age at baseline, sex, nativity (born in one of the 50 states or not), and working status at baseline. Study site was also included as a confounder because the six sites had different racial compositions, recruitment strategies, and occupational compositions.

Statistical analysis

Descriptive statistics, including person-years and rates of death, were tabulated by race/ethnicity. To examine differences in rates of death by race/ethnicity, we used the Cox proportional hazards model, with the two job characteristics (substantive complexity and hazardous conditions) as potential mediators while accounting for potential confounding of age at baseline, sex, nativity, working status at baseline, and study sites. We used a counterfactual framework of mediation (i.e., What if the independent variable or the hypothesized mediator variable took a different value? How does the counterfactual value change the overall result?) (Richiardi, Bellocco, & Zugna, 2013; Valeri & VanderWeele, 2013; VanderWeele & Vansteelandt, 2010). The analysis involves estimating two effects: the natural direct effect and the natural indirect effect. As the technical details are explained in Valeri and VanderWeele (2013), here we describe the specific application of the mediation analysis in this study. The *natural direct effect* (NDE) is the hazard ratio (HR) between a racial/ethnic minority group and whites while the occupational characteristic is kept constant at the mean level for whites. In other words, NDE indicates what the white-minority difference in rates of deaths would be *if the minority group experienced the same job characteristic as whites*. The HR is attributed to racial difference in rates of death not mediated by the job characteristic. The *natural indirect effect* (NIE) represented another counterfactual: *what the difference in rates of death would be if all participants experienced whites' job characteristic on one hand and the minority group's job on the other*. The HR is interpreted as racial difference in rates of death mediated by racial difference in the occupational characteristic. The total effect of race/ethnicity on mortality is the sum of NDE and NIE. The mediation analyses were conducted using the SAS macro developed by Valeri and VanderWeele (2013). Because of some macro constraints, substantive complexity and hazardous conditions were analyzed separately, and each of the three racial/ethnic minority groups was compared with whites separately. While splitting the sample is not ideal, the subsamples were defined *a priori* based on racial/ethnic category. The findings may be statistically conservative because of smaller sample sizes. Potential interaction between race/ethnicity and occupational characteristics on death was included in all models. All analyses were conducted using SAS v.9.3 (Cary, North Carolina).

Table 2
Deaths, person-years, and rate of death (95% confidence interval) per 1000 person-years by race/ethnicity.

	White	African American	Hispanic	Chinese American	Overall
Number of deaths	369	301	166	57	893
Person-years	29732.4	20335.3	15616.7	8365.7	74050.0
Rate per 1000 person-years	12.4	14.8	10.6	6.8	12.1
(95% confidence interval)	(11.2, 13.7)	(13.2, 16.6)	(9.1, 12.4)	(5.3, 8.8)	(11.3, 12.9)

Results

Average age of the study participants at recruitment was 61.9 years (SD = 10.2), 50.9% were female, and 36.8% had a college degree or higher. Characteristics of the included MESA participants by racial/ethnic group are presented in Table 1. While the effort was made to construct a cohort with an equal distribution of age and sex across racial/ethnic groups, Hispanic participants were on average slightly younger than whites and African Americans, the proportion of females was higher for African Americans, and the proportion of college graduates was lower for Hispanics and African Americans. Almost all Chinese Americans and two-thirds of Hispanics were born outside of the U.S. Nearly half of Chinese immigrants arrived in the U.S. as middle-age or older adults while most immigrants in other racial/ethnic groups migrated either as young adults or children. Racial/ethnic groups significantly differed on all study variables, including O*NET job characteristic scores. Whites had a higher median score for O*NET substantive complexity, and Hispanics had a higher median score for O*NET hazardous condition.

Among the 6342 participants, 893 deaths (14.1%) occurred during the study period. As shown in Table 2, Chinese Americans had the lowest rate of death (6.8 per 1000 person-years), and African Americans the highest (14.8 per 1000 person-years). Fig. 2 illustrates the unadjusted survival probability by race/ethnicity.

Table 3 presents the results of mediation analysis for the difference in rates of death between each of the racial/ethnic minority groups and whites, with job characteristics as mediators. Compared with whites, a 41% higher overall rate of death was seen in African-American participants (total effect: HR = 1.41, 95% Confidence Interval [CI]: 1.19, 1.66). The NIE (HR = 1.10, 95% CI: 1.04, 1.16) indicates that a 10% higher rate of death was attributable to the lower level of substantive complexity experience by African Americans compared with whites. This difference in rates of death attributable to racial difference in substantive complexity mediated 30% of the overall higher rate of death in African-Americans. The rate of death for Hispanics was not significantly different from that for whites (total effect: HR = 0.88, p = 0.39). Being Chinese American, on the other hand, was associated with a lower rate of death than being white (total effect: HR = 0.59, $p < 0.01$), but the lower rate was not mediated by either of the occupational characteristics.

Hazardous conditions did not have a significant mediation role for any of the racial/ethnic groups at the $p < 0.05$ level. However, for African Americans, the NIE approached statistical significance (HR = 1.03, 95% CI: 1.00, 1.07, p = 0.07); 9% of the higher rate of death among African Americans compared with whites was mediated by hazardous conditions.

Sensitivity analyses

We assessed the robustness of our findings regarding assumptions we made in the causal DAG (Fig. 1). First, we assumed that the racial/ethnic group membership would influence education, and thus the effect of education was subsumed in the direct and indirect paths from race/ethnicity to death. However, if racial/ethnic differences in education did not exist in truth (i.e., observed differences were all measurement errors), education should be considered as a confounder. We ran the same mediation analysis on an alternative hypothesis that education is an additional confounder that influences both occupational characteristics and death. The results were largely the same for Hispanics and Chinese Americans, and the weak mediation of hazardous conditions for African Americans was attenuated to null (p = 0.29). Their higher rate of death than whites was slightly attenuated (total effect: HR = 1.34, 95%CI: 1.13, 1.59), but 13.9% of the higher rate was still significantly medicated by substantive complexity.

Another assumption was that the effect of income would be subsumed in the pathway from job characteristics to mortality because jobs with high substantive complexity and low hazardous conditions tend to pay higher wages. We also assumed the link from race/ethnicity to education to income, as shown in Fig. 1. If there were no true differences in income by race/ethnicity or by occupational characteristics, then income should be seen as a confounder. Controlling for income in these models revealed that the mortality risk difference between whites

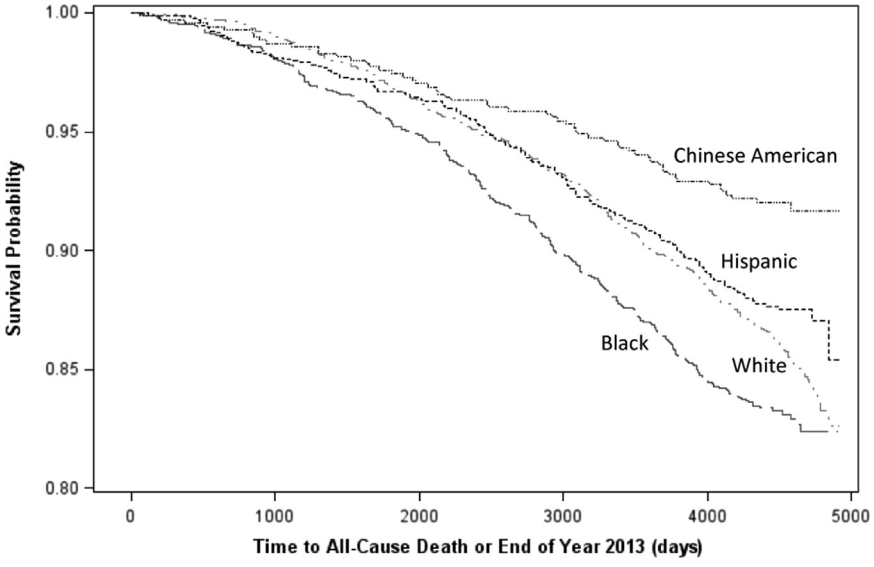

Fig. 2. Unadjusted survival probability by race/ethnicity.

Table 3
Hazard ratios (HR) and 95% confidence intervals (CI) for the natural direct, indirect and total effects of racial/ethnic group membership on mortality mediated through O*NET-derived job characteristics.

Effect of belonging to a racial/ethnic minority group compared with white	Mediator					
	Substantive complexity			Hazardous conditions		
	HR	(95%CI)	% mediated	HR	(95%CI)	% mediated
African American						
Natural direct effect (NDE)	1.28	(1.08, 1.53)		1.38	(1.16, 1.63)	
Natural indirect effect (NIE)	1.10	(1.04, 1.16)	30.1%	1.03	(1.00, 1.07)[a]	9.0%
Total effect	1.41	(1.19, 1.66)		1.42	(1.20, 1.68)	
Hispanic						
NDE	0.81	(0.60, 1.10)		0.86	(0.65, 1.14)	
NIE	1.09	(0.97, 1.22)	–	1.02	(0.98, 1.05)	–
Total effect	0.88	(0.67, 1.17)		0.88	(0.66, 1.16)	
Chinese						
NDE	0.61	(0.42, 0.88)		0.64	(0.44, 0.95)	
NIE	0.96	(0.83, 1.12)	–	0.94	(0.88, 1.01)	–
Total effect	0.59	(0.40, 0.85)		0.61	(0.41, 0.89)	

Abbreviations: O*NET, Occupational Information Network, HR, hazard ratio; CI, confidence interval; %mediated, proportion of the total effect mediated by the occupational characteristic. Notes. When indirect effect is not significant, %mediated is not estimated. All models were adjusted for age at baseline, sex, nativity, working status at baseline, and study sites.
[a] $p = 0.07$.

and African Americans was no longer significant (total effect: HR = 1.17, 95% CI: 0.97, 1.40).

As for biomedical mortality risk factors such as obesity, diabetes, hypertension, dyslipidemia, we assumed that they were subsumed in both the direct pathway from race/ethnicity to death and the pathway from job characteristics to death. If these risk factors were true confounders, that is, if they were not the consequences of any social, economic, or occupational experience of racial/ethnic groups, and if the biomedical risk factors influence the occupational characteristics, then they should be considered as confounders. We re-ran our analysis controlling for these biomedical risk factors and found that the overall findings did not change very much. The mediation effect of substantive complexity for African Americans remained significant, explaining 24% of the higher risk in mortality than whites. The results of these sensitivity analyses can be found in the Supplemental Table 2.

Finally, we ran the mediation models excluding those who changed jobs during the study period. The results were virtually identical to those presented in Table 3. We also ran the models using retirees only because the current workers may have reported post-retirement short-term jobs. This did not appreciably change the main results. The interaction between race/ethnicity on death was not statistically significant in any of the models, indicating that the association between the occupational characteristics and death did not differ by race/ethnicity.

Discussion

This study examined the contribution of two occupational characteristics, both closely related to SEP, to racial/ethnic difference in all-cause mortality using data from a community-based, multi-ethnic cohort. Compared with whites, African Americans in our sample had a higher rate of death, and 30% of the elevated rate was explained by the lower levels of substantive complexity their jobs offered. Hispanic and Chinese Americans in our sample tended to have similar or lower rates of death compared with whites, but no mediation effects by substantive complexity were observed. We did not find evidence that occupational exposure to hazardous conditions mediates racial/ethnic difference in rates of death, except for a weak mediation for African Americans.

Potential mechanisms linking substantive complexity of work and mortality

Our finding of substantive complexity being associated with lower mortality is consistent with a previous finding from the National Longitudinal Survey of Mature Men (Moore & Hayward, 1990). Moore and Hayward considered substantive complexity as a buffer against "occupationally induced stress" (p. 36), but more recent studies suggest additional mechanisms. Substantive complexity of work has been associated with lower risk for dementia and cognitive impairment (Kroger et al., 2008; Pool et al., 2016; Spreng et al., 2011; Suo et al., 2012). Given that cognitive impairment is a strong predictor for mortality (Dewey & Saz, 2001), these findings suggest that substantively complex jobs protect cognitive functioning in later life, which in turn reduces mortality risk.

Another possible mechanism is offered in the literature of organizational behavior. Parker and colleagues (Parker, 2014; Parker, Bindl, & Strauss, 2010) argue that if employees have opportunities to use a wide range of skills, they become proactive and self-efficacious. Proactive workers will "take initiative in improving current circumstances […] challenge the status quo rather than passively adapt present conditions" (Crant, 2000, p. 436). Therefore, they may address health and safety concerns in the workplace, create problem-focused stress coping strategies (e.g., changing organizational practices that induce stressful situations), and eventually generate a healthier work environment for them. Self-efficacy has been long known to be vital to adopting and maintaining positive health behaviors (Strecher, DeVellis, Becker, & Rosenstock, 1986). The health-protective effect of substantively complex jobs may be mediated by positive health behaviors (Fujishiro & Heaney, 2017), which may develop during working years and protect health even after retirement. However, in our analysis, after removing the effects of biomedical risk factors that are strongly related to health behaviors, the significant mediation effect of substantive complexity remained. This suggests that the mechanism though which substantive complexity protects health is multifaceted. Future studies should examine these and other possible pathways specifically.

Our findings suggest that the difference in rates of death between whites and African Americans could be reduced substantially if substantive complexity of their jobs were the same as whites. This illuminates at least two potential targets for change. First, substantively complex jobs should be equally available across races. Studies have documented that compared with whites with equal education, African

Americans have difficulty securing employment commensurate with their qualifications (Pager et al., 2009; Tomaskovic-Devey et al., 2005; Vaisey, 2006). Efforts to remove such inequalities may reduce mortality differences between whites and African Americans.

A second target for change is the nature of jobs in which African Americans are overrepresented, such as service, production, transportation, and material-handling occupations (U.S. Bureau of Labor Statistics, 2015). These jobs are often characterized by routinized tasks and little room for decision-making. In fact, *job simplification* (i.e., allocating decision-making, creativity, innovation, and problem-solving to managers, and only manual tasks to workers) has been a long-standing practice in various industries (Parker, 2014) despite a large body of literature since the 1970s reporting negative consequences. These include turnover, absenteeism, and job dissatisfaction (Hackman & Lawler, 1971; Humphrey, Nahrgang, & Morgeson, 2007). Our finding adds elevated mortality. Designing jobs in which workers have opportunities to use their skills may help alleviate health consequences for all workers, and especially benefit African Americans who disproportionally hold simplified jobs.

Revisiting income and education in the context of racial/ethnic health disparities

In the introduction, we argued that occupational characteristics be included as a manifestation of SEP. In our sensitivity analyses, we explored implications of controlling for education and income while analyzing the role of occupational characteristics in racial/ethnic health disparities. Controlling for education as a confounder showed a reduction in the difference in rates of death between whites and African Americans. However, for education to be a confounder, we would have to assume that there were no impacts of race on access, quality, or attainment of education. Since this is quite contrary to the current understanding of education gap between whites and African Americans (Office for Civil Rights, 2016), education should not be considered as a confounder. If our society is able to eliminate racial inequalities in education, our findings suggest that racial health disparities may be reduced. Equal education is therefore an important target for intervention.

As for the role of income, our sensitivity analysis showed that if there were no true racial differences in income, and if income levels determined occupational characteristics, then there would be no racial differences in rates of death. Currently, race influences income in various ways (as indicated by the dotted arrows in Fig. 1): racial gaps in education (Office for Civil Rights, 2016) and the same education not leading to similar jobs (Pager et al., 2009; Vaisey, 2006) or the same earning (Hout, 2012). Our results suggest that all these inequalities must be addressed in order to eliminate differences in rates of death between whites and African Americans.

Considering occupational characteristics together with education and income forces us to think explicitly how these conditions are linked with each other in creating racial/ethnic health disparities. By making various assumptions explicit, researchers will become more effective in illuminating intervention possibilities.

Nativity and health

Hispanics and Chinese Americans in MESA tend to have a lower risk of death than whites, but we did not find evidence that either of the working conditions mediated the protective effect of belonging to these ethnic groups. There may be other job characteristics that contributed to their lower mortality risk. One issue to be considered in this particular sample is the large presence of immigrants among the Hispanic and Chinese American participants, a majority of whom migrated as adults. This may introduce ambiguity as to where the reported job was located and whether the O*NET job characteristics, developed for the US workforce, could be accurately imputed to the job an immigrant held in the home country, even under the same job title. Factors specific to immigrants' experiences, such as cohesiveness within immigrant communities, healthy individuals' self-selection into migration, pre-migration resources, and economic advantages in post-migration life compared to those stayed in the home country, may play a protective role. In this study, we simply controlled for nativity and the age of migration, but immigrants' experience of working conditions must be examined in studies specifically focused on the topic with more precise occupational and personal history for each immigrant.

Limitations of the study

A limitation of this study is the inability to examine the relationship between occupational characteristics and specific causes of death. Different occupational characteristics are likely to have different mechanisms by which they affect health, but our sample was too small for such analysis. Also, there was some measurement error related to our measures of occupational characteristics. For those who were still working, we were not able to identify if the reported occupation was the main job in life or a post-retirement job. For those who had left the workforce before the MESA study began, the duration since retirement was not asked. After retirement, occupational exposure is removed, and some impacts on health may eventually attenuate (Chandola et al., 2008), though others may persist (e.g., cognitive functioning, Pool et al., 2016). We were not able to examine these dynamics surrounding retirement with this data. Job tenure was not available for retirees and many of the current workers, and thus we could not examine cumulative effects of working conditions. We also acknowledge that other working conditions may exist that should be considered as confounders (i.e., not causally influenced by race/ethnicity or by the two job characteristics in this study).

In this analysis, we assumed that the effects of biomedical mortality risk factors (e.g., diabetes, hypertension) were subsumed in the pathway from race/ethnicity to mortality and one from occupational characteristics to mortality, and thus we did not quantify the effects of these risk factors individually. Because clear racial differences in biomedical mortality risk factors exist, investigating them as health outcomes and examining the mediating role of occupational characteristics will help clarify racial health disparities and facilitate more targeted interventions.

Conclusions

The strengths of this study lie in the diversity of the sample, including oversampled racial/ethnic minority groups, a wide range of occupations, and the inclusion of both workers and non-workers. By including participants who were no longer working at the time of enrollment, we were able to capture those who had left work potentially because of work-related health problems and thus avoided the healthy worker survivor effect.

We believe that the findings we present for whites and African Americans may have important implications for future research. Our finding that substantive complexity of work accounts for nearly a third of mortality risk differences between whites and African Americans indicates that work organization interventions may help reduce racial health disparities in mortality. This study thus demonstrated that when we consider SEP as a mediating mechanism of racial health disparities, incorporating occupational characteristics as part of SEP illuminates potential causes, and thus intervention possibilities, for racial/ethnic health disparities.

Disclaimer

The findings and conclusions in this paper are those of the authors and do not necessarily represent the views of the National Institute for Occupational Safety and Health. This document has not been formally

reviewed by the U.S. Environmental Protection Agency (EPA). The views expressed in this document are solely those of the authors, and the EPA does not endorse any products or commercial services mentioned in this publication.

Acknowledgements

This research was supported by contracts HHSN268201500003I, N01-HC-95159, N01-HC-95160, N01-HC-95161, N01-HC-95162, N01-HC-95163, N01-HC-95164, N01-HC-95165, N01-HC-95166, N01-HC-95167, N01-HC-95168 and N01-HC-95169 from the National Heart, Lung, and Blood Institute (NHLBI) and by Grants UL1-TR-000040 and UL1-TR-001079 from the National Center for Research Resources (NCRR). The authors thank the other investigators, the staff, and the participants of the MESA study for their valuable contributions. A full list of participating MESA investigators and institutions can be found at http://www.mesa-nhlbi.org. The information contained herein was derived in part from data provided by the Bureau of Vital Statistics, New York City Department of Health and Mental Hygiene. Occupational coding was funded by the National Institute for Occupational Safety and Health Intramural Funds (NORA FY08 CRN SLB8). This publication was developed under a STAR research assistance agreement, No. RD831697 (MESA Air), awarded by the U.S Environmental Protection Agency. AH was also supported by K99ES023498 from the National Institute of Environmental Health Sciences.

Appendix A. Supplementary material

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.ssmph.2017.05.010.

References

Adler, N. E., & Rehkopf, D. H. (2008). U.S. disparities in health: Descriptions, causes, and mechanisms. *Annual Review of Public Health*, *29*, 235–252.

Andel, R., Vigen, C., Mack, W. J., Clark, L. J., & Gatz, M. (2006). The effect of education and occupational complexity on rate of cognitive decline in Alzheimer's patients. *Journal of the International Neuropsychological Society*, *12*, 147–152.

Andries, F., Kompier, M. A. J., & Smulders, P. G. W. (1996). Do you think that your health or safety are at risk because of your work? A large European study on psychological and physical work demands. *Work and Stress*, *10*, 104–118.

Antonovsky, A. (1967). Social class, life expectancy, and overall mortality. *Milbank Quarterly*, *45*, 31–73.

Bild, D. E., Bluemke, D. A., Burke, G. L., Detrano, R., Diez Roux, A. V., Folsom, A. R., et al. (2002). Multi-ethnic study of atherosclerosis: Objectives and design. *American Journal of Epidemiology*, *156*, 871–881.

Boffetta, P., Jourenkova, N., & Gustavsson, P. (1997). Cancer risk from occupational and environmental exposure to polycyclic aromatic hydrocarbons. *Cancer Causes Control*, *8*, 444–472.

Boschetto, P., Quintaballe, S., Miotto, D., Lo Cascio, N., Zeni, E., & Mapp, C. E. (2006). Chronic obstructive pulmonary disease (COPD) and occupational exposures. *Journal of Occuaptional Medicine and Toxicology*, *1*, 11.

Braveman, P. A., Cubbin, C., Egerter, S., Chideya, S., Marchi, K. S., Metzler, M., et al. (2005). Socioeconomic status in health research – one size does not fit all. *JAMA-Journal of the American Medical Association*, *294*, 2879–2888.

Briggs, N. C., Levine, R. S., Hall, I., Cosby, O., Brann, E. A., & Hennekens, C. H. (2003). Occupational risk factors for selected cancers among African American and white men in the United States. *American Journal of Public Health*, *93*, 1748–1752.

Centers for Disease Control and Prevention (2013). CDC health disparities and inequalities report – United States, 2013. *MMWR,* 62.

Chandola, T., Britton, A., Brunner, E., Hemingway, H., Malik, M., Kumari, M., et al. (2008). Work stress and coronary heart disease: What are the mechanisms? *European Heart Journal*, *29*, 640–648.

Chung-Bridges, K., Muntaner, C., Fleming, L. E., Lee, D. J., Arheart, K. L., LeBlanc, W. G., et al. (2008). Occupational segregation as a determinant of US worker health. *American Journal of Industrial Medicine*, *51*, 555–567.

Cifuentes, M., Boyer, J., Lombardi, D. A., & Punnett, L. (2010). Use of O*NET as a job exposure matrix: A literature review. *American Journal of Industrial Medicine*, *53*, 898–914.

Crant, J. M. (2000). Proactive behavior in organizations. *Journal of Management*, *26*, 435–462.

Dewey, M. E., & Saz, P. (2001). Dementia, cognitive impairment and mortality in persons aged 65 and over living in the community: A systematic review of the literature. *International Journal of Geriatric Psychiatry*, *16*, 751–761.

Dressler, W. W., Oths, K. S., & Gravlee, C. C. (2005). Race and ethnicity in public health research: Models to explain health disparities. *Annual Review of Anthropology*, *34*, 231–252.

Fujishiro, K., & Heaney, C. A. (2017). "Doing what I do best": The effect of skill utilization on employee health with healthy behavior as a mediator. *Social Science Medicine*, *175*, 235–243.

Fujishiro, K., Xu, J., & Gong, F. (2010). What does "occupation" represent as an indicator of socioeconomic status?: Exploring occupational prestige and health. *Social Science Medicine*, *71*, 2100–2107.

Hackman, J. R., & Lawler, E. E. (1971). Employee reactions to job characteristics. *Journal of Applied Psychology*, *55*, 259.

Hadden, W. C., Kravets, N., & Muntaner, C. (2004). Descriptive dimensions of US occupations with data from the O*NET. *Social Science Research*, *33*, 64–78.

Hayward, M. D., Friedman, S., & Chen, H. (1998). Career trajectories and older men's retirement. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, *53*, S91–S103.

Heikkila, K., Fransson, E. I., Nyberg, S. T., Zins, M., Westerlund, H., Westerholm, P., et al. (2013). Job strain and health-related lifestyle: Findings from an individual-participant meta-analysis of 118,000 working adults. *American Journal of Public Health*, *103*, 2090–2097.

Hout, M. (2012). Social and economic returns to college education in the United States. *Annual Review of Sociology*, *38*, 379–400.

Humphrey, S. E., Nahrgang, J. D., & Morgeson, F. P. (2007). Integrating motivational, social, and contextual work design features: A meta-analytic summary and theoretical extension of the work design literature. *Journal of Applied Psychology*, *92*, 1332.

Isaacs, S. L., & Schroeder, S. A. (2004). Class—the ignored determinant of the nation's health. *New England Journal of Medicine*, *351*, 1137–1142.

Johnson, N. J., Sorlie, P. D., & Backlund, E. (1999). The impact of specific occupation on mortality in the US national longitudinal mortality study. *Demography*, *36*, 355–367.

Karasek, R. A. (1979). Job demands, job decision latitude, and mental strain: Implications for job redesign. *Administrative Science Quarterly*, *24*, 285–308.

Kaufman, J. S., Cooper, R. S., & McGee, D. L. (1997). Socioeconomic status and health in blacks and whites: The problem of residual confounding and the resiliency of race. *Epidemiology*, 621–628.

Kawachi, I., Daniels, N., & Robinson, D. E. (2005). Health disparities by race and class: Why both matter – we must link efforts to address the injuries of race and class simultaneously if we are to reduce health disparities. *Health Affairs*, *24*, 343–352.

Kohn, M. L., & Schooler, C. (1978). The reciprocal effects of the substantive complexity of work and intellectual flexibility: A longitudinal assessment. *American Journal of Sociology*, *84*, 24–52.

Krieger, N. (2005). Embodiment: A conceptual glossary for epidemiology. *Journal of Epidemiology and Community Health*, *59*, 350–355.

Kroger, E., Andel, R., Lindsay, J., Benounissa, Z., Verreault, R., & Laurin, D. (2008). Is complexity of work associated with risk of dementia? *American Journal of Epidemiology*, *167*, 820–830.

Kurian, A. K., & Cardarelli, K. M. (2007). Racial and ethnic differences in cardiovascular disease risk factors: A systematic review. *Ethnicity and Disease*, *17*, 143.

Lang, J., Ochsmann, E., Kraus, T., & Lang, J. W. (2012). Psychosocial work stressors as antecedents of musculoskeletal problems: A systematic review and meta-analysis of stability-adjusted longitudinal studies. *Social Science Medicine*, *75*, 1163–1174.

Marmot, M. G., Bosma, H., Hemingway, H., Brunner, E., & Stansfeld, S. (1997). Contribution of job control and other risk factors to social variations in coronary heart disease incidence. *Lancet*, *350*, 235–239.

Marmot, M. G., Shipley, M. J., & Rose, G. (1984). Inequalities in death—specific explanations of a general pattern? *The Lancet*, *323*, 1003–1006.

Marmot, M. G., Smith, G. D., Stansfeld, S., Patel, C., North, F., Head, J., et al. (1991). Health inequalities among British civil-servants: The Whitehall II study. *Lancet*, *337*, 1387–1393.

McEwen, B. S. (1998). Protective and damaging effects of stress mediators. *New England Journal of Medicine*, *338*, 171–179.

Moore, D. E., & Hayward, M. D. (1990). Occupational careers and mortality of elderly men. *Demography*, *27*, 31–53.

Nam, C. B., & Boyd, M. (2004). Occupational status in 2000: Over a century of census-based measurement. *Population Research and Policy Review*, *23*, 327–358.

Neupane, S., Virtanen, P., Luukkaala, T., Siukola, A., & Nygård, C. H. (2014). A four-year follow-up study of physical working conditions and perceived mental and physical strain among food industry workers. *Applied Ergonomics*, *45*, 586–591.

Office for Civil Rights (2016). In U. D.o. Education (Ed.), *2013–2014 Civil rights data collection: a first look*. Washington, DC: US. Department of Education.

Pager, D., Western, B., & Bonikowski, B. (2009). Discrimination in a low-wage labor market a field experiment. *American Sociological Review*, *74*, 777–799.

Parker, S. K. (2014). Beyond motivation: Job and work design for development, health, ambidexterity, and more. *Annual Review of Psychology*, 661–691.

Parker, S. K., Bindl, U. K., & Strauss, K. (2010). Making things happen: A model of proactive motivation. *Journal of Management*.

Pool, L. R., Weuve, J., Wilson, R. S., Bültmann, U., Evans, D. A., & de Leon, C. F. M. (2016). Occupational cognitive requirements and late-life cognitive aging. *Neurology*, *86*, 1386–1392.

Richiardi, L., Bellocco, R., & Zugna, D. (2013). Mediation analysis in epidemiology: Methods, interpretation and bias. *International Journal of Epidemiology*, *42*, 1511–1519.

Rosvall, M., Östergren, P.-O., Hedblad, B., Isacsson, S.-O., Janzon, L., & Berglund, G. (2006). Socioeconomic differences in the progression of carotid atherosclerosis in middle-aged men and women with subclinical atherosclerosis in Sweden. *Social Science Medicine*, *62*, 1785–1798.

Schooler, C., Mulatu, M. S., & Oates, G. (1999). The continuing effects of substantively

complex work on the intellectual functioning of older workers. *Psychology and Aging*, *14*, 483.
Spreng, R. N., Drzezga, A., Diehl-Schmid, J., Kurz, A., Levine, B., & Perneczky, R. (2011). Relationship between occupation attributes and brain metabolism in frontotemporal dementia. *Neuropsychologia*, *49*, 3699–3703.
Steege, A. L., Baron, S. L., Marsh, S. M., Menéndez, C. C., & Myers, J. R. (2014). Examining occupational health and safety disparities using national data: A cause for continuing concern. *American Journal of Industrial Medicine*, *57*, 527–538.
Strecher, V. J., DeVellis, B. M., Becker, M. H., & Rosenstock, I. M. (1986). The role of self-efficacy in achieving health behavior change. *Health Education Behavior*, *13*, 73–92.
Strong, L. L., & Zimmerman, F. J. (2005). Occupational injury and absence from work among African American, Hispanic, and non-Hispanic White workers in the national longitudinal survey of youth. *American Journal of Public Health*, *95*, 1226–1232.
Suo, C., Leon, I., Brodaty, H., Trollor, J., Wen, W., Sachdev, P., et al. (2012). Supervisory experience at work is linked to low rate of hippocampal atrophy in late life. *Neuroimage*, *63*, 1542–1551.
Theorell, T., Hammarström, A., Aronsson, G., Bendz, L. T., Grape, T., Hogstedt, C., et al. (2015). A systematic review including meta-analysis of work environment and depressive symptoms. *BMC Public Health*, *15*, 1.
Tomaskovic-Devey, D., Thomas, M., & Johnson, K. (2005). Race and the accumulation of human capital across the career: A theoretical model and fixed-effects application1. *American Journal of Sociology*, *111*, 58–89.
U.S. Bureau of Labor Statistics (2015). Labor force characteristics by race and ethnicity, 2014. In: U.S.D.o. Labor (Ed.). Washington, DC.
Vaisey, S. (2006). Education and its discontents: Overqualification in America, 1972–2002. *Social Forces*, *85*, 835–864.
Valeri, L., & VanderWeele, T. J. (2013). Mediation analysis allowing for exposure–mediator interactions and causal interpretation: Theoretical assumptions and implementation with SAS and SPSS macros. *Psychological Methods*, *18*, 137.
VanderWeele, T. J., & Vansteelandt, S. (2010). Odds ratios for mediation analysis for a dichotomous outcome. *American Journal of Epidemiology*, *172*, 1339–1348.
Williams, D. R., Mohammed, S. A., Leavell, J., & Collins, C. (2010). Race, socioeconomic status, and health: Complexities, ongoing challenges, and research opportunities. *Annals of the New York Academy of Sciences*, *1186*, 69–101.