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Research Article

Pathways to Educational Disparities in Disability Incidence: The Contributions of Excess Body Mass Index, Smoking, and Manual Labor Involvement

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Abstract

Objectives: In the United States, educational disparities in disability are large and increasing, but the mechanisms underlying them are not well understood. We estimate the proportion of population-level educational disparities in disability incidence explained by excess body mass index (BMI), smoking, and manual labor.

Method: We use waves 2003–2015 of the nationally representative Panel Study of Income Dynamics to calculate observed disability incidence and counterfactual incidence absent the key mediators (3,129 individuals; 13,168 observations). We take advantage of earlier-life measures, including childhood socioeconomic status, 1986 BMI, and occupational history between 1968 and 2001. To account for distinct processes in women and men at middle versus older ages, we stratify by gender and at age 65.

Results: Educational disparities in disability incidence were evident in women and men at younger and older ages, and were largest among older women. Together, the mediators of interest were estimated to explain roughly 60% of disparities in younger women, 65%–70% in younger men, 40% in older women, and 20%–60% in older men. The main contributors to disparities appeared to be excess BMI and smoking in younger women; manual labor and smoking in younger men; excess BMI in older women; and smoking in older men.

Discussion: These mediators explain much of disparities in earlier-age disability; successful interventions to address these factors may substantially reduce them. However, a considerable proportion of disparities remained unexplained, particularly at older ages, reflecting the myriad pathways by which educational attainment can influence disability status.

Keywords: Functional health status, Health disparities, Obesity, Socioeconomic status, Work-related issues

In the United States, difficulty with activities of daily living and instrumental activities of daily living (ADL/IADL disability, i.e., "disability") is starkly patterned by education (Iezzoni et al., 2014; Schoeni et al., 2005). In a nationally representative study of adults aged 45–89, 21.5% of those without a high school degree reported experiencing ADL disability, compared to just 4.9% of those with a college degree or more (Montez et al., 2017). This gradient seems to be growing in adults at both older and middle ages (Montez et al., 2017; Schoeni et al., 2005; Zajacova and Lawrence, 2018), yet the mechanisms producing it are not well understood (Iezzoni et al., 2014). Compared to disparities in mortality, educational disparities in disability have received little attention. In particular, few empirical studies have examined potential mediators of the education–disability relationship and their respective contributions to disparities.

Educational attainment shapes health throughout the life course via a multifarious and complex set of pathways (Link and Phelan, 1995; Phelan et al., 2010; Zajacova et al., 2012; Zajacova and Lawrence, 2018). Higher educational attainment enables greater access to flexible resources, such as knowledge, power, money, and advantageous social connections, which can be deployed in any setting for the benefit of health (Link and Phelan, 1995). These resources operate at both the individual and contextual levels, influencing the individual behaviors that shape health, such as diet, exercise, and smoking, as well as the contexts an individual occupies, such as work environment—all of which can in turn influence disability risk (Phelan et al., 2010; Zajacova and Lawrence, 2018).

Educational disparities in disability prevalence appear to be growing in adults at both older and middle ages. While ADL/IADL disability prevalence among adults aged 70 and older fell for all educational groups during the 1980s and 1990s, the least educated experienced the smallest decline (Schoeni et al., 2005). Between 2000 and 2015, ADL/IADL disability prevalence among those aged 45–64 stabilized among the most educated and increased among other educational groups (Zajacova and Montez, 2017).

Despite widening disparities, the specific pathways underlying the education–disability relationship remain poorly understood. Excess body mass index (BMI) and smoking may be key mediators (Cutler and Lleras-Muney, 2010; Sainio et al., 2007), but existing research is limited and has a number of important limitations. First, a third mediator and likely confounder, involvement in manual labor (defined here as working as an operative or laborer), has received little attention (Cutler and Lleras-Muney, 2010). Manual labor can increase disability risk through repetitive stress and other mechanisms (Bang and Kim, 2001; Leigh and Fries, 1992; Marmot et al., 1997).

Second, prior research has focused predominantly on older adults, overlooking disparities in disability at middle ages. Yet these groups may exhibit important differences in the trends in and consequences of disability. Disability can have a range of adverse effects on individual well-being, influencing mental health, everyday task independence, role fulfillment, social relationships, finances, and other outcomes (Carr, 1999; Darling, 1987). Its occurrence among those under retirement age may be of particular concern, interfering with the ability to work, take care of children and aging parents, save for retirement, and engage in other activities important in middle life. Moreover, trends in earlier-life disability may differ in direction and magnitude from those in older adults (Martin and Schoeni, 2014; Schoeni et al., 2008). Between 1997 and 2010, for example, ADL/IADL disability prevalence increased among adults younger than 65 years, while decreasing among those aged 65 and older (Iezzoni et al., 2014; Martin and Schoeni, 2014). A more thorough understanding of the trends in and processes underlying earlier-life disability is needed.

Third, the respective roles of excess BMI, smoking, and manual labor in explaining educational disparities in disability incidence likely vary by age, cohort, and gender—due to variation both in the prevalence of the mediators by group, and in the associations among education, the mediators, and disability. For example, prevalence of smoking among women and educational disparities in smoking are greater in more recent cohorts (Escobedo and Peddicord, 1996; Link and Phelan, 2009; Pampel, 2009). In addition, the association between education and BMI is more pronounced in women (Brunello et al., 2013; Kim, 2016), and we might expect the effects of manual labor on disability to manifest predominantly during working ages. Such variations suggest that age–gender groups will differ in the pathways underlying educational disparities.

Fourth, by examining disability prevalence rather than incidence, existing research raises the specters of Neyman bias and reverse causation (Grimes and Schulz, 2002; Mehta, 2015). In Neyman bias, for example, smoking-related mortality results in a healthier observed population of smokers, reducing smoking's estimated effect on disability (Grimes and Schulz, 2002). In reverse causation, disability may lead to reductions in excess BMI or manual labor involvement, making these mediators appear protective in prevalence studies (Mehta, 2015). In addition, related research has typically estimated only mediation percentages, rather than accounting for the mediators' prevalence in the population and, in turn, estimating the percent of disparities they explain at the population level.

To address these gaps in the literature, this study uses the Panel Study of Income Dynamics (PSID) to estimate the contributions of excess BMI, smoking, and manual labor to disparities in incident disability at the population level, stratifying by age and gender. In doing so, we take advantage of life course factors including childhood socioeconomic status, earlier-life BMI, and historical occupation data.

Mediators of the Education–Disability Relationship

Excess BMI

The strong association between educational attainment and BMI, particularly among women, is well documented (Brunello et al., 2013; Kim, 2016). Using sibling data, for example, Kim (2016) finds that those with a college degree have an estimated 0.7-unit lower BMI than high school graduates with no college attendance (Kim, 2016). Less educated groups gain weight more rapidly during adulthood, such that educational disparities in BMI widen throughout much of the life course (Clarke et al., 2009). There is also evidence that BMI can influence educational attainment (Karnehed et al., 2006).

Mediators between education and BMI include health literacy and resources for deploying it, exposure to norms and social support, and stress related to social status, sense of control, and socioeconomic security, among others (for an overview, see Zajacova and Lawrence, 2018). Mediators between excess BMI and disability include higher risk of diabetes, coronary artery disease, and osteoarthritis—all of which can undermine mobility and independence (Samper-Ternent and Al Snih, 2012). The rising prevalence and duration of obesity in the U.S. population may partly explain rising disability rates, particularly in recent cohorts (Iezzoni et al., 2014; Martin and Schoeni, 2014).

Reverse causation, in which illness causes weight loss, can mask the BMI–disability relationship by making higher BMI look protective—particularly in older age, when health declines are more common (Stokes and Preston, 2016). Measurement of BMI at multiple points in the life course may therefore help capture the effects of excess BMI on health (Abdullah et al., 2011; Mehta, 2015).

Smoking

More educated groups may have more economic, cognitive, social, and cultural resources to avoid or quit smoking (Link and Phelan, 1995; Pampel, 2009). While smoking was not clearly patterned by educational status in the 1950s, an educational gradient emerged in the wake of the Surgeon General's Report on Smoking and Health and subsequent attention to smoking's adverse effects. Educational disparities grew as smoking rates declined earlier and more rapidly among the more educated (Escobedo and Peddicord, 1996; Link and Phelan, 2009; Pampel, 2009).

The strong educational gradient in smoking may be due in part to effects of educational attainment on smoking, and in part to common causes such as early-life exposures. Net of familial factors, however, individuals with less than a high school degree appear to make fewer quit attempts and be less likely to quit smoking (Gilman et al., 2008).

Disability rates in more recent cohorts would likely have risen more sharply absent declines in smoking in those groups (Martin and Schoeni, 2014). Smoking predicts disability via greater incidence of musculoskeletal injury (Altarac et al., 2000), higher probability of progression from injury to disability (Lincoln et al., 2003), contribution to cardiovascular and respiratory diseases (Murray and Lopez, 1997), and other pathways (Manouchehrinia et al., 2013). There is evidence of a dose–response relationship between smoking and disability incidence (Claessen et al., 2010), and evidence that cessation can reverse or diminish some adverse health consequences (Lincoln et al., 2003; Manouchehrinia et al., 2013). In addition to the causal effects of smoking on disability, these factors may have common causes, such as health consciousness and underlying mental health (Claessen et al., 2010).

Manual Labor

Manual labor involvement may be a third key mediator of the education–disability relationship (Cutler and Lleras-Muney, 2010). Occupation is starkly patterned by education: less educated individuals have fewer career options and are disproportionately likely to be unemployed or conduct manual labor (Leigh and Fries, 1992). In addition to the likely causal effect of educational attainment on manual labor involvement, these factors may be influenced by common causes such as family socioeconomic status and structural factors that channel educational groups into distinct vocations.

Manual laborers experience higher rates of disability than their counterparts, although research in U.S. populations is limited (Abdullah et al., 2011; Cutler and Lleras-Muney, 2010; Leigh and Fries, 1992; Li, 2000; Månsson, 1998). In the United States, for example, disability is most common among machine operators, farm workers, and laborers (Cutler and Lleras-Muney, 2010; Leigh and Fries, 1992). Manual labor often entails more occupational hazards and repetitive movements than other work, contributing to musculoskeletal injuries and disability (Leigh and Fries, 1992). Lack of job control associated with low-status work may contribute to disability by increasing stress, a risk factor for cardiovascular disease (Marmot et al., 1997). Manual labor may also increase disability risk by perpetuating low socioeconomic status: lower wages and status may impede individuals' ability to invest in their health and transition to a more health-conducive job.

The pathways between manual labor and disability may also include interactions with excess BMI and smoking. Smoking prevalence is higher in manual labor and related jobs (Bang and Kim, 2001), likely reflecting social network effects among other factors (Christakis and Fowler, 2008). Conversely, the physical activity involved in manual labor may promote lower BMI and prevent other adverse effects of more sedentary lifestyles (Rydwik et al., 2013).

Aims

We examine the proportion of educational disparities in disability incidence explained by excess BMI, smoking, and manual labor, independently and jointly. We use nationally representative, longitudinal data with up to seven waves of follow-up, and take advantage of earlier-life measures of socioeconomic status, BMI, and occupation. We compare actual disparities in disability incidence to their estimated counterfactuals in the absence of excess BMI, smoking, and manual labor, enabling estimation of the percentage of disparities explained by each mediator of interest.

We address several important gaps in the literature. To our knowledge, this is the first study to estimate the population-level contributions of three key mediators underlying the education–disability relationship. To account for distinct processes in men and women at middle versus older ages, we stratify by gender and age at exposure to the mediators. Third, whereas prior studies have examined predictors of disability prevalence, we study disability incidence, reducing the risks of Neyman bias and reverse causation.

Methods

Study Population

The PSID is a nationally representative survey that followed participants and their descendants annually from 1968 to 1997 and biennially thereafter (Supplementary Appendix A). Individuals were eligible for the analytic sample if they participated in PSID in 1986 (the earliest wave in which height and weight were reported) and at least two consecutive waves between 2003 and 2015.

Measures

In line with existing literature and PSID recommendations, disability was defined as difficulty with at least one ADL or IADL (Burkhauser et al., 2006; Cutler and Lleras-Muney, 2010; Iezzoni et al., 2014; Laditka and Laditka, 2016; Martin et al., 2010; Martin and Schoeni, 2014; Schoeni et al., 2005). Since 2003, PSID has asked about a standard set of ADLs (difficulty bathing or showering; dressing; eating; getting in or out of a bed or a chair; walking; getting outside; and using or getting to the toilet) and IADLs (difficulty preparing meals; shopping for toiletries or medicines; managing money; using the telephone; doing heavy housework; and doing light housework). Disability incidence was defined as a switch from no disability in wave t–1 to disability in wave t (Supplementary Appendix B).

Excess BMI was measured using two continuous indicators, calculated using self-reported height and weight: 1986 ("earlier-life") BMI and time-varying ("contemporaneous") BMI between 2003 and 2015. To examine associations between excess BMI and disability, these were equal to absolute BMI minus 25 (Mehta et al., 2014; Preston et al., 2013) (Supplementary Appendix C). Smoking history (never, former, current smoker) was time-varying. The manual labor variable was binary and indicated ever having been an "operative" or "laborer" between 1968 and 2001 (Supplementary Appendix D).

Because people may obtain education between waves, this variable was time-varying (less than high school, high school degree, college degree). Obtaining a GED, attending some college, receiving non-academic training after high school, and obtaining an Associate's degree were coded as "high school degree" (Supplementary Appendix E).

We controlled for sociodemographic factors likely to be independently related to education, disability, and the mediators: age (continuous), gender, childhood socioeconomic circumstances ("Were your parents poor when you were growing up, pretty well off, or what?": "poor," "average/it varied," "pretty well off"), race/ethnicity (non-Hispanic white, black, Hispanic non-black, and non-Hispanic other), and year (categorical) (Supplementary Appendix E).

Statistical Analysis

Regression models

Analyses were conducted in Stata 15.0. Logistic regressions, stratified by gender and age at exposure to the time-varying predictors (younger than 65 years vs 65 years and older), predicted disability incidence for up to seven waves of follow-up, between 2003 and 2015 (Supplementary Appendix F). Waves in which a respondent was at risk for disability incidence (i.e., did not currently report disability) were included in regression analyses, with an indicator of whether incidence occurred in the following wave. Individuals could experience multiple incident disability events. In total, 950 observations were excluded due to covariate missingness or extreme values of BMI (<15 and ≥50; 53 observations), driven predominantly by missing mediator data (Supplementary Appendix E). To alleviate reverse causation, all time-varying predictors were lagged one wave. Longitudinal population weights provided by PSID and adjusted to address for selective, non-mortality attrition were applied to obtain nationally representative estimates (Supplementary Appendix F).

Percent of disparities explained by mediators

Following regression, we calculated predictive margins and educational disparities by age–gender group, using the observed distribution of covariates to estimate disability incidence in each age–gender–educational category. Educational comparisons included college versus no high school degree; high school versus no high school degree; and college versus high school degree. We used the same approach to estimate disability incidence and disparities in each subgroup under four counterfactual scenarios: (a) no excess BMI in the population, in 1986 or contemporaneously; (b) no smoking, current or former; (c) no involvement in manual labor; and (d) none of the three risk factors in the population. That is, we set the indicator of the corresponding mediator(s) to zero for the entire sample and calculated the corresponding predictive margins, holding the values of all other covariates as observed. We compared the observed and counterfactual disparities to estimate the percentage of observed disparities explained by the mediators, individually and jointly. Confidence intervals were calculated using the delta method (Oehlert, 1992; Phillips and Park, 1988). These methods were only able to approximate the causal processes of interest and assume no unobserved confounding. For clarity, we use the terms “explained” and “contributed” to describe the estimated proportion of disparities attributable to a given mediator, but these cannot be interpreted to be true causal effects.

Supplementary analyses

First, we examined sedentariness in year of study entry (> 10 min of heavy exercise per week, or not) as a potential mediator in the regressions and re-estimated percentages of disparities explained (Supplementary Appendix G). Concerns about reverse causation precluded inclusion of sedentariness in the main analysis. Second, we examined the ADL and IADL with which participants most often had difficulty: walking and heavy housework. The higher frequency of difficulty with these activities could suggest that distinct processes underlie the ability to conduct them. Third, we examined persistent disability (disability lasting at least two consecutive waves). Fourth, we examined difficulty with ADLs and IADLs separately. Finally, we included additional childhood data—overall health between ages 0 and 16 and maximum parental educational attainment—to account for residual confounding of the mediator–disability relationships.

Results

Descriptive Statistics

Table 1 displays weighted sample characteristics. Disability incidence (i.e., a switch from no disability to disability in the subsequent wave) was evaluated for 3,129 individuals at risk for disability for an average of four to five waves. There were 1,398 cases of incidence. Disability incidence was greater in women (younger women: 4.4 cases per 100 person-years; younger men: 3.0 per 100 person-years; older women: 9.8 per 100 person-years; older men: 8.3 per 100 person-years). The sample was predominantly white (across age–gender groups, white: 80%–89%; black: 4%–14%; Hispanic non-black: 2%–4%; non-Hispanic other: 2%–4%). The majority of respondents had attained a high school degree but not a college degree (younger women: 66%; younger men: 59%; older women: 63%; older men: 54%), and men were more likely than women to have completed college (younger women: 26%; younger men: 34%; older women: 19%; older men: 29%).

BMI was lower in women than men in 1986 (younger women: 23.0; younger men: 25.2; older women: 24.0; older men: 26.1) and at study entry (i.e., the first wave, 2003–2015, present in the analytic sample; younger women: 26.6; younger men: 27.7 women; older women: 25.6; older men: 27.1). BMI increased between 1986 and study entry. Among older individuals, women were less likely than men to have ever smoked (40% vs 67%); this difference was less pronounced in younger individuals (56% vs 53%). Manual labor involvement between 1968 and 2001 was slightly more common at younger ages (younger women: 32%; younger men: 35%; older women: 29%; older men: 25%).

Walking was the most prevalent ADL difficulty and performing heavy housework was the most prevalent IADL difficulty (Supplementary Appendix Figure 1). Others were clustered with similar prevalence. Except in women 65 years and older, education was positively associated with ever having smoked (Supplementary Appendix Table 1; Supplementary Appendix Figure 2). In women, education was negatively associated with excess BMI; it was positively associated with excess BMI in older men. Across groups, education was negatively associated with ever participating in manual labor.

Regressions

Estimated associations between predictors and disability incidence varied by age–gender group (Table 2). Age was positively associated with incidence in all groups and being black (vs non-Hispanic white) was associated with incidence in men. With the exception of older men, higher education was associated with lower incidence, though estimates were not always statistically significant at the $p = .05$ level. Similarly, higher childhood socioeconomic status was associated with lower incidence in all but older women, although estimates were generally not statistically significant at the $p = .05$ level. Higher 1986 BMI, contemporaneous BMI, and smoking tended to be positively associated with incidence. Manual labor was associated with higher odds of incidence in younger men (OR = 1.50, 95% CI: 1.08–2.10).

Disparities in Disability Incidence and Estimated Percent Explained

Educational disparities in disability incidence were evident in both men and women (Figure 1). With the exception of older men, where incidence was higher among those with a college degree than those with a high school degree, incidence decreased with greater educational attainment. Larger disparities were observed among women than men, and this gender difference was most pronounced among the least educated. Among older men, disability incidence was slightly higher in those with a college degree than those with a high school degree; mediator contributions were therefore not calculated for this comparison.

Overall, excess BMI, smoking, and manual labor were estimated to explain a greater percentage of disparities in younger compared to older adults (younger women: 58%–62%; younger men: 65%–72%; older women: 38%–39%; older men: 20%–60%), although estimates did not reach statistical significance at the $p = .05$ level

Table 1. Sample Characteristics by Age Group and Gender

	Younger Than 65				65 and Older			
	Women		Men		Women		Men	
	Est.	95% CI	Est.	95% CI	Est.	95% CI	Est.	95% CI
Unique individuals	1,352	–	1,106	–	382	–	289	–
Waves at risk for disability, mean	4.0	–	4.2	–	4.5	–	5.1	–
Incidence, cases	492	–	300	–	354	–	252	–
Incidence, per 100 person-years	4.4	3.9–4.9	3.0	2.6–3.5	9.8	8.7–11.0	8.3	7.1–9.4
Characteristics at study entry								
Age, mean, years	50.2	49.7–50.6	50.4	49.9–50.8	73.9	73.2–74.6	72.5	71.8–73.2
BMI in 1986, kg/m^2								
Mean	23.0	22.8–23.3	25.2	25.0–25.5	24.0	23.6–24.5	26.1	25.7–26.6
Overweight or obese, %	23.0	20.5–25.7	48.6	45.3–51.9	30.1	25.3–35.3	60.1	54.1–65.8
Obese, %	7.3	5.8–9.1	9.5	7.7–11.6	7.0	4.7–10.2	11.5	8.2–15.8
BMI at study entry, kg/m^2								
Mean	26.6	26.3–27.0	27.7	27.5–28.0	25.6	25.1–26.1	27.1	26.6–27.5
Overweight or obese, % (BMI ≥ 25.0)	52.7	49.6–55.8	76.0	73.1–78.7	47.0	41.6–52.5	66.2	60.4–71.6
Obese, %	23.4	20.9–26.1	24.8	22.1–27.7	13.3	10.0–17.4	19.2	14.8–24.5
Smoking, %								
Never	54.2	51.0–57.3	47.2	43.9–50.5	59.8	54.3–65.1	32.5	27.2–38.4
Former	26.4	23.7–29.3	28.9	26.1–32.0	31.6	26.7–37.0	61.6	55.7–67.3
Current	19.4	17.1–22.1	23.9	21.2–26.8	8.5	5.9–12.2	5.8	3.6–9.2
Manual labor, %	32.4	29.5–35.4	35.3	32.3–38.5	28.9	24.2–34.1	25.2	20.4–30.6
Race/ethnicity, %								
Non-Hispanic white	79.9	77.3–82.2	88.7	86.5–90.5	85.1	80.6–88.7	88.7	83.9–92.2
Black	13.9	12.0–16.0	7.6	6.2–9.2	9.7	6.9–13.3	4.0	2.2–7.1
Hispanic non-black	4.2	3.0–5.9	2.1	1.2–3.5	3.0	1.5–6.0	3.1	1.5–6.2
Non-Hispanic other	2.0	1.3–3.2	1.7	0.9–3.2	2.2	5.3	4.3	2.1–8.3
Educational attainment, %								
Less than high school	8.2	6.7–10.0	7.3	5.9–9.1	17.4	13.5–22.1	16.8	12.9–21.7
High school degree	66.3	63.3–69.2	59.2	55.9–62.3	63.6	58.1–68.8	54.0	48.0–59.8
College degree	25.5	22.8–28.3	33.5	30.5–36.7	19.0	15.0–23.7	29.2	24.1–35.0
Childhood SES								
Poor	28.8	26.1–31.7	19.5	17.1–22.2	47.0	41.5–52.5	46.8	40.9–52.8
Average/it varied	52.6	49.5–55.7	49.6	46.4–52.9	43.0	37.7–48.5	39.3	33.6–45.2
Well off	18.6	16.3–21.2	30.8	27.9–33.9	10.1	7.1–14.0	13.9	10.3–18.6
Calendar year, mean	2003.6	2003.5–2003.7	2003.3	2003.2–2003.4	2004.0	2003.8–2004.2	2003.6	2003.4–2003.8

Note: BMI = body mass index; SES = socioeconomic status. Estimates are weighted. Overweight refers to BMI ≥25.0 and obese to BMI ≥30.0.

Table 2. Odds Ratios, Logistic Regressions on Disability Incidence, Age-Stratified

	Younger Than 65		65 and Older	
	Women	Men	Women	Men
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
BMI, contemporaneous	1.049** (1.017–1.082)	1.028 (0.988–1.069)	1.150*** (1.086–1.217)	1.020 (0.952–1.094)
BMI, 1986	1.077** (1.023–1.134)	1.089*** (1.036–1.144)	0.951 (0.874–1.035)	1.063 (0.987–1.145)
Smoking				
Never	Ref.	Ref.	Ref.	Ref.
Former	1.343* (1.001–1.801)	1.096 (0.754–1.594)	1.357 (0.984–1.871)	1.643** (1.143–2.361)
Current	1.851*** (1.307–2.621)	1.638* (1.102–2.436)	1.145 (0.638–2.056)	2.015 (0.923–4.399)
Manual	1.05 (0.784–1.407)	1.504* (1.075–2.104)	1.162 (0.819–1.647)	1.111 (0.734–1.680)
Age	1.052*** (1.028–1.076)	1.042** (1.014–1.071)	1.103*** (1.076–1.130)	1.088*** (1.058–1.119)
Race/ethnicity				
Non-Hispanic, white	Ref.	Ref.	Ref.	Ref.
Black	1.148 (0.833–1.582)	1.794** (1.193–2.697)	0.657 (0.369–1.170)	3.114** (1.355–7.154)
Hispanic, non-black	1.815 (0.902–3.655)	0.304 (0.043–2.156)	0.646 (0.202–2.068)	1.469 (0.557–3.871)
Non-Hispanic, other	0.624 (0.207–1.879)	2.189 (0.979–4.894)	0.666 (0.243–1.823)	0.716 (0.247–2.078)
Education				
Less than high school	Ref.	Ref.	Ref.	Ref.
High school degree	0.727 (0.454–1.165)	0.708 (0.400–1.251)	0.753 (0.455–1.245)	0.98 (0.605–1.588)
College degree	0.565* (0.324–0.986)	0.525* (0.276–0.997)	0.694 (0.385–1.251)	1.375 (0.756–2.503)
Childhood SES				
Poor	Ref.	Ref.	Ref.	Ref.
Average/varied	0.879 (0.662–1.167)	0.926 (0.641–1.336)	1.004 (0.731–1.380)	0.785 (0.547–1.126)
Well off	0.746 (0.514–1.082)	0.762 (0.471–1.235)	1.111 (0.669–1.844)	0.460* (0.246–0.859)
Year				
2003	Ref.	Ref.	Ref.	Ref.
2005	0.826 (0.576–1.184)	1.051 (0.656–1.684)	0.776 (0.483–1.245)	0.895 (0.541–1.482)
2007	0.802 (0.564–1.142)	1.046 (0.660–1.657)	1.084 (0.693–1.694)	0.832 (0.526–1.317)
2009	1.014 (0.712–1.444)	1.266 (0.804–1.996)	0.953 (0.597–1.522)	0.793 (0.478–1.316)
2011	1.000 (0.677–1.476)	1.707* (1.027–2.838)	1.036 (0.649–1.652)	0.667 (0.392–1.133)
2013	0.850 (0.538–1.343)	1.419 (0.832–2.423)	0.854 (0.512–1.424)	0.915 (0.552–1.517)
Constant	0.007*** (0.002–0.025)	0.005*** (0.001–0.026)	0.000*** (0.000–0.001)	0.000*** (0.000–0.003)
Observations	5,388	4,615	1,704	1,461

Notes: BMI = body mass index; SES = socioeconomic status.
*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

in older men (Table 3). In younger women, smoking and excess BMI appeared to be the main contributors to disparities (smoking: 21%–30%; excess BMI: 36%–39%), while in younger men, the main contributors appeared to be smoking and manual labor (smoking: 23%–35%; manual labor: 33%–38%). In older women, excess BMI appeared to be the main contributor to disparities (30%). While confidence estimates for older men were wide, smoking appeared to be the main contributor to disparities; higher BMI appeared to suppress educational disparities, reflecting lower average BMI among the least compared to more educated older men.

Supplementary Appendix Tables 2–6 and appendix text provide results of the supplementary analyses. When two additional early-life measures, childhood health and parental education, were included in the model, the overall pattern of percent explained results remained consistent, while two sets of point estimates shifted: in younger men, the estimated contribution of manual labor to disparities fell by 5–9 percentage points; in older women, the estimated contribution of excess BMI rose by 9–18 percentage points (Supplementary Appendix Table 6).

Discussion

This study was the first to estimate population-level contributions of three key mediators of educational disparities in disability incidence among both younger and older women and men. We took advantage of seven waves of nationally representative, longitudinal data on ADL/IADL disability, combined with information on life course factors

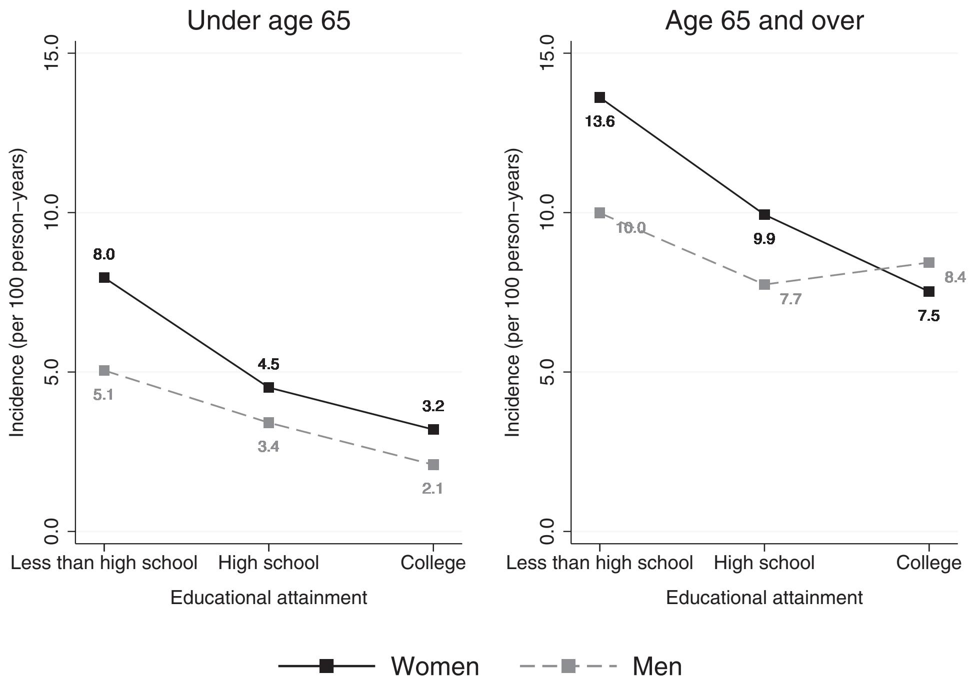

Figure 1. Disability incidence by age, gender, and education.

Table 3. Percent of Educational Disparities Explained by Mediators

	Women (95% CI)			Men (95% CI)		
	Most vs Least	Middle vs Least	Most vs Middle	Most vs Least	Middle vs Least	Most vs Middle
Younger than 65						
Observed disparity*	4.8 (1.6–7.9)	3.5 (0.4–6.5)	1.3 (0.3–2.4)	3.0 (0.6–5.3)	1.7 (−0.7 to 4.0)	1.3 (0.5–2.2)
Percent explained						
Smoking	23.1 (9.3–36.8)	20.5 (6.2–34.8)	29.8 (8.9–50.6)	29.5 (2.3–56.7)	34.5 (−2.0 to 70.9)	23.2 (−2.3 to 48.8)
Excess BMI	37.8 (18.3–57.2)	38.6 (13.6–63.5)	35.6 (14.4–56.9)	15.0 (2.0–28.0)	5.6 (−19.3 to 30.6)	26.7 (10.4–42.9)
Manual	4.0 (−19.5 to 27.5)	3.8 (−18.3 to 25.9)	4.5 (−22.8 to 31.8)	35.1 (5.9–64.3)	32.7 (1.3–64.0)	38.2 (4.8–71.6)
All	58.2 (33.3–83.0)	56.8 (29.9–83.8)	61.8 (25.2–98.4)	64.7 (36.0–93.4)	68.9 (26.7–91.0)	72.0 (37.6–106.4)
65 and older						
Observed disparity (per 100 person-years)	6.1 (1.8–10.4)	3.7 (−0.4 to 7.7)	2.4 (−0.2 to 5.0)	1.5 (−2.0 to 5.1)	2.3 (−1.1 to 5.6)	−0.7 (−3.2 to 1.8)
Percent explained						
Smoking	0.0 (−7.2 to 7.1)	−2.0 (−13.6 to 9.6)	3.0 (−8.1 to 14.2)	56.3 (−40.7 to 153.2)	20.5 (−2.6 to 43.5)	N/A
Excess BMI	29.9 (5.0–54.8)	30.1 (−6.5 to 66.8)	29.5 (1.5–57.6)	−17.3 (−81.2 to 46.6)	13.4 (−52.7 to 25.8)	N/A
Manual	10.2 (−14.1 to 34.4)	11.7 (−17.7 to 41.2)	7.8 (−11.3 to 26.9)	27.2 (−93.2 to 147.5)	11.2 (−33.5 to 55.9)	N/A
All	38.3 (8.3–68.3)	38.7 (−2.1 to 79.6)	37.7 (5.8–69.6)	60.4 (−58.0 to 178.7)	19.9 (−27.5 to 67.3)	N/A

Note: BMI = body mass index. "Least" education = less than high school degree; "middle" = high school degree; "most" = at least a college degree. * Per 100 person-years. N/A indicates that no mediator contribution was calculated because disability incidence was higher in the more compared to the less educated group.

including childhood socioeconomic circumstances, earlier-life BMI, and occupational history. Educational disparities in disability were evident among both younger and older adults (under 65, 65 and over) and were larger in women. Together, excess BMI, smoking history, and manual labor involvement appeared to account for roughly 60%–70% of disparities in disability incidence under age 65. Among women aged 65 and older, these factors tended to account for nearly 40% of educational disparities. Estimates in older men were more variable; while confidence intervals were large and overlapped with zero, the mediators were estimated to explain 60% of the disparity between older men with a college degree and those without a high school degree, and only 20% of the disparity between those with a college degree and those with a high school degree.

The stronger contribution of smoking to disparities in younger compared to older women likely reflects the growing prevalence and educational gradient in smoking in recent decades (Escobedo and Peddicord, 1996; Link and Phelan, 2009; Pampel, 2009). Smoking also appeared to explain more of the educational disparity in disability among men, a product of the starker educational gradient in smoking among men compared to women.

Conversely, excess BMI appeared to contribute more to educational disparities among women. This finding was related to the more consistent relationship between education and BMI among women. Indeed, contemporaneous BMI was higher among men with a high school degree than their more and less educated counterparts. This is consistent with prior research (Brunello et al., 2013; Kim, 2016), and may relate to findings that education predicts exercise and employment more strongly in women, factors inversely related to excess BMI (Brunello et al., 2013). Moreover, larger educational disparities in smoking and manual labor among men, factors inversely related to weight, may suppress an educational gradient in BMI in this group (Rydwik et al., 2013).

Ever conducting manual labor appeared to be a key driver of disparities in young men. It appeared to contribute less in older adults, although these differences were not statistically significant. The apparent differential by age may suggest that manual labor's effect on disability is most pronounced during working ages, although our study is not conclusive in this regard. While prevalence of and educational disparities in manual labor involvement were considerable in younger women, manual labor's estimated contribution to disparities in disability incidence was not significantly different from zero. This may suggest that women and men coded as "laborers" or "operatives" conduct substantively distinct types of work, with differential consequences for disability. More research on the contribution of manual labor to disability by gender and throughout the life course is warranted. More broadly, numerous dimensions of socioeconomic position—income, prestige, power, and others—that do not map one-to-one onto manual labor involvement likely contribute to educational disparities in disability. Additional research is needed to further elucidate these pathways.

The three mediators of interest appeared to explain less of disparities in the older group than in the younger group. Biological frailty may help explain this gap: more educated individuals, who on average have more financial resources, may be better able to manage growing frailty at older ages—for example, installing home infrastructure to prevent falls and, when a fall does occur, obtaining support to reduce the risk of developing a disability.

Because each age group comprised individuals from different birth cohorts, both age and cohort processes are likely combining to produce the patterns we observed. Increased educational attainment in more recent cohorts, resulting in compositional changes to the educational groups compared here, represents one important cohort effect (Dowd and Hamoudi, 2014). The consequences of attaining a given educational status for work, income, status, and other factors have also changed over time. These forces may help explain shifting educational disparities in the mediators of interest, and in turn differences in the mediators' contribution to disparities. For example, growing disparities in smoking in more recent cohorts may have in part resulted from compositional changes in educational groups, in which people more likely to smoke are increasingly concentrated in less educated groups. Because we are unable to distinguish these and other cohort effects from age effects, we can neither draw conclusions about changes in education's impact on disability over time nor make projections about the mediators' contributions to disparities as the younger adults in this study age. Research examining multiple birth cohorts over time is needed to untangle these effects.

Reflecting the unique disadvantage of not obtaining a high school degree, disparities between the most and least educated tended to be largest, followed by those between the middle and least educated. Moreover, despite strong associations between education and the mediators, substantial disparities were left unexplained after accounting for them—a product of the myriad pathways by which limited education can influence health, and which we were unable to account for. These might include persistent stress, environmental exposures, neighborhood resources, social influence, unstable housing, unemployment, unstable employment, and others (Bambra and Eikemo, 2009; Baum et al., 1999; Burgard et al., 2012; Christakis and Fowler, 2008; Glass et al., 2006). Therefore, while successful behavioral interventions may reduce disparities in disability, they alone are not sufficient. Broad-based policies that improve access to quality education are also needed (Link and Phelan, 1995).

Separate examination of ADLs, IADLs, and the two most common manifestations of ADL/IADL disability (difficulty walking and conducting heavy housework) did not meaningfully change our conclusions. In a supplementary analysis of persistent disability, defined as disability lasting at least two waves, the estimated percentage of disparities explained in women grew, driven in younger women by a larger estimated contribution of manual labor. Exposure to manual labor may be associated with musculoskeletal injuries that contribute to earlier-life and prolonged disability spells.

This study has limitations. First, comparisons between mediators and across age–gender groups of the percent of disparities explained were complicated by imprecise estimates, particularly in older adults. We reported apparent trends between groups or mediators, but were often unable to reject the null hypothesis of no difference at an alpha of .05. Despite the strengths afforded by our longitudinal data, reverse causation remains a challenge. We attempted to address this by including 1986 BMI in addition to contemporaneous BMI, providing a measure less related to concomitant health decline. As our analyses reflected, earlier-life BMI predicts health outcomes independent of baseline or contemporaneous BMI (Abdullah et al., 2011; Mehta et al., 2014). To further address reverse causation, we lagged BMI and smoking by one wave (2 years), and fixed the measure of ever having participated in manual labor to 2001, the wave prior to initiation of analysis. Reverse causation concerns precluded inclusion of one potential mediator of disparities: unemployment. Unemployment is strongly related to disability (Leigh and Fries, 1992; Månsson, 1998), but much of this relationship may be due to the effects of disability on unemployment.

Selection into educational attainment is nonrandom and is shaped, for instance, by early-life factors such as childhood socioeconomic status, parental education, and childhood health. Our aim, however, was not to identify the suite of factors that determine educational attainment. Rather, it was to understand the mechanisms that link educational attainment to disability. Nonetheless, these early-life factors may also be correlated with occupational exposure, behavioral factors, and disability, independent of educational attainment. To minimize bias from such confounding in our estimates, we included a measure of childhood socioeconomic status in the regression models. In a sensitivity analysis, we included two additional early-life indicators—childhood health and parental education—which decreased the estimated contribution of manual labor in younger men and increased that of excess BMI in older women. While these covariates may help reduce residual confounding of the relationships of interest, controlling for many antecedents of education arbitrarily limits the estimated effects of education to those resulting from the subset of determinants that remain. The optimal balance between addressing confounding and controlling away the antecedents of education can be unclear.

Our measure of whether the participant had ever conducted manual labor was imperfect. We likely underestimated manual labor involvement among the older group due to incomplete data on their working years: when PSID began in 1968, individuals in the older group were already 30–58 years old, so some manual labor involvement was likely missed. Second, while some domestic work may contribute to disability via manual labor, we did not capture such work, as it was not clear how to categorize more versus less physically demanding household tasks described by PSID's occupation variable. This could lead to underestimation of disability related to manual labor, particularly in women (Leigh and Fries, 1992). Third, missingness in the occupation variable may have resulted in misclassification of some individuals as "never manual"; this would also result in conservative estimates of manual labor's contribution to disparities.

While evidence suggests that excess BMI can itself contribute directly to disability incidence (Samper-Ternent and Al Snih, 2012), it may also function as a proxy for other important risk factors such as exercise. However, in the supplementary analysis in which sedentariness in the year of study entry was included as a potential mediator, the estimated contribution of excess BMI to disparities fell by only 0–4 percentage points, suggesting our main estimates for excess BMI are not merely capturing the effects of sedentariness on disability.

Against a backdrop of population aging and widening educational disparities in disability, this study provides important insight into the mechanisms underlying those gaps. Our findings suggest that excess BMI, smoking, and manual labor explain roughly 60% of disparities in younger women, 65%–70% in younger men, 40% in older women, and 20%–60% in older men. The main contributors to disparities appeared to be excess BMI and smoking in younger women; manual labor and smoking in younger men; excess BMI in older women; and smoking in older men. Further research is needed to account for the proportion of disparities left unexplained and to better characterize the ways in which the mediators of interest translate into health conditions and, ultimately, disability.

Supplementary Material

Supplementary data are available at *The Journals of Gerontology, Series B: Psychological Sciences and Social Sciences* online.

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Conflict of Interest

None declared.

Author Contributions

T. Townsend planned the study, conducted all data management and analysis, and wrote the manuscript. N. K. Mehta planned the study, oversaw data analysis, and contributed to revising the manuscript.

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