Title: Differential returns to state-level educational quality in cardiovascular health by race: early-life exposures and late-life health

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PAA Abstract (150 words)

Cardiovascular disease (CVD) is strongly patterned by educational attainment, however, educational quality is rarely examined. We examine relationships between state-level educational quality and CVD, and test for heterogeneities by race. Health and Retirement Study respondent data were linked to a state-level composite educational quality index, comprised of school term length, student-to-teacher ratio, and per-pupil expenditures. Race/ethnicity was White, Black, and Hispanic. Analysis models predicting self-reported (N=23,045) and objectively measured (N=8,925) CVD outcomes were adjusted for individual and state-level confounders; heterogeneities were evaluated using educational quality by race interaction terms. There was little relationship between educational quality and CVD outcomes overall or among Whites. Among Blacks, higher state-level educational quality predicted poorer heart disease ever-smoking, uncontrolled blood pressure, and stroke outcomes, but lower obesity; patterns were similar among Hispanics. Higher state-level educational quality was associated with both better and worse cardiovascular outcomes among minorities; research examining mechanisms is warranted.

Introduction

Cardiovascular disease (CVD) is a leading cause of morbidity and mortality in the United States, with minorities disproportionately affected[1–4]. While extensive work has characterized these racial disparities[1,4,5], there is limited evidence on root causes; as such, scalable, population-level solutions to address racial disparities in CVD have not yet been identified[6].

A promising mechanism to reduce disparities in CVD is through educational interventions. For example, eligibility for the college education subsidies provided by the Korean War and Vietnam War GI Bills is associated with smaller socioeconomic disparities among veterans compared to non-veterans in markers of mental[7], physical[8], and cognitive[9] health. Similarly, a randomized high-quality preschool intervention resulted in better cardiovascular and metabolic outcomes for intervention children compared to controls (outcomes assessed in participant's mid-30s)[10].

There are several pathways through which education may influence health overall, and CVD specifically. Those with more education have better access to health promoting resources such as living in better neighborhoods[11], access to healthy food[12], medication, and healthcare, as well as more salubrious health behaviors and social norms around exercise[13] and smoking[14], benefitting cardiovascular health[15–17]. Those with more education also report less discrimination[18]; less stress and discrimination may be protective for a variety of cardiometabolic risk factors[19]. There is also evidence that these relationships differs by race[20]; among Blacks, for example, those with more education report more discrimination[18], indicating there may be heterogeneities in the relationships between education and CVD outcomes.

The literature on education and CVD to date has focused almost exclusively on years of schooling (i.e. quantity of education); for example, a recent meta-analysis suggested that compulsory schooling laws, which mandate additional years of K-12 schooling, resulted in improvements in CVD and related risk factors across multiple country settings[21]. Although a relatively small literature examines educational quality and CVD[10,22], prior work suggests educational quality may be an important target for intervention in efforts to reduce disparities.

Diverse educational quality measures, including school term length, student-to-teacher ratio, and per-pupil expenditure have been associated with higher educational attainment[23] and earnings[24,25], with low-income and

minority students benefitting more[23,26–28]. In terms of health outcomes, longer term length (which is thought to indicate better quality) has been associated with lower hypertension[22] and mortality[29], and better cognitive function[30], while lower student-to-teacher ratio (better quality) is associated with better cognitive function[30], and higher teacher pay (better quality) is associated with lower mortality[29]. There is also evidence of heterogeneities by race such that Black women in particular benefit from better educational quality in predicting hypertension[22]. However, other work found lower student-to-teacher ratio (better quality) led to higher mortality through age 29, indicating the potential for unintended negative consequences[31].

We examine the association between state-level educational quality and a variety of diverse CVD outcomes and risk-factors, using a large sample of U.S. older adults, and test for differential effects by race. The state is an appropriate and relevant level to evaluate educational quality as quality improvement programs and policies around class size[31,32] and teacher tenure[33] have been enacted by state legislatures. Because improving educational quality is an active area of policymaking in the U.S., this work has important implications for understanding the long-term health consequences of such policies.

Methods

Sample

Data came from the 1992-2014 waves of the U.S. Health and Retirement Study, a longitudinal, biennial sample of adults aged 50 years and older and their spouses. Analyses were restricted to individuals born in the U.S. as we used birth state to link individuals to average state-level educational quality markers. Educational quality data were collected in prior studies from state and federal educational reports[34], and these were linked to respondents born 1900 -1951 for term length and student-to-teacher ratio, and respondents born 1901-1937 for per-pupil expenditure. We included both self-reported (N = 23,045; years: 1992 - 2014), and objectively measured (N = 8,925; years: 2006 - 2014) outcome data in these analyses; objectively measured outcome data were collected from 2006 onwards, resulting in smaller sample size for these outcomes. Covariate information was not missing for any individuals with outcome data. Ethics approval was provided by the institutional review board of the University of California, San Francisco.

Exposure

We created a composite measure of state-level educational quality from data on average state-level term length, student-to-teacher ratio, and per-pupil expenditure. All three quality measures were assessed when the respondent was 6 years old and matched to the respondent's state and year of birth. Per-pupil expenditure data was inflation adjusted to 1982-1984 dollars.

All three quality measures were normalized to a mean of zero and a standard deviation of one (standardized). One standard deviation corresponds to 13 days of term length, 5 students per teacher, and $270 in per-pupil expenditures (in 1982-1984 dollars). We reverse-coded student-to-teacher ratio so it would be consistent with the other exposure variables, i.e., higher values indicating higher quality, then averaged the three quality measures to create a composite quality index; if data were missing for one or more measures, the remaining measures were averaged. We normalized the composite measure to a mean of zero and standard deviation of one for interpretability.

Educational policies are often enacted at the state-level (e.g. interventions on class size[31,32] and teacher tenure[33]). Partially due to these state-level policies, K-12 educational quality varies widely across states; these variations in quality are considered a primary reason for historical state-level variations in graduation rates[35] and current variations in test scores[36]. While there are important and meaningful educational quality differences within states[30], because funding and quality improvement decisions are also made at the state-level, the state is an appropriate and relevant level to evaluate educational quality.

Outcomes

We included both self-reported and objective measures of CVD and related risk factors, as the effect of state-level educational quality may vary by mechanistic pathway (e.g., health behavior pathway vs. stress pathway). The self-reported outcomes, assessed biennially from 1992 onwards, were self-reported doctor's diagnosis of hypertension, diabetes, heart disease, and stroke, as well as self-reported obesity (calculated from self-reported height and weight), and history of ever smoking. The objectively measured outcomes, assessed every four years for a random half of the sample each year from 2006 onwards[37,38], were uncontrolled

hypertension (systolic blood pressure > 140 or diastolic blood pressure > 90), uncontrolled diabetes (hemoglobin A1c >= 6.5), high-density lipoprotein cholesterol (HDL, i.e., "good cholesterol"), total cholesterol, and C-reactive protein (CRP, a marker of inflammation). We used the natural log of CRP to address skewed values.

We considered three different operationalizations for the dichotomous outcomes (all self-reported outcomes, uncontrolled hypertension, and uncontrolled diabetes): 1) ever having the disease (i.e. ignoring the information on timing); 2) repeated measures (i.e. longitudinal generalized estimating equations); and 3) incidence coding (where prevalent cases were considered "incident" at the time of follow up; we coded this by using age as the time scale and setting the entry time as the age before the individual began the study). Results were similar across operationalizations; to reduce to possibility of selection bias and to improve statistical efficiency, we present results from the incidence models in this paper. Dichotomous outcomes were coded as 0 until disease onset, with disease onset coded as 1; once the respondent had the disease, they were no longer included in the analysis; individuals who died or were loss to follow up were censored at their last observation.

Effect modifier

We evaluated race as a potential effect modifier. Race was a four-category variable: non-Hispanic White (ref), non-Hispanic Black, Hispanic, and other race / missing. Those considered other race or missing were included in the analysis to improve statistical efficiency, however, we do not present or discuss these results due to small sample size and ambiguity in interpretation.

Covariates

We adjusted all models for individual-level and state-level confounders. Individual-level confounders were gender and a cubic spline for birth year to adjust for secular trends in schooling. Age was the time scale in both the survival and longitudinal models, discussed below; age and age-squared were also included in the longitudinal models. State-level confounders were percent urban, percent foreign born, percent Black, manufacturing jobs per capita, and average manufacturing wages (inflation adjusted to 1982-1984 dollars). We additionally included state-of-birth "fixed effects" (i.e., indicator variables) to account for time-invariant state characteristics.

Analysis

For the dichotomous outcomes (coded as incidence of disease, discussed above), we conducted survival analysis (Cox regressions), and adjusted for all individual-level and state-level confounders. For continuous outcomes, we used generalized estimating equations (GEE) with an exchangeable correlation structure. Model 1 adjusted for educational quality, race, and all individual-level and state-level confounders. To examine heterogeneities by race, Model 2 additionally included race by educational quality interaction terms. As it is difficult to interpret interactions on the hazard ratio scale (because the main effect and interaction hazard ratios must be multiplied to get the appropriate effect estimates for each subgroup), we ran the interaction models three times for each outcome with each of the three racial groups (White, Black, Hispanic) as the reference group; this allowed us to get an interpretable hazard ratio, as well as a confidence interval, for the relationship between state-level educational quality and CVD outcomes for each racial group. In sensitivity analyses, we examined each quality measure as independent predictors to determine if our results were driven by any single quality marker. The standard errors for all models were clustered at the state level to account for correlated observations. All analyses and data cleaning were performed using Stata 14.

Results

Sample Characteristics

Respondents were born in the 1930s on average and over half were female (> 54%). Black respondents lived in states with a lower proportion of urban residents, more foreign-born residents, a higher proportion of Black residents, and lower manufacturing wages. Black respondents also lived in states with poorer state-level educational quality than White or Hispanic respondents. More than half of the respondents developed high blood pressure, but Black respondents were most likely to have uncontrolled blood pressure. White respondents were most likely to have doctor-diagnosed heart disease, while Black respondents were more likely to report stroke, and obesity. Hispanics were most likely to report diabetes, but Black and Hispanic respondents reported similar proportions of uncontrolled diabetes. Smoking was equally common across racial groups.

Main Effects

In the overall sample (Figure 1; Appendix Table 5, Model 1), better state-level educational quality was associated with lower obesity (HR = 0.90, 95%CI: 0.84, 0.96), and lower ln(CRP) (β = -0.08, 95%CI: -0.15, -0.01). There was no overall relationship between state-level educational quality and the remaining CVD outcomes and risk factors

Effects by Race

In interaction analyses, we examined whether the association between state-level educational quality and CVD differed by race. Among Blacks (Figure 1), better educational quality was associated with better CVD health for obesity (Black HR = 0.90, 95%CI: 0.84, 0.96), but worse CVD health for heart disease (Black HR = 1.09, 95%CI: 1.03, 1.17), ever smoking (Black HR = 1.14 95%CI: 1.05, 1.23), stroke (Black HR = 1.20, 95%CI: 1.07, 1.34), and uncontrolled diabetes (Black HR = 1.25, 95%CI: 1.01, 1.56). The relationship between state-level educational quality different among Blacks and Whites in predicting diabetes, heart disease, stroke, ever smoking, and HDL cholesterol (Appendix Table 1, Model 2).

Among Hispanics (Figure 1), better educational quality was associated with better CVD health for obesity (Hispanic HR = 0.73, 95%CI: 0.63, 0.84), but worse CVD health in terms of uncontrolled blood pressure (Hispanic HR = 1.20, 95%CI: 1.01, 1.42). The relationship between educational quality different among Blacks and Whites in predicting high blood pressure (self-reported), and obesity (Appendix Table 1, Model 2).

Results were substantively similar across sensitivity analyses examining each measure of state-level educational quality separately. Higher state-level educational quality as operationalized by student to teacher ratio was particularly aversive for Blacks (Appendix Table 2, Model 2), while higher state-level educational quality as operationalized by term length was aversive for both Blacks and Hispanics (Appendix Table 3, Model 2). Higher state-level educational quality as operationalized by per-pupil expenditure predicted uncontrolled diabetes overall, and among Whites (Appendix Table 4, Models 1 and 2).

Discussion

We examined the relationships between state-level educational quality and several CVD outcomes and risk factors and tested for heterogeneities by race. We found that state-level educational quality had little

relationship with cardiovascular outcomes overall or among Whites. Among Blacks, however, better state-level educational quality predicted poorer CVD health in terms of heart disease, ever smoking, and stroke, but predicted better CVD health in terms of obesity. Similarly, among Hispanics, better educational quality predicted poorer CVD health in terms of uncontrolled blood pressure, but better CVD health in terms of obesity. These relationships were largely consistent across numerous sensitivity analyses. Our work adds to the growing literature finding evidence of heterogenous treatment effects in the relationship between education and health outcomes among sociodemographic subgroups[20,22].

Our results suggest that the mechanistic pathway from state-level educational quality to CVD varies by both race and disease process. State-level educational quality may be linked to better CVD outcomes such as lower obesity through better health behaviors (Figure 2). Those with better educational quality typically go on to attain more schooling[39,40], which in turn can lead to better health behaviors, such as eating heathier foods[12] and exercising more[13], possibly due to increased knowledge and empowerment[41] and / or living in areas with better access to nutritious food[42] and more salubrious social norms[43]. Both nutrition and physical activity are predictors of lower obesity[44]; results for total and HDL cholesterol, which are also associated with diet and exercise[45,46] did not fit this pattern, suggesting the situation may either be more nuanced, or there may be variations by health outcome. Minorities may benefit from improved educational quality while Whites do not due to a "resource substitution" effect[47]. Resource substitution suggests the effect of educational quality on health may be more pronounced for minorities because they have less access to alternative resources such as power, authority, and earnings[47]; this means minorities will be more dependent on the limited resources they have access to (i.e. better educational quality), while Whites are less impacted any one specific measure, resulting in larger effect sizes for minorities compared to Whites.

State-level educational quality may be linked to with poorer CVD outcomes such as heart disease, ever-smoking, and stroke through stress pathways and race / ethnicity-related discrimination (Figure 2). Better educational quality leads to higher educational attainment[39,40]. Among Blacks, those with higher educational attainment have been shown to experience more discrimination[18], perhaps due to living and moving through social environment where their presence is more unique and therefore less "expected." Discrimination in turn is

associated with a higher prevalence of hypertension[48], and higher rates of smoking, a stress coping mechanism[49]. Both hypertension and smoking are risk factors for stroke[50,51], and heart disease[16], outcomes in our study that were similarly associated with better educational quality among minorities. In this way, it is possible that higher state-level educational quality lead to more discrimination among minorities, resulting in poorer cardiovascular health for outcomes on stress-related pathways.

There are several limitations to these analyses. First, self-reported health outcomes may be subject to standard reporting biases, which may be more severe for those with lower levels of educational attainment. Second, our study is restricted to individuals born before 1951; important social changes following school desegregation and the Civil Rights movement means these results may not generalize to younger cohorts. Replication of these analyses in datasets including younger birth cohorts is an important area for future research, although younger cohorts may not yet be old enough to develop the conditions we examined. Third, we were unable to account for within-state variations in educational quality[30]. That is, in our analysis, Black and White respondents within the same state were considered exposed to the same level of educational quality. Since our study period is prior to desegregation, Blacks and Hispanics included in this analysis were almost certainly assigned higher state-level educational quality than they actually received. Repeating these analyses with educational quality measures dis-aggregated by race is an important area for future research.

We found that better state-level educational quality had little association with cardiovascular disease outcomes among Whites, while predicting both better and worse CVD outcomes among minorities. These mixed findings among minorities may be due to different mechanistic pathways through which state-level educational quality impacts different CVD outcomes. It may be that higher educational quality predicts healthy behaviors resulting in better CVD health for some outcomes, while higher state-level educational quality predicts more experiences of discrimination among minorities, resulting in poorer CVD health for other outcomes; however, not all the outcomes we examined followed this pattern, indicating that more work is needed in this area. Repeating these analyses to determine if our findings are robust to variations in time and population is an important area for future research. Our results suggest that policies impacting state-level educational quality may differentially affect

racial minorities compared to Whites, and that policies to improve educational quality may not eliminate health disparities due to broader structural inequities.

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Table 1. Sample characteristics by race

Variable	White	Black	Hispanic
Individual-level characteristics			
Birth year (mean ± sd)	1931 ± 12	1934 ± 12	1936 ± 11
Female (%)	54.6	59.3	53.6
State-level characteristics			
% urban (mean ± sd)	56.8 ± 20	42.9 ± 20.3	55.8 ± 17.1
% foreign-born (mean ± sd)	9.3 ± 7.59	31.0 ± 4.91	6.02 ± 4.50
% Black (mean ± sd)	9.20 ± 11.2	26.3 ± 13.9	9.22 ± 7.96
Manufacturing wages (inflation-adjusted; mean ± sd)	11,047 ± 3,655	9,667 ± 3,755	12,434 ± 3,807
Manufacturing jobs per 100 jobs (mean ± sd)	7.14 ± 3.64	6.03 ± 3.23	3.93 ± 2.51
State-level educational quality			
Composite educational quality index (mean ± sd)	0.12 ± 0.93	-0.59 ± 1.18	-0.01 ± 0.78
Student to teacher ratio (mean ± sd)	30 ± 5	33 ± 5	30 ± 4
Per-pupil expenditure (1982 – 1984 dollars, mean ± sd))	533 ± 264	339 ± 241	523 ± 275
Term length (mean ± sd)	174 ± 12	166 ± 17	171 ± 11
Self-reported outcomes			
Ever self-reported high blood pressure (%)	63.3	79.5	70.5
Ever self-reported heart disease (%)	40.2	33.7	30.5
Ever self-reported stroke (%)	16.6	20.0	16.9
Ever self-reported diabetes (%)	22.8	36.6	40.1
Ever self-reported obese (%)	32.6	47.4	46.1
Ever self-reported smoker (%)	60.4	61.1	59.7
Measured outcomes (value at first assessment)			
Uncontrolled blood pressure (%)	33.4	43.7	38.0
Uncontrolled diabetes (%)	11.5	24.6	24.3
HDL cholesterol (mg/dL; mean ± sd)	54 ± 16	55 ± 16	53.6 ± 16
Total cholesterol (mg/dL; mean ± sd)	198.6 ± 43	196 ± 41	199 ± 45
C-reactive protein (mg/L; mean ± sd)	4.2± 8	6.4 ± 14	4.3 ± 6.2

sd is standard deviation
HDL is high-density lipoprotein
mg/dL is milligrams per deciliter
The Health and Retirement Study is a national biennial sample of adults aged 50+ years and their spouses; outcome data from 1992 – 2014. N = xxx individuals who reported their race as “other race” or “missing” were included in analysis to improve statistical efficiency, but are not discussed due to small numbers and ambiguity in interpretation.

Figure 1. Heterogeneities in the relationship between state-level education quality and CVD outcomes overall, and by race

Figure 1a. Dichotomous outcomes (null = 1)

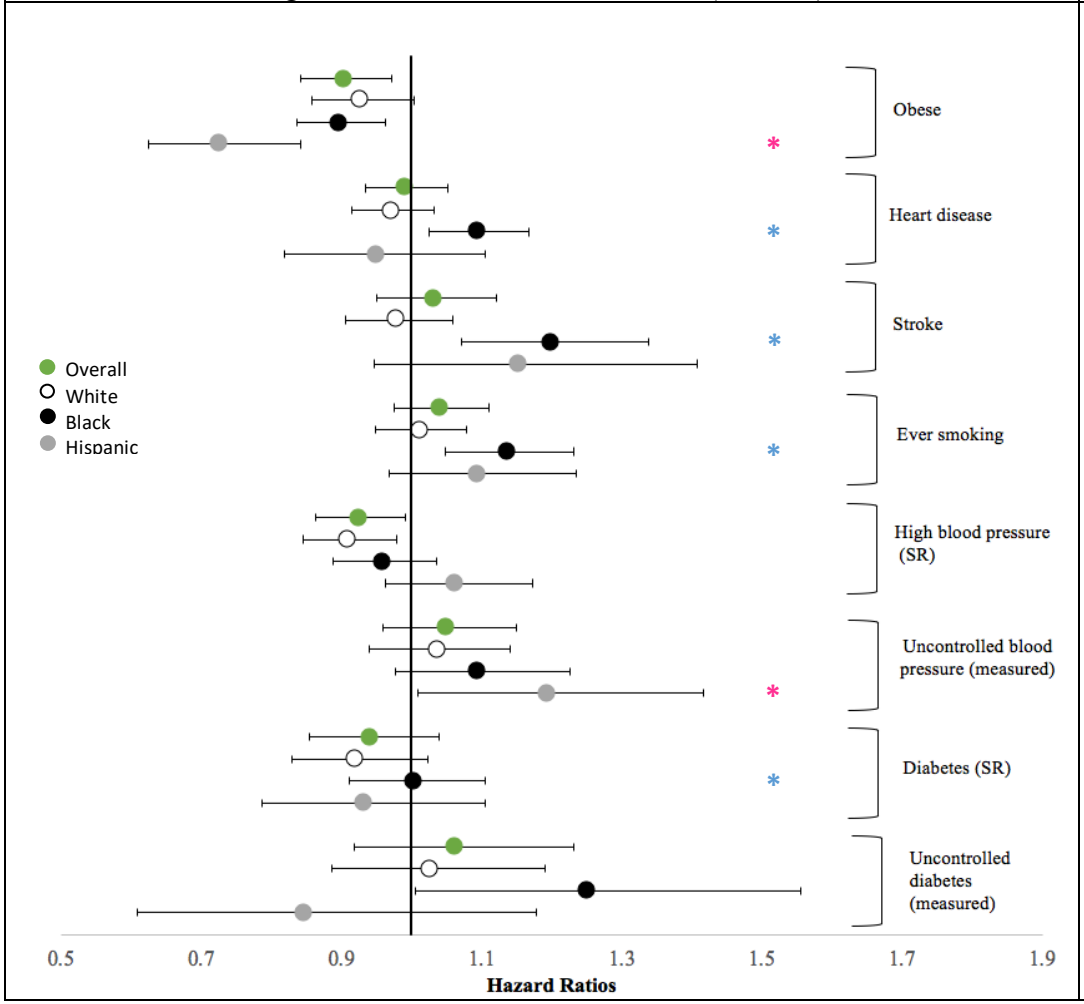
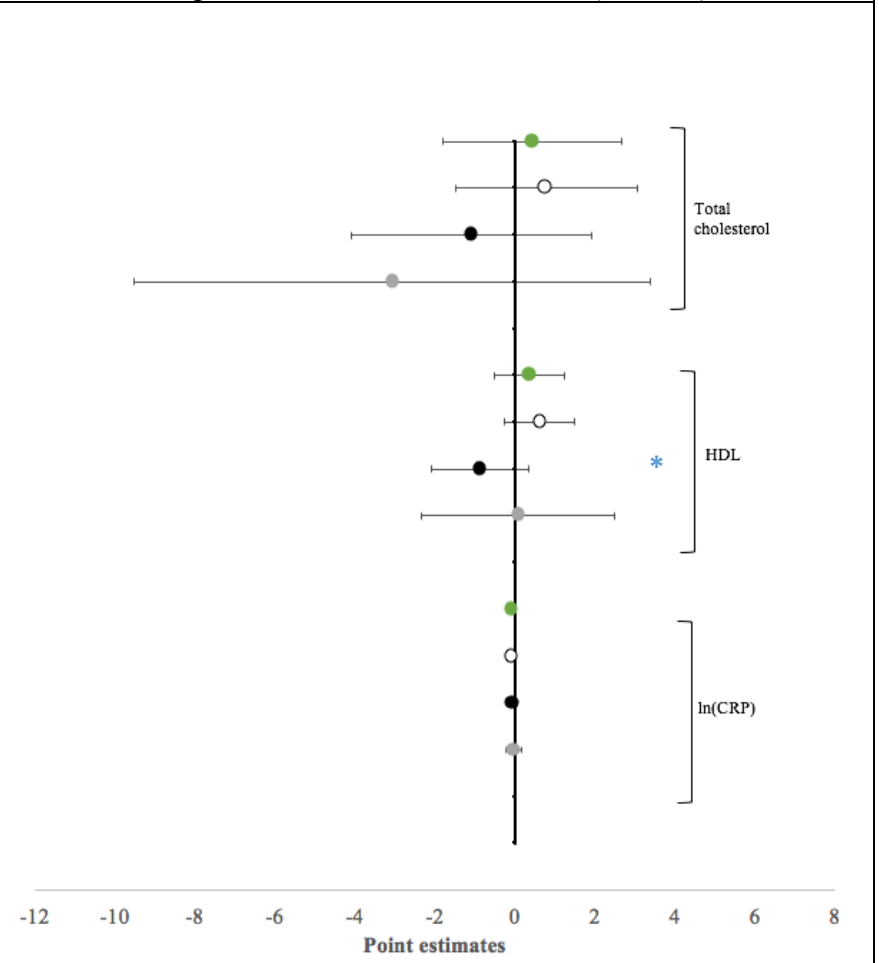


Figure 1b. Continuous outcomes (null = 0)



* indicates the educational quality relationship for Blacks is different than for Whites in interaction analyses (see Appendix Table 1 for details)

* indicates the educational quality relationship for Hispanics is different than for Whites in interaction analyses (see Appendix Table 1 for details)

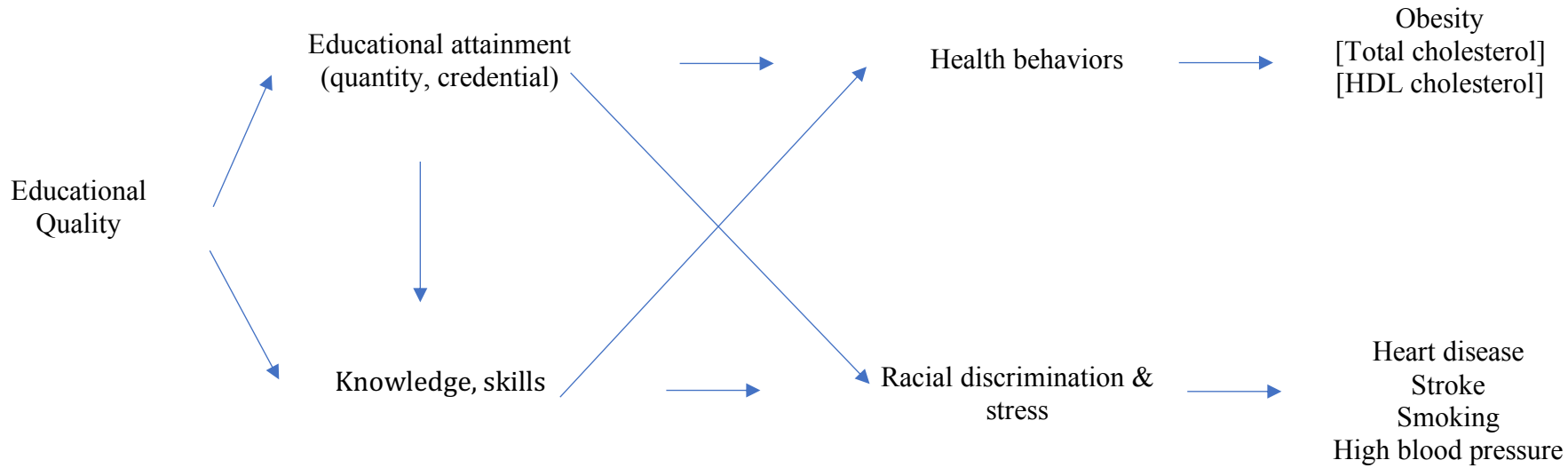


Figure 2. Mechanistic pathways linking educational quality to heart disease outcomes among minorities

Better education quality can result in both higher educational attainment and / or more knowledge and skills. Both educational attainment and knowledge and skills can result in better health behaviors, which in turn can lead to lower rates of obesity, total cholesterol, and HDL cholesterol (total and HDL cholesterol are in brackets because this pathway would predict better HDL and total cholesterol, but our cholesterol results were null,, suggesting the complete story may have more nuance). Similarly, both educational attainment and knowledge and skills may put minorities in a social world where their presence is more unique, resulting in more experiences of discrimination and stress, which in turn can lead to higher rates of hypertension, heart disease, stroke, and smoking (as a stress coping mechanism).

Appendix

Appendix Table 1. Associations between state-level educational quality (composite measure) and CVD outcomes overall, and by race

Dichotomous Outcomes (null = 1)	Model 1: Overall	Model 2: interaction Reference group (Whites)	Differential effect for Blacks	Differential effect for Hispanics
High blood pressure (self-reported)	0.926	0.909	1.055	1.168
	(0.864, 0.992)	(0.845, 0.978)	(0.999, 1.115)	(1.060, 1.287)
Uncontrolled high blood pressure (measured)	1.050	1.035	1.057	1.155
	(0.959, 1.150)	(0.940, 1.140)	(0.963, 1.162)	(0.968, 1.377)
Diabetes (self-reported)	0.942	0.921	1.090	1.012
	(0.854, 1.039)	(0.830, 1.023)	(1.014, 1.171)	(0.886, 1.155)
Uncontrolled diabetes (measured)	1.063	1.027	1.218	0.824
	(0.918, 1.232)	(0.886, 1.190)	(0.998, 1.486)	(0.616, 1.103)
Heart disease (self-reported)	0.992	0.972	1.125	0.979
	(0.935, 1.052)	(0.914, 1.033)	(1.061, 1.193)	(0.860, 1.114)
Stroke (self-reported)	1.033	0.979	1.223	1.178
	(0.951, 1.122)	(0.906, 1.059)	(1.126, 1.328)	(0.971, 1.430)
Obese (self-reported)	0.904	0.927	0.968	0.783
	(0.841, 0.971)	(0.857, 1.003)	(0.912, 1.027)	(0.679, 0.903)
Ever smoking (self-reported)	1.041	1.011	1.124	1.081
	(0.976, 1.110)	(0.948, 1.079)	(1.067, 1.184)	(0.980, 1.194)
Continuous Outcomes (null = 0)				
HDL cholesterol (measured)	0.381	0.620	-1.492	-0.534
	(-0.491, 1.253)	(-0.261, 1.502)	(-2.432, -0.553)	(-2.882, 1.815)
Total cholesterol (measured)	0.448	0.786	-1.851	-3.841
	(-1.788, 2.684)	(-1.486, 3.057)	(-4.166, 0.463)	(-10.10, 2.420)
CRP (natural log; measured)	-0.0793	-0.0911	0.0427	0.0668
	(-0.151, -0.008)	(-0.163, -0.0187)	(-0.0371, 0.123)	(-0.107, 0.241)

Outcomes listed as the rows.
All results adjusted for all confounders.
Model 1 is the overall relationship between state-level education quality and each outcome
Model 2 includes a state-level education quality by race interaction term

Appendix Table 2. Associations between state-level educational quality as operationalized by student to teacher ratio and CVD outcomes overall, and by race

Dichotomous Outcomes (null = 1)	Model 1: Overall	Model 2: interaction Reference group (Whites)	Differential effect for Blacks	Differential effect for Hispanics
High blood pressure (self-reported)	0.970	0.957	1.034	1.142
	(0.918, 1.025)	(0.903, 1.015)	(0.994, 1.074)	(0.939, 1.387)
Uncontrolled high blood pressure (measured)	1.035	1.019	1.048	1.162
	(0.945, 1.133)	(0.918, 1.132)	(0.946, 1.161)	(0.834, 1.617)
Diabetes (self-reported)	0.992	0.963	1.093	1.145
	(0.915, 1.075)	(0.887, 1.045)	(1.006, 1.188)	(0.983, 1.334)
Uncontrolled diabetes (measured)	1.042	0.975	1.245	1.210
	(0.884, 1.230)	(0.829, 1.146)	(1.001, 1.549)	(0.906, 1.615)
Heart disease (self-reported)	1.006	0.996	1.096	0.878
	(0.955, 1.061)	(0.942, 1.052)	(1.003, 1.197)	(0.723, 1.067)
Stroke (self-reported)	1.051	1.000	1.219	1.103
	(0.979, 1.129)	(0.917, 1.092)	(1.103, 1.346)	(0.813, 1.498)
Obese (self-reported)	0.985	1.001	0.968	0.869+
	(0.929, 1.043)	(0.941, 1.065)	(0.905, 1.036)	(0.736, 1.026)
Ever smoking (self-reported)	0.997	0.966	1.132	1.112
	(0.940, 1.057)	(0.914, 1.020)	(1.052, 1.218)	(0.972, 1.271)
Continuous Outcomes (null = 0)				
HDL cholesterol (measured)	0.0593	0.348	-1.910	-0.304
	(-0.773, 0.892)	(-0.505, 1.201)	(-3.057, -0.763)	(-2.522, 1.913)
Total cholesterol (measured)	-0.400	0.0683	-2.544	-4.355
	(-2.480, 1.679)	(-2.085, 2.222)	(-5.295, 0.206)	(-10.06, 1.355)
CRP (natural log; measured)	-0.0371	-0.0455	0.0301	0.0347
	(-0.104, 0.0303)	(-0.114, 0.0234)	(-0.0724, 0.133)	(-0.133, 0.203)

Outcomes listed as the rows.
All results adjusted for all confounders.
Model 1 is the overall relationship between state-level education quality and each outcome
Model 2 includes a state-level education quality by race interaction term

Appendix Table 3. Associations between state-level educational quality as operationalized by term length and CVD outcomes overall, and by race

Dichotomous Outcomes (null = 1)	Model 1: Overall	Model 2: interaction Reference group (Whites)	Differential effect for Blacks	Differential effect for Hispanics
High blood pressure (self-reported)	0.981 (0.934, 1.029)	0.965 (0.920, 1.013)	1.043 (0.989, 1.099)	1.145 (1.057, 1.239)
Uncontrolled high blood pressure (measured)	1.053 (0.957, 1.159)	1.049 (0.946, 1.164)	1.020 (0.936, 1.113)	1.004 (0.845, 1.193)
Diabetes (self-reported)	0.996 (0.903, 1.098)	0.978 (0.869, 1.102)	1.066 (0.997, 1.140)	0.989 (0.890, 1.099)
Uncontrolled diabetes (measured)	1.146* (1.007, 1.305)	1.087 (0.969, 1.219)	1.191 (0.951, 1.493)	0.827 (0.605, 1.130)
Heart disease (self-reported)	1.019 (0.966, 1.076)	1.002 (0.944, 1.063)	1.092 (1.036, 1.151)	0.981 (0.900, 1.070)
Stroke (self-reported)	1.047 (0.970, 1.131)	0.996 (0.925, 1.072)	1.193 (1.104, 1.289)	1.178 (1.014, 1.369)
Obese (self-reported)	0.931+ (0.865, 1.001)	0.968 (0.883, 1.060)	0.959 (0.895, 1.027)	0.771 (0.662, 0.898)
Ever smoking (self-reported)	1.012 (0.958, 1.069)	0.977 (0.921, 1.036)	1.112 (1.069, 1.156)	1.042 (0.982, 1.106)
Continuous Outcomes (null = 0)				
HDL cholesterol (measured)	0.128 (-0.756, 1.012)	0.482 (-0.425, 1.390)	-1.490 (-2.434, -0.546)	-0.0353 (-2.578, 2.507)
Total cholesterol (measured)	-0.342 (-2.646, 1.962)	0.203 (-2.176, 2.582)	-2.063+ (-4.381, 0.255)	-3.210 (-11.04, 4.619)
CRP (natural log; measured)	-0.0645+ (-0.138, 0.00891)	-0.0806* (-0.156, -0.00558)	0.0465 (-0.0331, 0.126)	0.0422 (-0.162, 0.246)

Outcomes listed as the rows.
All results adjusted for all confounders.
Model 1 is the overall relationship between state-level education quality and each outcome
Model 2 includes a state-level education quality by race interaction term

Appendix Table 4. Associations between state-level educational quality as operationalized by per-pupil expenditure and CVD outcomes overall, and by race

Dichotomous Outcomes (null = 1)	Model 1: Overall	Model 2: interaction Reference group (Whites)	Differential effect for Blacks	Differential effect for Hispanics
High blood pressure (self-reported)	0.939	0.932	1.006	1.121
	(0.863, 1.021)	(0.858, 1.014)	(0.912, 1.110)	(0.976, 1.287)
Uncontrolled high blood pressure (measured)	1.015	1.006	0.995	1.148
	(0.905, 1.138)	(0.896, 1.129)	(0.849, 1.166)	(0.908, 1.452)
Diabetes (self-reported)	1.026	1.024	1.063	0.971
	(0.921, 1.144)	(0.925, 1.133)	(0.909, 1.244)	(0.833, 1.131)
Uncontrolled diabetes (measured)	1.307	1.325	1.122	0.757
	(1.008, 1.695)	(1.040, 1.688)	(0.912, 1.380)	(0.528, 1.084)
Heart disease (self-reported)	1.055	1.047	1.147	1.082
	(0.957, 1.164)	(0.950, 1.154)	(1.054, 1.249)	(0.975, 1.202)
Stroke (self-reported)	1.077	1.069	1.085	1.075
	(0.961, 1.206)	(0.957, 1.193)	(0.964, 1.222)	(0.870, 1.328)
Obese (self-reported)	0.999	1.011	0.938	0.903
	(0.892, 1.118)	(0.908, 1.125)	(0.858, 1.025)	(0.764, 1.068)
Ever smoking (self-reported)	1.061	1.051	1.134	1.104
	(0.950, 1.184)	(0.942, 1.172)	(1.023, 1.256)	(1.002, 1.217)
Continuous Outcomes (null = 0)				
HDL cholesterol (measured)	-0.826	-0.696	-0.783	-1.305
	(-2.318, 0.666)	(-2.191, 0.799)	(-2.165, 0.599)	(-3.285, 0.675)
Total cholesterol (measured)	-0.930	-0.736	1.127	-4.174+
	(-4.812, 2.952)	(-4.633, 3.162)	(-2.423, 4.678)	(-8.835, 0.488)
CRP (natural log; measured)	0.0155	0.0111	-0.0168	0.0844
	(-0.109, 0.140)	(-0.114, 0.136)	(-0.126, 0.0926)	(-0.0761, 0.245)

Outcomes listed as the rows.
All results adjusted for all confounders.
Model 1 is the overall relationship between state-level education quality and each outcome
Model 2 includes a state-level education quality by race interaction term