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Lifecourse Educational Trajectories and Hypertension in Midlife: An Application of Sequence Analysis

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Abstract

Background: Higher educational attainment predicts lower hypertension. Yet, associations between nontraditional educational trajectories (eg, interrupted degree programs) and hypertension are less well understood, particularly among structurally marginalized groups who are more likely to experience these non-traditional trajectories.

Methods: In National Longitudinal Survey of Youth 1979 cohort data (N = 6 317), we used sequence and cluster analyses to identify groups of similar educational sequences—characterized by timing and type of terminal credential—that participants followed from age 14–48 years. Using logistic regression, we estimated associations between the resulting 10 educational sequences and hypertension at age 50. We evaluated effect modification by individual-level indicators of structural marginalization (race, gender, race and gender, and childhood socioeconomic status [cSES]).

Results: Compared to terminal high school (HS) diploma completed at traditional age, terminal GED (OR: 1.32; 95%CI: 1.04, 1.66) or Associate degree after <HS (OR: 1.93; 95%CI: 1.11, 3.35) was associated with higher hypertension. There was some evidence of effect modification. Hypertension associated with delayed HS diploma versus HS diploma at a traditional age (the reference) was lower for Black men than White men (interaction term: 0.44; 95%CI: 0.21, 0.91); similarly, hypertension associated with <HS versus completing HS at a traditional age was lower for people with low cSES than people with high cSES (interaction term: 0.52; 95%CI: 0.30, 0.90).

Conclusions: Both type and timing to terminal credential matter for hypertension but effects may vary by experiences of structural marginalization. Documenting the nuanced ways in which complex educational trajectories are associated with health could elucidate underlying mechanisms and inform systems-level interventions for health equity.

Keywords: Education, GED, Health inequity, Hypertension

Education is an established social determinant of health; whereby higher educational attainment is associated with better health outcomes (1–3). However, the public health literature has typically operationalized education with simplified terms. For example, "years of schooling" or "degree attained by age 25" are common measures, often further coarsened by dichotomizing at high school (HS) completion and combining General Educational Development (GED) and HS diploma credentials (1–3). Such approaches impose strong assumptions regarding (1) timing to degree completion (ie, education beyond age 25 is unlikely to occur or does not matter for health), (2) equivalency of subsequent health experiences (ie, those who complete a GED and HS diploma will have equivalent health outcomes), and/or (3) a monotonically increasing relationship between each additional year of schooling and health (1–4). These assumptions

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may oversimplify the relationship between education and health, particularly as U.S. adults are less likely to follow so-called "traditional" educational trajectories—defined as consecutive, full-time training through to terminal degree completion—and more commonly follow "non-traditional" educational trajectories, including additional schooling beyond age 25, interruptions in schooling before eventual degree completion, and/or part-time schooling (5–10). Recent work also finds GEDs versus HS diplomas may be differentially associated with several outcomes, like self-reported physical and mental health, such that GED recipients report greater health hardships (5–10). While there are innumerable trajectories individuals can take to the same educational credential over the lifecourse (eg, undergraduate degree completed at age 21 vs at age 40), prior quantitative modeling approaches have not been able to effectively differentiate between these trajectories.

To date, a nascent educational trajectories literature seeking to enumerate these variable paths and associated health outcomes has examined only broad health constructs like the physical health component summary score (SF-12) (10). Findings from these analyses, however, suggest important links between educational trajectories and physical health in older adulthood, thus motivating the evaluation of a clinically defined physical health outcome, for which implications may be better understood.

Hypertension is a particularly important chronic health outcome to examine given that it is very common (70% of U.S. adults aged 65 years or older have been diagnosed with hypertension), mechanistically linked to major cardiometabolic (eg, diabetes) and other health conditions, and responsive to societal factors (11–13). Higher educational attainment is generally associated with reduced hypertension risk (14–17). However, emerging evidence suggests departures from this gradient for those with non-baccalaureate credentials (eg, Associate degree, some college), who appear to have a similar risk for hypertension as those with a terminal HS diploma (18,19). These associations may be mediated by opportunities for employment, chronic exposure to psychosocial stressors, and access to health-promoting resources (14–16). To our knowledge, there have been no previous studies of the association between nontraditional education trajectories across the lifecourse and hypertension among older adults.

There are notable inequities in both educational attainment and hypertension by experiences of structural marginalization. Populations made to navigate the myriad ways that racism and classism present report lower educational attainment (1,20,21) and are at increased risk of hypertension (15,22). For example, Black adults have the highest prevalence of hypertension across racial groups in the United States (17). Additionally, U.S. children whose families experience economic disenfranchisement are at increased risk of hypertension in adulthood (23–25). By contrast, studies that examine differences by sex find that men have a higher incidence of hypertension compared with same-aged women until age 60 (17,26). At the intersections of race and sex, however, studies report a decrease in hypertension risk with greater educational attainment among both White men and women, but not among Black men and women—drawing attention to the importance of conducting intersectional analyses (27). Lastly, structurally marginalized populations (eg, racially minoritized people, women) more commonly experience interrupted or otherwise discontinuous trajectories (1). While studies of nontraditional education trajectories and health suggest patterned inequity by individual-level indicators of structural marginalization (9,10), to our knowledge, no prior work has evaluated hypertension as a primary health outcome.

In this manuscript, we implemented sequence analysis and clustering algorithms—a novel modeling strategy that allows us to incorporate information on both educational attainment and the timing of that attainment—to assess the following research questions:

1. In the United States, do varying educational trajectories (characterized by both timing to, and type of credential) differentially predict hypertension at age 50 and;
2. Do these associations vary by participant gender, race, gender and race combined, or childhood socioeconomic status?

Method

Sample

We used National Longitudinal Survey of Youth 1979 cohort (NLSY79) data. Among the 12 686 participants recruited between the ages of 14 and 22 years in 1979, those who remained eligible were interviewed annually until 1994, then biennially through 2016. For this analysis, we defined the eligible sample as the 7 912 NLSY79 participants who were not lost to follow up before age 48, as data through age 48 were needed to construct the exposure. From this eligible sample, participants were excluded if missing data on covariates other than indicators of childhood socioeconomic status (N = 141; detailed below) or the primary outcome of hypertension (N = 1 454), yielding a final analytic sample of 6 317 participants (79.8% of eligible sample; Supplementary Table 1). Below, we discuss mechanisms through which these data may be missing and approaches we used to understand and mitigate potential bias resulting from missingness.

Exposure

To generate the education sequences, we first identified each eligible study participant's education trajectory. Following prior work (10), we used each eligible participant's self-reported age, highest grade completed, enrollment status, and degree attained at each survey wave to determine which one of ten educational states they were in at each age between 14 and 48 years. These mutually exclusive states consisted of: (1) enrolled in HS; (2) not completed HS and not enrolled in HS; (3) HS graduate, not enrolled in higher education; (4) completed GED and not enrolled in higher education; (5) completed HS or a GED and enrolled in higher education full-time; (6) completed HS or a GED and enrolled in higher education part-time; (7) completed some college without degree conferral and not enrolled in formal schooling; (8) completed an Associate degree (AA) and not enrolled in higher education; (9) completed a Bachelor degree (BA) (we use the acronym "BA" to signal any bachelor's degree, regardless of whether it was a BA or BS, for example) and not enrolled in higher education; (10) enrolled in or completed graduate school (we collapse all trajectories after "completed BA" [ie, started graduate school, master's degree, professional degree] due to small numbers). This resulted in 3 185 unique trajectories across the sample.

We then used sequence analysis and cluster analysis to reduce the 3 185 trajectories to the most distinct, mutually exclusive educational sequences. Specifically, accounting for both credential attained and duration within each educational state (28), we used sequence analysis, with Halpin's optimal matching algorithm, to assign "costs" for each change that was required to transform one educational trajectory to each of the other educational trajectories in the data using insertion/deletion (inserting or deleting a state to make 2 sequences equivalent) and substitution (changing one state

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to another state, eg, enrolled in high school to high school graduate) (28). Each insertion or deletion was assigned a cost of 0.5 while substitution costs ranged from 1.9874985 to 2. We selected this ratio of insertion/deletion costs to substitution costs a priori given literature supporting substitutions (eg, complete one degree vs another) as more costly than insertion/deletions (eg, complete a degree earlier vs later); however, what constitutes an ideal ratio is an emerging area of research. While substitution costs were approximately 2, variability was introduced by calculating the "mean probability distance" such that more common transitions (eg, enrolled in HS to HS graduate) had relatively lower costs while less common transitions had relatively higher costs. Halpin's optimal matching algorithm additionally applied a downward duration adjustment to these insertion/deletion and substitution costs to account for the nonindependence of educational states at consecutive ages (eg, age 15 and 16). Finally, we summed costs for each pair of educational trajectories to calculate the "distance" between trajectories, resulting in a square (3 185 rows and columns), symmetric, cost matrix. We then performed a cluster analysis on the cost matrix, using the Ward's linkage, to group similar education sequences resulting in a 24-cluster solution (Supplementary Figure 1) (10). Detailed accounts of this procedure have been published elsewhere (10).

Finally, using the chi-square test, we further collapsed across sequences with the same terminal degree that were statistically similar ($p \geq .20$) in predicting the primary health outcome, hypertension.

Outcome

Data for the outcome—*having ever been diagnosed with high blood pressure or hypertension*—were derived from the NLSY79 Age 50 Module. Specifically, at approximately age 50, participants were asked "has a doctor ever told you that you have high blood pressure or hypertension?" (yes/no). This measure has been validated in several populations and has demonstrated consistency with clinical measures of hypertension (29). Given a literature on cardiometabolic risk that groups hypertension with diabetes (30), we also assessed diabetes as a secondary outcome ("has a doctor ever told you that you have diabetes or high blood sugar?"; yes/no).

Effect Modifiers

We tested for effect modification of the association between educational sequences and hypertension by self-reported race (respondents were asked during 1979 interviews to identify their racial/ethnic origins from a listing of more than 20 categories; re-coded as Black, Latinx (NLSY collects these data using the response option "Hispanic," which includes "Mexican American, Chicano, Mexican, Mexicano, Cuban, Cubano, Puerto Rican, Puertorriqueno, Boriccua, Latino, Other Latin American, Hispano, or Spanish descent" (31). [Note: corrected Spanish language spelling is "Puertorriqueño" and preferred spellings are "Boricua/Boriqua"]), White, Other/Missing), by interviewer assigned gender (during household screening, assigned "female" or "male"), by race and gender combined (eg, Black woman), and by childhood socioeconomic status (cSES). To generate the "Other/Missing" racial category, we grouped participants who reported one or more of the remaining racial identities into "Other," then collapsed "Other" and "Missing" into a single category due to small numbers. We do not, however, present these data given their ambiguous interpretation. As elsewhere (10), we operationalized cSES using maternal education (high = 12 or more years; low = less than 12 years or missing), which had less missing information than paternal education (6.2% of mothers; 14.2% of fathers).

Confounders

We adjusted for several potential confounders of the association between the educational trajectories and hypertension. Potential confounders included variables that temporally precede the exposure period (eg, occurred before age 14) and may either (1) be associated with educational trajectories and cause hypertension or (2) serve as proxies for such variables otherwise unavailable in the dataset. In addition to the proposed effect modifiers, these were birth year, birth in a southern state (32), rural residence at baseline (calculated by NLSY at county level), birth in a country other than the United States (1), and the following indicators of cSES for each parent when the participant was interviewed at baseline: parental education (centered at 12 years), indicators for unknown or missing values on parents' education (6.2% of mothers; 14.2% of fathers), work for pay (yes/no), missing indicators for work for pay (2.2% of mothers; 18.6% of fathers), Duncan Socioeconomic Index (SEI) score of "occupational prestige" (a 3-level variable: high vs low dichotomized at 45 using 2-digit SEI score; or did not work for pay/no mother or father), and missing indicators for SEI score (2.9% of mothers; 6.1% of fathers). Rather than exclude participants with missing cSES data, we created indicators for missing given a literature that finds missing cSES data to be associated with lower socioeconomic status in childhood (33). Lastly, we do not adjust for factors that temporally follow the exposure window (ie, after baseline survey), as these factors may mediate the relationship between educational trajectories and hypertension at 50 and adjusting for a mediator could bias estimates (34).

Statistical Analyses

We used logistic regression to assess the association between educational sequences and hypertension at age 50, after adjustment for potential confounders. We used HS diploma at traditional age as our referent category for 2 reasons: (1) it was among the most prevalent educational sequences in our analytic sample; and (2) HS diploma is a common referent across various measures of educational attainment (eg, HS graduate, less than HS) allowing us to situate our analysis in the broader literature which consistently finds high school diploma as a consequential lifecourse experience (for a detailed description of the ten sequences, see Table 1). We then tested for effect modification using interaction terms ($p < .05$) and used stratified analyses to present statistically significant results in accompanying figures for improved interpretability. All analyses were performed using Stata statistical software version 16 (StataCorp. 2019. *Stata Statistical Software: Release 16*. StataCorp LLC, College Station, TX); all data cleaning and analysis code were reviewed by a second programmer (SRW) who was not involved in the initial programming, as is recommended best practice (35).

Sensitivity and Secondary Analyses

First, given that hypertension is a relatively common outcome, we used a modified Poisson regression approach with robust error variance to estimate risk ratios for the primary analysis and gauge whether these estimates differed meaningfully from our estimated odds ratios. Second, we examined whether our results were robust to missingness in the covariate data. For the 141 eligible participants missing covariate data, we used multiple imputation with 10 imputed datasets to test for consistency with our complete case analysis results. While there was greater missingness on the outcome (18.4%), imputing outcome data is not recommended (36). Therefore, as a third sensitivity analysis, we assessed for the presence of selection bias by regressing an indicator of

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Table 1. Descriptions and Visualizations for Ten Education Sequences, Unweighted $N = 6\,317$

Education Sequence	Sequence Description	N (%) of Analytic Sample in Sequence	Modal Trajectory Within Sequence
1. <HS	Early exit from HS without diploma and did not re-enroll in formal schooling	616 (9.8%)	
2. HS diploma at traditional age	HS diploma in late teens or early 20s (mean: 19.8 y) and did not re-enroll in formal schooling	901 (14.3%)	
3. HS diploma delayed	HS diploma in early to late 20s (mean: 21.1 y) and did not re-enroll in formal schooling	520 (8.2%)	
4. GED	GED after less than HS and did not re-enroll in formal schooling	686 (10.9%)	
5. Some college	Enrolled in college after HS diploma, exited prior to degree completion, and did not re-enroll in formal schooling	1,251 (19.8%)	
6. AA	AA and did not re-enroll in formal schooling	849 (13.4%)	
7. AA after <HS	AA after <HS and did not re-enroll in formal schooling	63 (1.0%)	
8. BA	BA completion after HS and did not re-enroll in formal schooling	735 (11.6%)	
9. BA after interruption	Enrolled in BA program, experienced interruption before degree completion and did not re-enroll in formal schooling	75 (1.2%)	
10. Graduate school	Enrolled in or completed graduate degree	621 (9.8%)	

Notes: We used cluster analysis to differentiate educational trajectories. Cluster analysis minimizes within-sequence variability and maximizes between-sequence variability based on a cost matrix. The costs, which are based on the individual-level educational trajectories, do not directly consider terminal credential when determining the educational trajectory clusters. For example, it is possible that someone in the GED trajectory cluster enrolled in college towards the end of their educational trajectory and their last educational state was "some college", but their overall costs were more similar with the other GED trajectories than the other "some college" trajectories.

AA = Associate degree; BA = Bachelor's degree; enrld = enrolled; coll = college; GED = General Educational Development; HS = High School.

Interpretation. Column 1: Assigned sequence name; Column 2: Summary descriptions of each educational sequence; Column 3: the proportion of the sample within a given educational sequence; Column 4: Modal plot, which illustrates the most common educational trajectory (from one educational state to the next, between ages 14 and 48 years) at each age within that given sequence. Color schemes for each of the possible educational states can be found in the Key.

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whether hypertension data were missing at age 50 (yes/no) on the educational sequences, adjusting for confounders ($p < .05$) (37). This approach allowed us to test whether participants for whom outcome data are missing systematically differed from those with outcome data and, if so, the direction of potential bias in our results (37). Fourth, to assess whether adjustment for remaining cSES variables in the cSES effect modification analysis constituted overadjustment, we reran the analysis removing these covariates. Fifth, as an alternative, potentially more interpretable presentation of the main analysis results, we estimated the predicted probability of hypertension for each educational sequence, first setting each predictor to its grand mean value and then to its education sequence-specific mean value. Finally, as a secondary analysis, we used logistic regression to assess the association between the educational sequences and diabetes at age 50, after adjustment for potential confounders.

Results

Sample Characteristics

There were 6 317 participants comprising our final analytic sample (Supplementary Table 1). The mean birth year among these participants was 1961. Approximately half of participants were identified as women (51.7%) with the remaining identified as men. The sample primarily self-reported their racial identity as White (50.9%), with fewer Black (28.2%) and Latinx (16.2%) participants. Just over one-third of participants were born in the U.S. South (36.4%), 7.3% were born outside of the United States, and 20.4% resided in a rural county at baseline. 25.6% of participants reported being diagnosed with hypertension at age 50.

Using our sequence analysis, cluster analysis, and chi-square test approach, we grouped the 6 317 participants who comprised our final analytic sample into 10 distinct educational sequences (Table 1). Of these, the most common was "some college," comprising 19.8% of the sample; this sequence consisted of participants who enrolled in college, exited prior to degree completion, and did not re-enroll in formal schooling thereafter. Participants with a terminal HS diploma at traditional age (mean graduation age: 19.8 years; mean graduation year: 1980) were the next most common sequence (14.3% of sample). Participants with the following demographic characteristics were associated with educational sequences that resulted in advanced terminal degrees: woman-identified, non-Hispanic White, nonrural residence, U.S.-born, and higher cSES (Supplementary Table 2). Additionally, fewer of these participants reported having ever been diagnosed with our primary outcome, hypertension.

Overall Results

Compared to the HS diploma at traditional age sequence, the following sequences were associated with increased odds of hypertension: GED (OR: 1.32; 95%CI: 1.04, 1.66) and AA after <HS (OR: 1.93; 95%CI: 1.11, 3.35; Figure 1). Less than HS diploma (OR: 1.20; 95%CI: 0.94, 1.53), HS diploma delayed (OR: 1.25; 95%CI: 0.97, 1.62), some college (OR: 1.20; 95%CI: 0.98, 1.47), AA (OR: 1.09; 95%CI: 0.87, 1.36), and BA after interruption (OR: 1.46; 95%CI: 0.86, 2.47) were consistent with elevated odds of hypertension, though confidence intervals included the null. By contrast, compared to HS diploma at traditional age, the BA sequence (OR: 0.80; 95%CI: 0.62, 1.03) and graduate school sequence (OR: 0.86; 95%CI: 0.65, 1.12) had lower odds of hypertension, though again including the null.

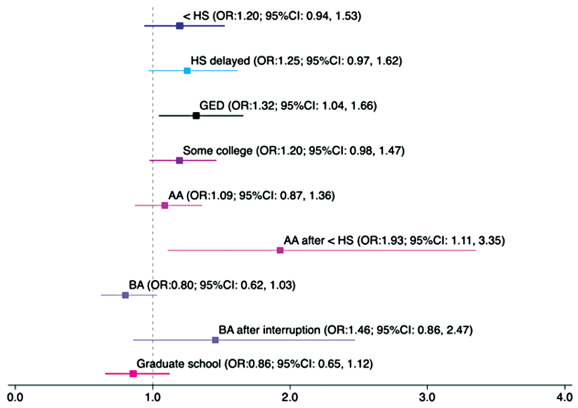

Figure 1. Odds ratios for hypertension age 50 associated with education sequence (ref = HS at traditional age), *N* = 6 317. HS = High School; GED = General Educational Development; AA = Associate degree; BA = Bachelor's degree; OR = Odds ratio; CI = Confidence interval. Procedure. Adjusted for birth year, race, gender, birth in a southern state, birth outside the United States, age 14 rural residence, mother education, father education, indicators for missing parental education, mother work for pay, father work for pay, missing indicators for parental work for pay, mother occupation SEI, father occupation SEI, missing indicator for parental occupation. Referent group comprised participants in the HS diploma at traditional age sequence.

Effect Modification

We found some evidence of effect modification. While separately, neither gender nor race appeared to modify the association between educational sequences and hypertension, when we examined effect modification by race and gender combined, we found the odds of hypertension associated with delayed HS diploma versus completing HS at a traditional age was lower for Black men than White men (interaction term: 0.44, 95%CI: 0.21, 0.91; Figure 2; Supplementary Tables 3 and 4; Supplementary Figure 2). While not statistically significant, the direction and magnitude of the remaining estimates were patterned such that, compared to terminal high school at traditional age, educational trajectories resulting in higher degree attainment were generally consistent with lower odds of hypertension for White men, with a less clear gradient for Black men (Supplementary Table 3; Supplementary Figure 2). In analyses of effect modification by cSES, we found the odds of hypertension associated with <HS versus completing HS at a traditional age was lower for people with low cSES versus those with high cSES (interaction term: 0.52, 95%CI: 0.30, 0.90; Figure 3; Supplementary Tables 5 and 6). We did not observe significant effect modification across other interactions tested (Supplementary Tables 4 and 6).

Robustness Checks and Secondary Analysis Results

Using the modified Poisson regression with robust error variance approach for the main analysis between the educational trajectories and hypertension, we found that the resulting risk ratios were slightly attenuated when compared to the odds ratios produced by the logistic regression approach; however, direction and statistical significance of the estimates were unchanged (Supplementary Table 7). Multiple imputation of the 141 eligible participants' missing covariate data did not substantively change main analysis results with regard to magnitude, direction, or precision around the estimate (Supplementary Table 8). The sequence most sensitive to the imputed covariate data was AA after <HS (complete case analysis OR: 1.93; 95%CI: 1.11, 3.35; multiple imputation analysis OR:

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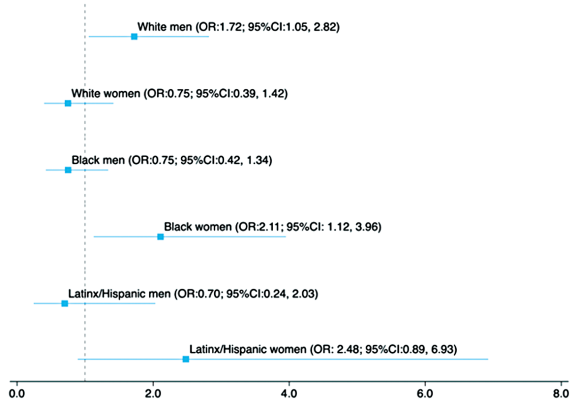

Figure 2. Odds ratios for hypertension at age 50 associated with delayed HS diploma versus HS diploma at traditional age, by race and gender (N = 6 317). HS = High School; OR = odds ratio; CI = confidence interval. Procedure. Adjusted for birth year, race, gender, birth in a southern state, birth outside the United States, age 14 rural residence, mother education, father education, indicators for missing parental education, mother work for pay, father work for pay, missing indicators for parental work for pay, mother occupation SEI, father occupation SEI, missing indicator for parental occupation We tested for effect modification using interaction terms (p < 0.05); however, for improved interpretability, Figure 2 presents race and gender-stratified analyses for the education sequence in which our test for interaction yielded statistically significant results. Interpretation. The odds of hypertension associated with delayed HS diploma versus completing HS at a traditional age was lower for Black men than White men (interaction term: 0.44, 95% CI: 0.21, 0.91). We did not observe significant effect modification across other interactions tested. See Supplementary Materials for interaction results.

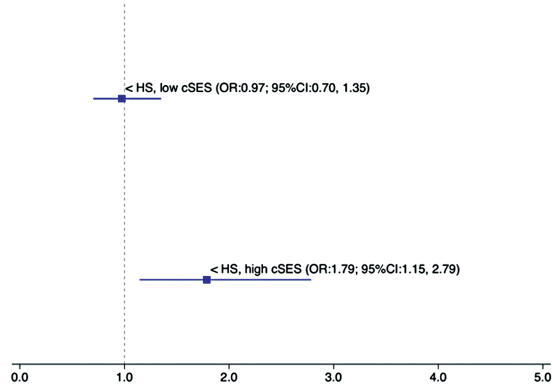

Figure 3. Odds ratios for hypertension at age 50 associated with less than HS diploma versus HS diploma at traditional age, by childhood SES (N = 6 317). HS = High School; OR = odds ratio; CI = confidence interval; cSES = childhood socioeconomic status. Procedure. Adjusted for birth year, race, gender, birth in a southern state, birth outside the United States, age 14 rural residence, mother education, father education, indicators for missing parental education, mother work for pay, father work for pay, missing indicators for parental work for pay, mother occupation SEI, father occupation SEI, missing indicator for parental occupation. We tested for effect modification using interaction terms (p < .05); however, for improved interpretability, Figure 3 presents childhood SES-stratified analyses for the education sequence in which our test for interaction yielded statistically significant results. Interpretation. The odds of hypertension associated with <HS versus completing HS at a traditional age was lower for people with low cSES versus those with high cSES (interaction term: 0.52, 95% CI: 0.30, 0.90). We did not observe significant effect modification across other interactions tested. See Supplementary Materials for interaction results.

1.78, 95%CI: 1.05, 3.02), which might be expected given the small number of participants in this sequence (N = 63). With regard to the missing outcome data, using our approach of estimating the odds of missingness, we found some evidence of selection bias which also focused on the AA after <HS sequence. Specifically, participants in the AA after <HS sequence had a higher odds of missing hypertension data compared to the reference category of HS diploma at a traditional age (OR: 1.85; 95%CI: 1.12, 3.06;Supplementary Table 9). All remaining education sequences did not differ from HS diploma at a traditional age in predicting missingness. When we compared the cSES effect modification analyses with and without adjustment for remaining cSES covariates, we found that they were not meaningfully different.

In addition to our main OR results, alternative, potentially more interpretable predicted probabilities for the main analysis results can be found in Supplementary Table 10. Results for the secondary outcome, diabetes, were generally similar to that of the hypertension analyses. Compared to the HS diploma at traditional age sequence, AA after <HS was associated with higher odds of diabetes (OR: 2.83; 95%CI: 1.55, 5.16;Supplementary Table 11). Most other estimates were in the same direction as the hypertension results, although confidence intervals included the null. The exception was for the BA after interruption sequence, which was not associated with elevated odds of diabetes (OR: 0.68; 95%CI: 0.27, 1.73).

Discussion

Using prospectively collected data from the National Longitudinal Survey of Youth 1979 cohort, we applied sequence and cluster analysis to construct education sequences, which account for both type and timing to credential, and estimated their association with hypertension at age 50. Our findings support 3 general conclusions: both (1) type of credential, and (2) trajectory to credential have implications for hypertension in ways that complicate the established education-health gradient, and (3) associations between educational trajectories and hypertension may vary by individual-level indicators of structural marginalization. To our knowledge, this study is the first to examine the association between nontraditional trajectories across the lifecourse (eg, additional schooling beyond age 25, interruptions or delays in degree completion) and hypertension among older adults.

With regard to credential type, we found that participants in the GED sequence had higher odds of hypertension than participants in the HS diploma at traditional age sequence. This finding adds to an emerging literature on differential economic and health returns for those with GEDs versus HS diplomas, which suggests that outcomes among people with GEDs may be more comparable to outcomes among people who exit high school prior to degree completion (5–10). Results for the "some college" sequence also suggested higher odds of hypertension than HS diploma at traditional age, although the confidence interval included the null. This is consistent, however, with a literature that suggests risk for hypertension among those with non-baccalaureate credentials, like "some college," may not reflect a constant gradient between more education and better health (3,18,19). Rather, "some college" trajectories may predict similar or greater risk for hypertension compared to terminal HS diploma trajectories (3,18,19). Differential health outcomes among GED and "some college" trajectories as compared to terminal HS diploma at traditional age trajectories may result from several mechanisms. For example, the experience of early exit from a program before

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credential completion (high school for GED trajectories; college for "some college" trajectories)—including loss of critical social supports among others—could itself be a health-harming stressor (1,3). Additionally, GED completion and college attendance in later life may be disproportionately stressful compared to completing a HS diploma at younger ages. Further, when compared to completed HS diplomas, GEDs and "some college" trajectories may be treated inequitably by the labor market, resulting in lower income, higher job strain, and less access to health care (1,3,38–40). If these are not recognized as valuable credentials in the labor market, the costs associated with pursuing additional schooling may not be offset by the intended benefits. Taken together, these findings support calls in the literature to no longer conflate GED and HS diploma in data collection and analysis (9,10). Further, they encourage structural intervention (eg, termination of high-stakes testing, provisions of Pell Grants, Affirmative Action) to support students through to high school or college degree completion by disrupting structural mechanisms that interrupt their educational trajectories and push students out of their schools (3,9,41–43).

Our second general finding was that trajectory taken to terminal credential has implications for hypertension. Specifically, compared to HS diploma at traditional age, the Associate degree (AA) without prior completion of a HS diploma sequence was associated with higher odds of hypertension. By contrast, the sequence for all other AA trajectories was similar to HS diploma at traditional age in predicting hypertension. Similarly, while results included the null, the delayed HS diploma sequence was associated with higher odds of hypertension compared to HS diploma at traditional age and the BA sequence—aside from BA after some interruption—was consistent with lower odds of hypertension than HS diploma at traditional age. Our findings are similar to limited prior work suggesting differential returns to same-degree credentials; for example, one study found that "vocational AA" recipients did not have systematic improvements in cardiovascular health compared to HS diploma recipients, while "academic AA" recipients did (18). We add to this nascent literature by showing different educational trajectories to the same degree (eg, AA after <HS vs AA most trajectories), may also differentially predict hypertension. Researchers posit that mechanisms underlying observations of differential risk for hypertension across educational trajectories ending in the same terminal credential may include higher total cost of educational training and/or reductions in related social and economic benefits, in part through the imposition of steadily increasing educational costs over time as well as less time to accumulate credential-associated benefits (1,3). To assess whether these patterns are robust to variations in time, place, and population, we encourage future research on education and health to account for dynamic trajectories to terminal degree. Given that implementing the analytic approaches used here may not be feasible in datasets with less extensive longitudinal follow-up, future research may consider other approaches that allow for gathering information on these dynamic educational trajectories (eg, cross-sectionally querying study participants on key educational events over their lifecourse to generate a historical accounting of their trajectories).

Third, we found some preliminary evidence of effect measure modification. We present these results as the field urgently needs to assess for the presence of effect heterogeneity, but the findings should be interpreted cautiously as they may reflect chance. Specifically, we found that compared with HS diploma at traditional age, Black men who completed high school later had lower odds of hypertension than same-trajectory White men, with a pattern emerging across the remaining estimates suggesting uninterrupted educational trajectories resulting in higher attainment predicted lower odds of hypertension for White men and a less clear gradient for Black men. Additionally, compared to HS diploma at traditional age, participants with low cSES who exited high school early without a diploma had lower odds of hypertension than same-trajectory participants with high cSES. These findings are consistent with a broader literature that finds a more nuanced association between education and health among populations marginalized by racism and/or classism (3,27,44,45). Mechanisms proposed in this literature suggest this pattern may result from differential earnings and employment opportunities within the same trajectories by experiences of marginalization; differential baseline wealth such that equal earnings within trajectories maintain inequity; and the role of educational institutions themselves in reproducing inequality through systematic differences in educational resource distribution and academic opportunities, among others (1,3,44,45). For example, studies noted a precipitous drop in Black men's income relative to that of same-credentialed White men between 1979 and 1997 which they attributed to structural racism in deindustrialization-related job loss (44,45)—years during which this NLSY79 cohort would have been entering and participating in the labor market. Additionally, studies have documented differential experiences of pre-school through post-secondary educational opportunity by parental SES and race, linking educational and housing policy to a structural divestment from the educational experiences of marginalized children (3,46). Importantly, looking at race and gender combined in this analysis appeared to reveal associations that were obscured by looking at race and gender separately. Given the results of our stratified models, however, it is possible that, in the presence of confounders whose effects on hypertension are also modified by race and gender, our approach of using an interaction term to assess effect modification may introduce bias into the results (47). However, the magnitude of the estimates using these two approaches were similar, though as might be expected, findings did not reach the threshold of statistical significance in the stratified models. Given these preliminary results, we recommend future research: (1) examine whether these findings can be replicated in other datasets; and (2) build on these preliminary results using emerging qualitative and quantitative, intersectionality theory-based methods to examine if and how multiply-marginalized populations may be uniquely impacted by the education-health association to inform structural intervention (48–50).

Study Limitations

This study had limitations. First, variables were largely self-reported, which may raise concerns around their validity and reliability, particularly regarding exposure and outcome assessment (3). However, exposure data were collected prospectively from age 14 through 48, minimizing recall bias; additionally, the exposure was operationalized using a combination of age, highest grade completed, enrollment status, and degree attained per survey wave—each serving as an internal gauge of concordance; and the outcome was assessed using a validated measure shown by several studies to be consistent with clinical measures (29). Still, given the outcome is assessed by inquiring after a physician diagnosis of hypertension, this measure may underestimate the outcome in populations that are systematically excluded from accessing medical care, which may vary by education trajectory. Second, while we adjusted for relevant, measured pre-exposure confounders, there may be unmeasured or

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residual confounding, so we caution against causal interpretations of these findings. Third, we were limited by these data to assessing effect modification by interviewer-assigned gender as opposed to self-reported gender. We recommend future research build on these analyses by examining how associations may vary by self-reported gender given documented experiences of education-based discrimination and adverse health outcomes (51). Lastly, given 18.4% of the eligible sample were missing hypertension data, we conducted a sensitivity analysis to assess for the presence of selection bias in our results. While most of our findings were robust to missingness on the outcome, compared to HS diploma at a traditional age, the AA after <HS sequence was associated with a significantly higher odds of missing hypertension data. A review of the literature suggests missing data may be an indicator of adverse outcomes, like hypertension (52). If so, the true magnitude of the association between an Associate degree after <HS, compared to HS diploma at a traditional age, and hypertension may be greater than our estimates indicate.

Study Strengths

This study also had notable strengths, including the prospective design involving a large, nationally representative sample followed since as early as age 14. Additionally, through this novel application of sequence analysis, we were able to respond to calls in the literature for more comprehensive, empirically driven measures of educational attainment that reflect the nuanced trajectories taken to terminal degree (1,3). Further, by employing this replicable, parsimonious strategy to develop and collapse educational trajectories, we not only reduced nonsystematic coding decisions while maximizing statistical power to detect differences but were able to document important nuances in how education matters for health that were concealed by prior methodologic approaches.

Conclusion

Our findings suggest both type and timing to terminal credential matter for hypertension, but their effects may vary by experiences of structural marginalization. These findings are consistent with an emerging literature that increasingly points to greater complexity in the established education-health gradient. Future research should disaggregate credentials and trajectories that have consistently been shown to be differentially associated with health (eg, GED and HS diploma), replicate our analysis in other datasets to confirm whether newly observed patterns persist (eg, Associate degree after <HS increasing odds of hypertension vs. HS diploma at traditional age), and examine variation by experiences of structural marginalization. Documenting the nuanced ways in which increasingly complex educational trajectories may be associated with health could be key to elucidating underlying mechanisms, informing relevant systems-level interventions, and ensuring equity in impacts on population health and wellbeing.

Supplementary Material

Supplementary data are available at *The Journals of Gerontology, Series A: Biological Sciences and Medical Sciences* online.

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Author Contributions

AMV and CD developed the statistical analysis. CD performed the statistical analysis and wrote the first draft of the article. SRW conducted an independent review of the statistical analysis. All authors provided critical feedback on the conceptualization of the study, interpretation of the results, reviewed drafts of the article, and approved the final submission.

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Conflict of Interest

None declared.

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