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Job complexity and hazardous working conditions: How do they explain educational gradient in mortality?

Kaori Fujishiro[1], **Leslie A. MacDonald**[1], **Virginia J. Howard**[2]

[1]National Institute for Occupational Safety and Health

[2]University of Alabama at Birmingham

Abstract

While education's protective effects on health have been well recognized, specific mechanisms through which higher education is associated with better health are still debated. Occupation, although strongly shaped by education, has rarely been examined as a mediating mechanism. Education attainment is patterned by race in the United States, and the same education does not lead to similar occupations for members of different racial/ethnic groups. Therefore, examining the link from education to jobs to mortality can illuminate potential mechanisms that create racial health disparities. Using a large U.S. national cohort of black and white men and women, we examined if two occupational characteristics, substantive complexity of work and hazardous working conditions, mediate the effect of education on mortality. Data on occupation were collected between 2011 and 2013, and mortality follow-up data up to March 2018 were included in this analysis. The race- and gender-stratified analyses showed that among white men, the association between higher education and lower mortality was mediated by lower hazard on the job. Among black men and white women, higher complexity of work explained the association between higher education and lower mortality. Among black women, neither job characteristic mediated the association. These results suggest that occupational characteristics help explain health inequalities not only by education but by race and gender. Investigating occupation explicitly in the causal chain of health disparities will help us better understand the mechanism of and potential solutions for health inequalities.

Keywords

socioeconomic status; occupational hazards; substantive complexity of work; mediation analysis; health disparities

Differences in health status by socioeconomic position (SEP) have long attracted interest in public health. As a commonly used indicator of SEP, education has been consistently associated with various measures of health (Elo, 2009; Grossman, 2015); however, specific mechanisms through which education influences health are still debated (Galama, Lleras-Muney, & van Kippersluis, 2018). Implicit or explicit, a common assumption is that highly educated individuals have skills and knowledge to lead a healthy life (Galama et al., 2018).

Correspondence concerning this article should be addressed to Kaori Fujishiro, National Institute for Occupational Safety and Health (NIOSH), 1090 Tusculum Avenue (MS R-15), Cincinnati, OH 45226. kfujishiro@cdc.gov.

Even though education strongly shapes occupational experiences, work has seldom been considered as a mediating factor in the relationship between education and health (Braveman et al., 2005; Elo, 2009).

Reviewing health economics and sociology literatures, we first summarize how education is conceptually associated with health in the current literature and discuss why occupation should be brought into the framework more specifically. Then we extend the discussion to health inequalities because racial differences are substantial in education (Office for Civil Rights, 2016), demographic compositions are not proportional to the workforce across occupations (Bureau of Labor Statistics, 2018a), and racial health inequalities clearly exist (Cunningham et al., 2017). Using data from the REasons for Geographic and Racial Differences in Stroke (REGARDS) study, a large national cohort of blacks and whites, we examine two occupational characteristics as potential mediating mechanisms in the association of education with all-cause mortality, an ultimate measure of general health (DeSalvo, Bloser, Reynolds, He, & Muntner, 2006), with a special focus on differential mechanisms by race and gender. This study contributes to occupational health psychology in the following ways. First, by examining education and occupation separately and modeling their relationship to health explicitly, we disentangle SEP. Better understanding how education and occupation are associated with health will help identify intervention opportunities through occupation, especially for those with lower education attainment. Second, by conducting race- and gender-stratified analyses, we explore potentially different mechanisms linking education to health for different demographic groups. This offers additional explanations for persistent health inequalities by race and SEP (Ahonen, Fujishiro, Cunningham, & Flynn, 2018).

How Education Is Associated with Health: Human Capital and Fundamental Causes

A traditional explanation for the association between education and health uses the human capital framework (Grossman, 1972, 2015): education cultivates individuals to become efficient consumers of health care as well as informed users of new knowledge and technology, and thereby increases the likelihood of healthy behaviors (Galama & Van Kippersluis, 2018). This human capital explanation, supported by a large body of literature (Cutler & Lleras-Muney, 2006), solely focuses on the individual's ability to access and use health-enhancing resources. A recent critical review brings in a wider perspective. Reviewing studies with designs that are higher in quality of evidence (i.e., randomized control studies, identical twin studies, and quasi-experimental studies), Galama et al. (2018) reported that the health benefits of education depend on gender, the labor market returns to education, the quality of education, and education's effects on the characteristics of one's peers.

This expanded perspective is in line with the fundamental cause theory of health inequalities: personal resources such as money, knowledge, power, prestige, and social connections are "fundamental causes" of health because they allow individuals to accumulate health advantages over time. Therefore, if these resources were distributed

unequally, health inequalities arise (Link & Phelan, 1995). The fundamental cause theory focuses not only on individuals' access to health-enhancing resources but also on the social and environmental contexts in which individuals are engaged, such as workplaces, neighborhoods, and peer networks. Following the theory, we consider education's impacts on health through its influence on individuals' abilities as well as on the workplace social and environmental contexts.

Occupation as a Mediating Mechanism

Our specific focus in this paper is occupation as an environmental context that is strongly influenced by education. It is well-recognized that education largely dictates what types of occupations are available to the person. It is also recognized that some job characteristics such as stress and long hours have health consequences. However, occupation has seldom been examined as a mediating mechanism between education and health, and the few previous studies reported inconclusive findings. In general, studies that examined occupation as a general marker of SEP have not found a significant mediating effect: occupation-based SEP measures (e.g., occupational prestige, skill-based social class; Miech & Hauser, 2001) or occupational categories (i.e., unskilled, semiskilled, farmers, skilled, technicians and middle management, professionals; White, John, Cheverie, Iraniparast, & Tyas, 2015) did not explain the association between education and health. Neither did U.S. Census Industry and Occupation codes (Cutler & LlerasMuney, 2006).

However, studies that examined specific characteristics of work have reported consistently significant results. For example, Ross and Wu (1995) found that some aspects of work (e.g., intrinsic gratification from work, sense of control) explained a substantial portion of the association between higher education and better health. Other earlier studies, such as Leigh (1983) and Kemna (1987), reported that the effect of education on health had a significant indirect effect through hazardous jobs. These findings are consistent with a large body of occupational health literature, but few subsequent studies on education and health have examined specific job characteristics as potential mediators.

The importance of examining specific job characteristics lies in its organizational and social institutional nature. If certain aspects of work are identified as impacting health, they offer opportunities for intervention at organizational and societal levels. Since most adults' working years span many decades, health-enhancing work experiences can potentially have large effects. Moreover, for those with limited education attainment, health-enhancing work may mitigate the health disadvantages associated with lower education. For this purpose, job characteristics need to be examined explicitly as a potential mediating mechanism in the relationship between education and health.

In this study, we examined two job characteristics as potential mediations in the association between education and health: substantive complexity of work and hazardous working conditions. *Substantive complexity of work* represents the extent to which the job requires decision making, skill utilization, information synthesis, inductive and deductive reasoning, and critical thinking (Kohn & Schooler, 1978). This is similar to, but broader than, job control (Karasek, 1979), a robust predictor of health and well-being. Substantive complexity

has been associated with incident hypertension more strongly than self-reported job control (Meyer, Cifuentes, & Warren, 2011). In addition, substantive complexity has been associated with future disabilities (Hayward, Grady, Hardy, & Sommers, 1989) and all-cause mortality (Fujishiro, Hajat, et al., 2017; Hayward & Gorman, 2004; Moore & Hayward, 1990). It is presumed that higher education is required to perform substantively complex jobs. Therefore, we hypothesize the following:

Hypothesis 1: The association between education and all-cause mortality is mediated by substantive complexity of work such that higher education leads to higher complexity, which leads to lower risk of death.

Hazardous working conditions, such as exposures to dangerous chemicals, extreme temperatures, elevated heights (e.g., scaffolding), and noise have been a major concern for occupational health researchers. Occupational fatality is constantly high in industries that involve highly hazardous conditions such as construction, transportation, mining, and farming/fishing/forestry (Bureau of Labor Statistics, 2018b). Hazardous working conditions may not directly lead to death on the job, but many of these conditions are known risk factors for cardiovascular disease (Schnall, Belkic, Landsbergis, & Baker, 2000), chronic obstructive pulmonary diseases (Boschetto et al., 2006), and various types of cancer (Briggs et al., 2003), all among the leading causes of deaths in the United States. Limited education does not necessarily mean that only dangerous jobs are available: some jobs with lower levels of hazard exposure (e.g., retail, administrative support) may not require especially high education. However, labor economists have shown that those with limited education may choose to work in high-hazard jobs because, compared to low-hazard jobs available to them, high-hazard jobs pay higher wages (Biddle & Zarkin, 1988; Brown, 1980; Leigh, 1983). Then, low levels of education may increase the likelihood of experiencing more hazardous working conditions, which in turn may lead to higher mortality.

Hypothesis 2: The association between education and all-cause mortality is mediated by hazardous working conditions such that higher education leads to lower hazard exposure, which leads to lower risk of death.

Considerations for Race and Gender

In examining education, job characteristics, and health, we must consider gender and race carefully. Research has generally found that the education gradient in mortality is stronger for men than for women (Galama & Van Kippersluis, 2018), and for whites than for racial/ethnic minorities (Everett, Rehkopf, & Rogers, 2013; Masters, Hummer, & Powers, 2012). Moreover, evidence suggests that blacks are less likely to have access to high-quality elementary and secondary education (Office for Civil Rights, 2016). The proportion of blacks who have completed college is consistently lower than whites by about 15% points for men and 10% points for women (US Census Bureau, 2019). Even within the same educational strata, job opportunities and earnings of blacks are less than for whites, especially among men (Eckstein & Wolpin, 1989; Hout, 2012; Tomaskovic-Devey, Thomas, & Johnson, 2005). As for gender, until the mid-1980s, women were less likely to earn a Bachelor's degree than men, but since the mid-1980s, more women graduate from college

each year (National Center for Education Statistics, 2016). This reflects social expectations for women's education; that is, being a woman influenced the level of education she was expected to complete. However, gender stereotypes hinder women's career advancement especially in fields traditionally dominated by men such as military, surgery, science and technology (Heilman, 2012). The success on the job itself can be detrimental to women if the job is considered a man's job (Heilman, Wallen, Fuchs, & Tamkins, 2004). Women's life-time earnings are generally lower than men's, partly reflecting career trajectories in the context of family life (Sorenson & Dahl, 2016). These observations suggest that the accumulation of personal resources—i.e., money, knowledge, power, prestige, and social ties—based on education and through occupation may differ considerably by gender and race. Moreover, education attainment itself can be influenced by race and gender, in addition to the paths from education to occupation and occupation to health. These differences may ultimately create differences in health status between genders and races (Masters, Link, & Phelan, 2015).

Figure 1 illustrates the complex relationships among race, gender, education, occupation, and mortality conceptualized for this study. The direct arrow from education to mortality represents all potential mechanisms linking education to mortality (some of them are indicated in parentheses), known or unknown in the current literature, except for occupational characteristics. The dotted arrows acknowledge potential links among some of the linking mechanisms that we do not distinguish in this study. Although we did not illustrate this in the figure, many of the dotted arrows would be moderated by race and gender (e.g., the eduction-income link may differ by race and gender). Because the relationship among race, gender, education, occupation, and all-cause mortality is so intricate, in this study we do not attempt to form *a priori* hypotheses concerning gender and race. Instead, we explore potentially different relationships among education, occupation, and mortality by conducting gender- and race-stratified analyses. Kaplan et al. (2015) reported from the REGARDS study that income, cardiovascular disease risk factors, and health behaviors explained some of the education gradient in mortality but still significant effects of education remained unexplained. The current study examines occupational characteristics, gender, and race as part of the unexplained effect of education on mortality.

Methods

Participants and Data Collection

We used data from the REGARDS study, a national cohort of black and white women and men, aged 45 years and older at enrollment. In addition to age and race, the eligibility criteria included not undergoing active treatment for cancer, not having cognitive impairment or medical conditions that would prevent long-term participation, not living in a nursing home or being on a waiting list for one, and being able to communicate in English (Howard et al., 2005).

Although the REGARDS cohort was formed between 2003 and 2007 with over 30,000 participants, the sample for the current analyses was derived from the occupational ancillary study conducted from 2011 to 2013 (MacDonald, Pulley, Hein, & Howard, 2014). Because of the median 6.5 years between enrollment and administration of the occupational survey,

the analytic sample of this study was older, and the person-years of follow-up was lower than the previous REGARDS education and mortality study (Kaplan, Howard, Safford, & Howard, 2015). After accounting for 12,850 participants who had either died, were lost to follow-up, or declined to participate in the occupational module; 17,333 participants consented and completed the occupational data collection, which resulted in an 87% response rate (MacDonald et al., 2014). Participants provided written informed consent at the time of enrollment to the REGARDS study, and later provided verbal consent for the occupational ancillary study.

For this analysis we focused on the characteristics of the job that participants held for the longest duration because we assumed that that job would be the most influential to mortality. We excluded those who did not report adequate information on the longest-held job or the job tenure was short (<5 years); thus data from 15971 individuals were analyzed. Mortality data were available up to March 31, 2018 (see below for more details). The median follow-up duration was 5.1 years. The REGARDS study protocol was approved by the Institutional Review Boards (IRB) of University of Alabama Birmingham (UAB), and the occupational ancillary study was approved by the IRBs at UAB and the National Institute for Occupational Safety and Health (NIOSH).

Measures

Education.—At REGARDS enrollment, all participants were asked, “What is the highest grade or year of school you have completed?” The response options included nine levels, ranging from “never attended or kindergarten only” to “postgraduate or professional degree.” For this analysis, we combined the responses into five categories: 1) less than high school graduate or GED certificate, 2) high school graduate or GED certificate, 3) some education beyond high school but not college graduate, 4) college graduate, and 5) postgraduate or professional degree. Given the age of the cohort (≥45 years), we assumed that education attainment reported at enrollment had not changed at the time of the occupational ancillary study.

Occupational characteristics.—All occupational survey respondents who had ever worked outside the home after the age of 25 were asked to describe their longest-held job such as main duties, job title, employer’s name, the year they started, and if they no longer had the job, the year they left the job. Trained coders at NIOSH reviewed the descriptions to assign the Census 2002 Occupation Codes (see MacDonald et al., 2014 for more details). Census codes were then used to link to data on occupational characteristics from the Occupational Information Network (O*NET) version 21 (see Fujishiro, MacDonald, et al., 2017 online supplement for details of the data linkage). O*NET is a publicly available database of job characteristics for most occupations in the United States. Although the original purpose was to aid job seekers to identify suitable jobs, O*NET has been effectively used to impute job exposure data in epidemiologic studies (Cifuentes, Boyer, Lombardi, & Punnett, 2010).

Two job characteristics, substantive complexity of work and hazardous working conditions, were both derived from O*NET variables as specific job characteristics that potentially

mediate the association of education with health. Following the factor structure of Hadden et al. (2004), we used 11 O*NET variables and calculated the mean score as the measure of substantive complexity of work. Cronbach's alpha for the 11 items was 0.96. After computing the substantive complexity score of all of the Census 2002 job titles, we standardized the score with the mean of zero and standard deviation of one. That is, the standardized complexity score of 0 indicates the average level of complexity among 505 Census 2002 jobs for which O*NET data are available, the score of 1 means the job's level of complexity is one standard-deviation higher than the average, and −1 means one standard-deviation lower than the average. This way the O*NET substantive complexity score has meaning within the distribution of complexity in US jobs.

The measure of hazardous working conditions scores was the mean score of 8 O*NET variables that capture traditional occupational hazards such as high levels of noise, extreme temperatures (i.e., <32F or >90F), extremely bright or inadequate light, high places (e.g., scaffolding, catwalks, ladders), outdoors exposed to all weather conditions, and requirements for personal protective equipment. Cronbach's alpha for the 8 items was 0.95. Similar to the complexity score, the mean score was standardized with the mean of zero and standard deviation of one. The higher the score, the more hazardous the working condition of the job, and zero means the average level of hazardousness among all US jobs.

Mortality follow-up.—Active follow-up of the REGARDS cohort consists of routine biannual contact by telephone to obtain updated information on any serious medical events. If a participant has died, the participant's proxy or next of kin provides information on the date of death. In addition, the study staff routinely review the National Death Index to confirm participants' deaths and to identify the vital status of those who have been lost of follow-up.

Race, gender, and other covariates.—Self-identified race, gender, and age were recorded at the time of enrollment. Because REGARDS's principal focus is stroke, participants were oversampled from eight southeastern states (North Carolina, South Carolina, Georgia, Tennessee, Alabama, Mississippi, Louisiana, and Arkansas) that comprise the "stroke belt" (i.e., region with higher mortality from stroke than the rest of the nation). Blacks were also oversampled because of their higher stroke mortality compared to whites. At the time of the occupational module data collection, the participants' workforce participation (i.e., currently working, currently not working) was asked.

Statistical Analysis—All analyses are stratified by race and gender. After showing characteristics of the sample, we present age-adjusted rates of death per 1000 person-years by race and gender. Then, using proportional hazard models, we modeled the effect of education on mortality with each occupational characteristic separately as the mediator while accounting for age, baseline working status, and stroke-belt region, as potential confounders. Applying the counterfactual framework of causal mediation (Richiardi, Bellocco, & Zugna, 2013), we estimated two effects, the natural direct effect (NDE) and natural indirect effect (NIE), with the technical details provided by VanderWeele (2011). The specific application of the mediation analysis in this study can be described as the following: NDE is the hazard ratio (HR) between a lower and higher level of education (e.g.,

less than high school vs. high school diploma) estimated while the level of occupational characteristic (e.g., hazardous working conditions) was kept constant at the mean of the higher level of education (i.e., high school). That is, NDE represents the mortality difference associated with one-level increase in education not influenced by difference in hazardous conditions that would accompany the education difference. This is a counterfactual: *What if education difference did not lead to difference in hazardous working conditions? What is the association between education and mortality then?* In contrast, NIE involves another counterfactual: *What if people with lower education experience the same occupational characteristics as people with higher education? What is the association between education and mortality then for those with lower education?* NIE is the HR estimated while changing the occupational characteristic as the mean of the lower and higher levels of education. Thus NIE represents the effect of education on mortality mediated by the difference in the occupational characteristic. Finally, the total effect (TE) of education is calculated as the sum of NDE and NIE. The mediation analyses were conducted using the SAS macro developed by Valeri and VanderWeele (2015). Because of some macro constraints, the two proposed mediators (substantive complexity and hazardous working conditions) were analyzed separately. Education was included in the macro as a continuous variable, and we present NDE and NIE by each incremental increase in education levels (e.g., < high school vs. high school) rather than setting one level as a reference with which all other levels are compared. This is because we assume that comparisons of closer education differences would allow NIE estimates to be less confounded than comparisons of vastly different education levels (e.g., high school vs. graduate degree). All analyses were conducted using SAS v.9.4 (Cary, North Carolina).

Results

Tables 1 shows sample characteristics by gender, race, and education. Education attainment differs greatly by race and less by gender: white men had the highest proportion of post-graduate degree holders, and black men and women had the highest proportions of those without a high school diploma. In all race-gender groups, average age was the highest for those without a high school diploma. Table 2 shows the age-adjusted rates of death per 1000 person-years by gender, race, and education. Within each race-gender group, the education gradient in point estimates is clearly seen. White women seem to have generally lower rates of death than other gender-race groups.

Comparisons of occupational characteristics by gender, race, and education are shown in Figure 2. The job characteristic scores were standardized relative to all jobs in the US workforce (i.e., zero indicates the average of all US jobs). Substantive complexity of work (top panel) shows a clear education gradient for all gender-race groups; however, within each education level, white men consistently had the highest average score of substantive complexity. For example, white men with a high school diploma had a mean score of complexity higher than the US average; however, for all other gender-race groups, it took higher levels of education to have above-US average scores (college education for black men, some education beyond high school for women of both races). Hazardous working conditions (bottom panel) shows an education gradient only among men (i.e., higher the

education, lower the hazardous level). Women were employed in jobs with low levels of hazardous conditions regardless of education level.

Table 3 presents results in men for the direct and indirect effects of education on mortality with the two occupational characteristics as mediators. For white men, none of the NIEs for substantive complexity of work were statistically significant; that is, even though each incremental increase in education was associated with lower mortality (i.e., TE <1.00 and significant), substantive complexity of work did not mediate the effect of education on mortality at any level of education for white men. In contrast, for black men, having some education beyond high school, compared to only having high school diploma, was associated with 20% lower mortality (TE HR=0.80, 95%CI: 0.68, 0.94), and 44.6% of the protective effect of education was mediated by having more complex jobs (NIE HR=0.90, 95%CI: 0.81, 1.00). Similarly, compared to having some education beyond high school, having graduated from college was associated with 9% lower mortality, and 41.5% of the effect was mediated by having jobs with higher complexity. Thus Hypothesis 1 was supported among black men of mid-level education but not among white men.

Hazardous working conditions showed a different pattern of mediating effects for men (Table 3). Among white men with the highest two educational categories, about 18% to 20% of the association between higher education and lower risk of deaths was mediated by the association between higher education and jobs with lower hazard levels. This mediation effect was not found among white men with less than college education or among black men at any level of education. Hypothesis 2 was supported among highly educated white men but not among black men.

The results of mediation analysis for women are shown in Table 4. Substantive complexity had significant indirect effects only among white women. Except for the lowest levels of education, each incremental increase in education was associated with 10% to 17% lower risk of death, and a large proportion (42.6% to 54.8%) of the protective effect of education was explained by NIE through jobs with higher substantive complexity. Among black women, no significant NIEs were found. Hypothesis 1 was supported among white women but not among black women. Hazardous working conditions did not mediate the association between education and mortality for women of either race (i.e., Hypothesis 2 not supported among women).

Because REGARDS is an older cohort (median age at the time of occupational module administration = 70), it is possible that those with lower education may be highly selective individuals (mortality selection bias, Masters, 2012). To address this issue, we conducted the same analysis with older and younger participants separately (i.e., split at the median age within each race-gender group). While overall findings and interpretations were unchanged, the younger and older samples did show some differences. The statistically significant mediation by substantive complexity found in black men remained significant only among those ≤70 years of age. The significant mediation by hazardous working conditions among white men remained significant only for those >71 years of age. Similarly, mediation by substantive complexity among white women was significant among those >69 years of age. The full results are shown in the Appendix (Tables A1 through A4).

Discussion

Using a large national cohort of middle-age and older black and white men and women, this study examined two occupational characteristics, substantive complexity of work and hazardous working conditions, as potential mechanisms linking education to all-cause mortality. The analysis showed different patterns of mediation for each race-gender group. For white men, the education gradient in mortality was explained in part by higher education leading to less hazardous jobs. For black men and white women, the education gradient was explained in part by higher education leading to more complex jobs. For black women, neither of the occupational characteristics explained the education gradient in mortality.

These different patterns of mediation may reflect the different social dynamics related to gender, race, and occupation. The fundamental cause theory posits that personal resources such as knowledge, money, power, prestige, and social ties enable individuals to accumulate health advantages over time (Link & Phelan, 1995). Even though work is closely related to many of these personal resources, for white men, the accumulation of health advantages may not rely on having substantively complex jobs. Our results showed that the direct effects from education to mortality were consistently significant for white men but not so in other gender-race groups. This suggests that education is beneficial to white men, but they may not acquire health-protecting personal resources through complex jobs that result from education. In contrast, for black men and white women, the link from education to complex jobs may be an important way to obtain personal resources and subsequent accumulation of health advantages.

As for hazardous working conditions, white men seemed to benefit from higher education leading to less hazardous jobs, but not black men. Since the distribution of hazardous working conditions by education was similar between white and black men, this is difficult to understand. One possible explanation is that the less hazardous jobs of black and white men may be different in some ways that were not captured by our measure. By attaining higher education, white men may not only avoid highly hazardous jobs, but also gain access to jobs that provide other health-protective characteristics such as higher prestige (Fujishiro, Xu, & Gong, 2010). The less hazardous jobs that highly educated black men have may not come with such benefits at the same level. In our sample, the most common job titles among white men with a college degree included chief executives, general and operation managers, and financial managers. In contrast, among black men with a college degree, the most common job titles included secondary school teachers, education administrators, and first-line supervisors of office support workers. These sets of occupations may require similar levels of education and may expose workers to similar (low) levels of hazards; however, these jobs may not offer the same levels of personal resources that fundamental causes theory identifies as health protecting (i.e., money, power, prestige, knowledge, and social ties). As for women, we did not see any mediating effects through hazardous working conditions. This is understandable given there was no association between education and hazardous working conditions among women.

Overall, our mediation results were not very strong in the sense of statistical significance. This could be the true magnitude of association since job characteristics are distal causes of

health or underestimated because of the nature of the cohort (discussed below). Alternatively, if there is a substantial confounder that causally influences both the occupational characteristics and risk of death, our findings could be inflated. Using the approach proposed by Ding and VanderWeele (2016), we estimated that if an unmeasured hypothetical confounder diminished the risk of death by 10% and also suppressed occupational complexity by 10%, the significant mediation effect observed among black men and white women would have become null. Similarly, a confounder that increased the risk of death by 10% and also increased hazardous working conditions by 10% would have made the mediation effect for white men null. Race, gender, age, and education would have been such factors, but they were all addressed in our analyses. Income may be associated with both occupational characteristics and risk of death, but it is unlikely that income determines what kind of job the person goes into; rather, the kind of job the person has typically determines the level of pay. Thus, income would be part of the causal pathway from education and occupation to risk of death as shown in our conceptual figure. In fact, besides education and demographic characteristics, it is not well understood what factors would sort people into certain types of jobs. If those factors also have implications for risk of death, they should be included in future research.

A major limitation in our data is the advanced age of the cohort and relatively short follow-up period. Even though we expect that the impact of occupational characteristics would unfold throughout the adult life including post-retirement, the median age of 70 in this cohort is not ideal because of mortality selection. The literature on mortality selection bias or crossover suggests that as a cohort becomes very old, it becomes heterogeneous reflecting selection, that is, those who experience unfavorable conditions (e.g., low education) yet survived to that age are especially resilient individuals because frail ones would have died before reaching the age, and thus mortality difference by education may diminish or even reverse (summarized in Masters, 2012). If this selection bias is operating in our sample, our results may have underestimated the true association among education and mortality, as well as the role of occupational characteristics in the association. At the same time, several studies have reported that the education gradient in mortality is becoming steeper for younger birth cohorts (Everett et al., 2013; Masters et al., 2012). In our sample, birth year ranges from 1911 to 1962. Analyzing all participants together might have obscured differences in education gradient in mortality across different birth cohorts. The age-stratified analysis, however, did not show clearly in which direction our findings might have been biased: most of the significant mediation among whites (both men and women) was in the older half of the cohort, while significant results for black men were only found for the younger half. Rather than speculating on these post-hoc findings, we suggest the need for younger cohorts and longer follow-up time in order to clarify the complex relationships among education, job characteristics, mortality, race, and gender.

We conducted race-gender stratified analysis instead of fitting a moderated mediation model. This is partly because the technique is not yet available for the survival outcome (Hayes, 2017), and also because we conceptualized education as an endogenous factor influenced by race and gender. In a moderated mediation model, X (education in our case) must be exogenous. While our approach acknowledges the potentially different mediation patterns by race and gender, it does not test statistical significance of the moderation effect. Other

limitations include potential measurement error in O*NET-derived mediator variables. Because job exposures were imputed by O*NET based on job title (i.e., Census code), an underlying assumption is that all workers with the same job title experience the same level of complexity and hazards, which may not be accurate in a diverse cohort. This is an inherent limitation of using a job exposure matrix. Our race- and gender-stratified analysis reduces the impact of systematic measurement error across race and gender, but we must use caution in racial and gender comparisons of our results. Additionally, although we used the state-of-the-art causal mediation analysis technique, it does not allow for multiple mediators. It is possible that the two job characteristics we examined separately might have synergistic effects if analyzed together. Finally, other job characteristics may mediate the path from education to mortality, and the mediation may differ by race and gender. One such characteristic may be racial and gender discrimination in and around work (e.g., hiring, performance evaluation, promotion, leave policies). In this study we did not examine specific pathways through which racial or gender inequalities may play out. Future studies with carefully derived hypotheses will greatly contribute to unpacking health inequalities from an occupational perspective.

Conclusion

Glymour and Manly (2018) recently declared that “exploring the possibility of heterogeneous effects of education on health for different groups […] is necessary for progress” (p. 68) in understanding the impact of education on health. They also urged researchers to pursue mechanisms and mediators. Drawing on the fundamental causes of health inequalities, we posited that occupational characteristics would explain the link between education and allcause mortality. Our results suggest different patterns of this link by race and gender: higher education leading to less hazardous jobs reduces mortality in white men, and higher education leading to more complex jobs reduces mortality in both black men and white women. Occupation is an understudied aspect of SEP in the United States. Because jobs are still strongly patterned by race and gender, investigating occupation explicitly in the causal chain of health inequalities will help us better understand the mechanism of and potential solutions for health inequalities.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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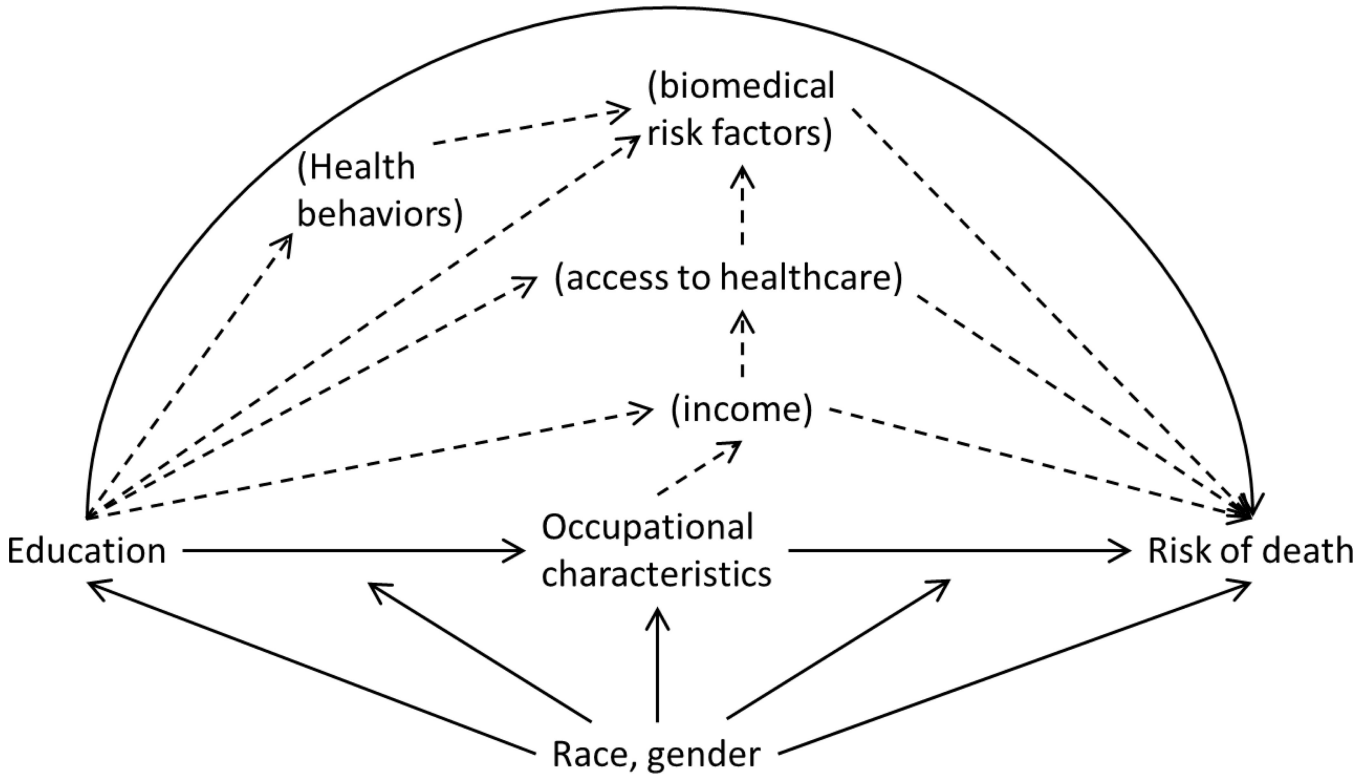

Figure 1.
A conceptual framework for race, gender, education, occupation, and mortality

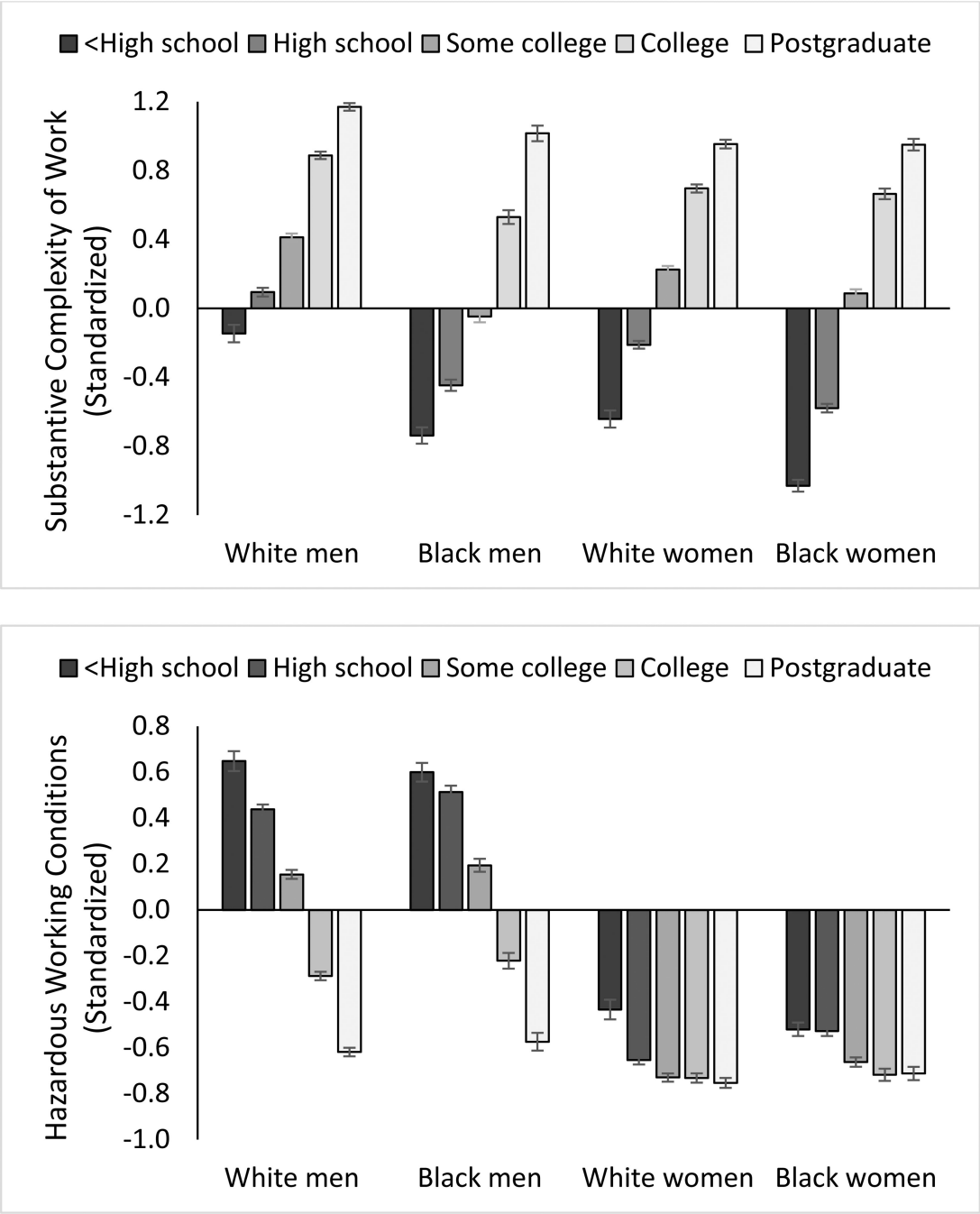

Figure 2.

Mean value and standard error of standardized substantive complexity score (top panel) and hazardous working conditions (bottom panel) by gender, race, and education. Both job characteristic scores are standardized (mean=0, standard deviation=1) relative to all jobs in the US workforce (e.g., a score of 0 = the average level of complexity or hazardousness within all US jobs).

Table 1

Sample characteristics by gender, race, and education

	Men					Women				
	<high school	**High school**	**Some college**	**College**	**Graduate degree**	**<high school**	**High school**	**Some college**	**College**	**Graduate degree**
White										
n	242	982	1204	1344	1307	251	1228	1416	1109	960
Age[1], years, mean (SD)	74.1 (8.6)	72.1 (8.7)	71.2 (8.8)	70.9 (9.0)	71.0 (8.5)	73.2 (9.2)	71.3 (8.8)	69.6 (9.2)	68.5 (9.3)	67.9 (8.5)
Working[1], %	18.2	21.9	30.7	33.0	37.4	11.6	23.1	29.2	34.7	37.7
Living in stroke belt or buckle, %	66.9	57.6	55.6	52.3	45.1	76.5	64.7	62.0	60.0	52.9
Black										
n	279	584	570	391	304	529	996	1081	651	543
Age[1], years, mean (SD)	73.9 (8.9)	69.3 (8.5)	68.8 (8.6)	68.8 (8.8)	71.2 (8.7)	72.5 (8.3)	69.2 (8.4)	67.7 (8.6)	68.3 (8.9)	69.5 (8.9)
Working[1], %	14.0	23.8	28.4	37.1	31.6	16.3	21.5	27.6	32.4	29.1
Living in stroke belt or buckle, %	57.4	52.6	47.0	53.5	46.4	63.5	56.4	48.7	51.5	54.3

[1]*Notes.* At the time of occupational data collection

Table 2

Deaths, person-years, and age-adjusted rate of death (95% confidence interval [CI]) per 1000 person-years by gender, race, and education

	Men					Women				
	<high school	**High school**	**Some college**	**College**	**Graduate degree**	**<high school**	**High school**	**Some college**	**College**	**Graduate degree**
White										
Number of deaths	64	177	192	169	141	44	125	144	74	53
Person-years (pys)	1068.3	4926.3	6101.2	7200.6	7184.7	1172.1	6297.5	7374.1	6148.3	5415.2
Age-adjusted rate per 1000 pys	32.0	22.4	21.1	15.8	13.3	20.0	12.6	14.0	9.2	8.4
(95%CI)	(24.0, 42.7)	(18.2, 27.5)	(17.3, 25.8)	(12.9, 19.4)	(10.7, 16.6)	(14.3, 28.2)	(9.9, 15.9)	(11.2, 17.5)	(7.0, 12.1)	(6.2, 11.4)
Black										
Number of deaths	63	75	78	42	35	87	88	89	45	39
Person-years (pys)	1173.8	2876.9	2877.6	2099.6	1561.3	2435.2	5045.6	5555.2	3483.5	2926.0
Age-adjusted rate per 1000 pys	31.7	20.0	22.1	16.3	15.6	27.6	15.8	16.1	12.3	11.7
(95%CI)	(23.2, 43.3)	(15.0, 26.6)	(16.7, 29.1)	(11.6, 23.1)	(10.7, 22.7)	(21.6, 35.2)	(12.5, 19.9)	(12.8, 20.2)	(9.1, 16.8)	(8.4, 16.4)

Table 3

The hazard ratio (HR) associated with 1-level increase in education (total effect), decomposed into mediated effect (natural indirect effect) and direct effect (natural direct effect) for men

	White men (n=5079)			Black men (n=2128)		
Education levels and effect	**HR**	**(95%CI)**	**% mediated**	**HR**	**(95%CI)**	**% mediated**
Mediator: Substantive complexity of work						
High school graduate vs. <high school						
Natural direct effect	0.91	(0.87, 0.96)		0.97	(0.90, 1.04)	
Natural indirect effect	0.99	(0.96, 1.02)	--[a]	0.98	(0.94, 1.02)	--
Total effect	0.90	(0.85, 0.96)		0.95	(0.88, 1.03)	
Some college vs. high school graduate						
Natural direct effect	0.76	(0.67, 0.87)		0.89	(0.73, 1.08)	
Natural indirect effect	0.98	(0.91, 1.04)	--	0.90	(0.81, 1.00)	44.6%
Total effect	0.74	(0.67, 0.83)		0.80	(0.68, 0.94)	
College graduate vs. some college						
Natural direct effect	0.92	(0.88, 0.95)		0.95	(0.89, 1.01)	
Natural indirect effect	0.99	(0.97, 1.02)	--	0.96	(0.92, 1.00)	41.5%
Total effect	0.91	(0.87, 0.95)		0.91	(0.85, 0.97)	
Graduate degree vs. College						
Natural direct effect	0.92	(0.88, 0.96)		0.94	(0.88, 1.01)	
Natural indirect effect	0.99	(0.96, 1.03)	--	0.96	(0.91, 1.01)	--
Total effect	0.91	(0.87, 0.96)		0.90	(0.83, 0.98)	
Mediator: Hazardous working conditions						
High school graduate vs. <high school						
Natural direct effect	0.93	(0.89, 0.97)		0.92	(0.85, 0.98)	
Natural indirect effect	1.00	(0.97, 1.02)	--	0.99	(0.97, 1.02)	--
Total effect	0.93	(0.88, 0.98)		0.91	(0.84, 0.98)	
Some college vs. high school graduate						
Natural direct effect	0.80	(0.70, 0.91)		0.77	(0.64, 0.93)	
Natural indirect effect	0.95	(0.90, 1.01)	--	1.01	(0.92, 1.10)	--
Total effect	0.76	(0.68, 0.85)		0.78	(0.67, 0.91)	
College graduate vs. some college						
Natural direct effect	0.92	(0.88, 0.95)		0.93	(0.88, 0.98)	
Natural indirect effect	0.98	(0.96, 1.00)	18.4%	1.00	(0.97, 1.04)	--
Total effect	0.90	(0.87, 0.93)		0.93	(0.88, 0.99)	
Graduate degree vs. College						
Natural direct effect	0.91	(0.88, 0.95)		0.93	(0.88, 0.98)	
Natural indirect effect	0.98	(0.95, 1.00)	20.5%	1.01	(0.96, 1.05)	--
Total effect	0.89	(0.85, 0.93)		0.94	(0.87, 1.01)	

Notes. Age, region, and working status at the time of NIOSH module are adjusted for in all models.

[a] %mediated is not calculated because the natural indirect effect is not significant.

Table 4

The hazard ratio (HR) associated with 1-level increase in education (total effect), decomposed into mediated effect (natural indirect effect) and direct effect (natural direct effect) for women

	White women (n=4964)			Black women (n=3800)		
Education levels and effect	**HR**	**(95%CI)**	**% mediated**	**HR**	**(95%CI)**	**% mediated**
Mediator: Substantive complexity of work						
High school graduate vs. <high school						
Natural direct effect	0.98	(0.92, 1.05)		0.93	(0.86, 1.00)	
Natural indirect effect	1.00	(0.97, 1.04)	-- [a]	0.98	(0.94, 1.02)	--
Total effect	0.99	(0.92, 1.06)		0.91	(0.83, 0.98)	
Some college vs. high school graduate						
Natural direct effect	0.92	(0.77, 1.11)		0.80	(0.65, 0.98)	
Natural indirect effect	0.90	(0.82, 0.99)	54.8%	0.96	(0.84, 1.10)	--
Total effect	0.83	(0.72, 0.96)		0.76	(0.66, 0.88)	
College graduate vs. some college						
Natural direct effect	0.94	(0.89, 0.99)		0.93	(0.88, 0.99)	
Natural indirect effect	0.95	(0.92, 0.99)	42.6%	0.99	(0.93, 1.04)	--
Total effect	0.90	(0.85, 0.95)		0.92	(0.86, 0.99)	
Graduate degree vs. College						
Natural direct effect	0.93	(0.88, 0.99)		0.94	(0.88, 1.00)	
Natural indirect effect	0.94	(0.90, 0.99)	44.1%	0.99	(0.93, 1.06)	--
Total effect	0.88	(0.82, 0.94)		0.93	(0.84, 1.02)	
Mediator: Hazardous working conditions						
High school graduate vs. <high school						
Natural direct effect	0.93	(0.89, 0.97)		0.92	(0.88, 0.97)	
Natural indirect effect	1.00	(0.99, 1.00)	--	1.00	(0.99, 1.01)	--
Total effect	0.93	(0.88, 0.97)		0.92	(0.87, 0.97)	
Some college vs. high school graduate						
Natural direct effect	0.80	(0.70, 0.92)		0.78	(0.67, 0.90)	
Natural indirect effect	1.00	(0.98, 1.02)	--	0.99	(0.96, 1.02)	--
Total effect	0.80	(0.70, 0.91)		0.77	(0.67, 0.89)	
College graduate vs. some college						
Natural direct effect	0.93	(0.89, 0.97)		0.92	(0.87, 0.96)	
Natural indirect effect	1.00	(0.99, 1.01)	--	1.00	(0.98, 1.01)	--
Total effect	0.93	(0.89, 0.97)		0.91	(0.87, 0.96)	
Graduate degree vs. College						
Natural direct effect	0.93	(0.89, 0.97)		0.92	(0.87, 0.96)	
Natural indirect effect	1.00	(0.99, 1.01)	--	1.00	(0.98, 1.01)	--
Total effect	0.93	(0.89, 0.98)		0.91	(0.87, 0.96)	

Notes. Age, region, and working status at the time of NIOSH module are adjusted for in all models.

[a] %mediated is not calculated because the natural indirect effect is not significant.