The Long Arm of Childhood Policy

Historical Schooling Laws and COVID-19 Pandemic-era Mortality

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Background: Low educational attainment was strongly associated with higher coronavirus disease 2019 (COVID-19) mortality. Whether this association is causal remains controversial. We evaluated the impact of historical state-level compulsory schooling laws (CSLs) on older individuals' pandemic-era mortality via a natural experiment.

Methods: We defined the US population of older adults using the 2019 American Community Survey and included all US death certificates from March 2019 to December 2021. We linked each individual to state-level CSLs at school age. We estimated effects of state-level CSLs on individual-level COVID-19 mortality and all-cause mortality pre-pandemic (March 2019–February 2020), pandemic year 1 (March 2020–February 2021), and pandemic year 2 (March 2021–December 2021), controlling for birth year, sex, race and ethnicity, state-level demographics, and state-of-birth fixed effects. We also examined the effect heterogeneity by sex and racial identity.

Results: Each additional year of policy-mandated compulsory schooling was associated with lower odds of COVID-19 mortality (pandemic year 1 odds ratio [OR] for 8 vs. 9 years: 1.16 [95% confidence interval [CI]: 1.11, 1.20]; OR for 10 vs. 9 years 0.96 [95% CI: 0.93, 0.98]; similar estimates in year 2). The relationship between CSLs and COVID-19 mortality roughly mirrored the relationship with all-cause mortality immediately before and during the pandemic. The gradient was steepest among Black women.

Conclusion: Older adults born into states requiring longer schooling experienced markedly lower mortality during the pandemic, suggesting historic investments in children's education reduced pandemic-era mortality decades later. Our findings support a causal relationship between population-level education policy and long-term population health.

Keywords: COVID-19; Compulsory schooling laws; Education; Educational inequities; Quasi-experiments; Social determinants of health

(Epidemiology 2026;37: 654–661)

Debates about policy influences on mortality during the coronavirus disease 2019 (COVID-19) pandemic have largely centered on pandemic response policies.[1–3] Policies enacted before the pandemic may also have influenced COVID-19 era outcomes. For example, many policies increase educational attainment, and higher individual and community-average education predicted lower mortality during the pandemic.[4–7] Although it remains controversial whether educational differences in COVID-19 mortality reflect causal effects of education, these patterns mirrored negative associations between education and mortality before the pandemic.[8–10]

In the 20th century, US states implemented many policies to increase educational attainment. Compulsory schooling laws (CSLs)—mandating the age at which children were required to enter and allowed to leave school—increased the educational attainment of children in affected birth cohorts.[9,11] Prior literature indicates that CSLs affect life expectancy,[8] cognition in older ages,[12] and physical and mental health.[13] Similarly, CSLs may have influenced COVID-19 mortality via increased education among individuals constrained by the schooling laws. Because COVID-19 differentially affected older adults, the most relevant policies occurred decades before the pandemic, when these cohorts were completing schooling. If education affected COVID-19 mortality, historical

Editors' note: A related article appears in this issue.
Submitted August 12, 2025; accepted April 30, 2026
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The following grant supported the collection and preparation of Compulsory Schooling Law data: R01 AG039588 (PI: Howard). W.W. was partially supported by the National Institute on Minority Health and Health Disparities, NIH (Grant No. T32MD015070).
The authors report no conflicts of interest.
SDC Supplemental digital content is available through direct URL citations in the HTML and PDF versions of this article (www.epidem.com).
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Public Use Microdata Sample data are publicly available. The use of restricted death certificate data underwent review and approval by the National Center for Health Statistics (NCHS); researchers may request access to these data through NCHS. Compulsory Schooling Law data are available via the following GitHub repository: https://github.com/GlymourGroup/SchoolQuality. Code is available on GitHub.

ISSN: 1044-3983/26/375-654661
DOI: 10.1097/EDE.0000000000002002

education policies would be associated with pandemic-era mortality. The association between CSLs and mortality is not vulnerable to the potential confounders of individual-level education, such as parental socioeconomic status or cognitive skills established before school.[14]

Additionally, the association between CSLs and mortality captures potential pathways beyond impacts on individual-level educational attainment that are often ignored in existing literature. Educational attainment can have benefits that spill over into an individual's family, spouse, friends, and the broader community. Further, many education interventions (such as CSLs) affect the educational attainment of the wider community. Community-level educational attainment may affect risk of mortality, especially with infectious conditions such as COVID-19, for example, by influencing disease spread in the local community via knowledge sharing, behavioral norms, or political pressure (e.g., masking, social distancing, enforcement of containment policies). These spillover processes would further enhance the importance of historical schooling policies enacted at the state level. Such community-level pathways are often not reflected in prior research aiming to identify the direct effect of individual-level education, including prior CSL analysis using instrumental variable estimation that aims to isolate effects via individual educational attainment. Prior estimates may thus underestimate the extent to which investments in education impact health. We contribute to the literature by using intent-to-treat estimation of the effect of CSL policy changes that capture alternative pathways via community-level education.

Following fundamental cause theory, education is a flexible resource that individuals may deploy to promote their health, even in the context of rapid changes in the major threats to health.[15,16] Fundamental cause theory's disease preventability approach posits that flexible resources provide a stronger buffer for highly preventable diseases, leading to varying social inequities by disease.[17] However, there is conflict in the limited existing research on education and COVID-19-era mortality, with one study finding a stark increase in educational disparities during the pandemic, and another finding no such increase.[18,19]

Further, we lack insight into whether educational inequities in mortality fluctuated throughout the pandemic as disease transmission and prevention dynamics evolved. Under fundamental cause theory's preventability shifts approach, as new information and strategies for disease prevention emerge, inequities grow as these tools can be better leveraged by those with more privilege.[17] For example, as knowledge and tools for COVID-19 prevention and treatment grew, educational inequalities would be expected to grow; those with greater education would be better able to protect themselves, such as via working from home and social distancing.[20] Insight into how educational gradients in mortality compared between COVID-19 and all-cause mortality and across changing outbreak dynamics can improve understanding of how education performs as a flexible resource in the face of new and evolving threats to public health.

This research leverages historical variation in state-level CSLs to investigate whether mandates for additional years of education decreased individual-level COVID-19 or all-cause mortality decades later and if this differed from effects on pre-pandemic mortality. We hypothesized that exposure to more years of state-mandated schooling when an individual was school-age would lower the risk of all-cause and COVID-19 mortality during the pandemic.

METHODS

Population Data and Measures

We used the weighted 1-year 2019 American Community Survey (ACS) Public Use Microdata Sample (PUMS), which sampled households and group quarters to capture roughly 1% of the US population to define our population.[21,22]

Outcome Data and Measures

Our outcomes were mortality with COVID-19 listed as an underlying cause of death (*International Classification of Diseases, Tenth Revision* diagnostic code of U07.1) and all-cause mortality. We used individual-level death records from the National Center for Health Statistics between March 2019 and December 2021.[23] We evaluated mortality in three periods: pre-pandemic (March 2019–February 2020), pandemic year 1 (March 2020–February 2021), and pandemic year 2 (March 2021–December 2021).

Study Sample

CSL measures were available for individuals born 1900–1964; we therefore excluded individuals born after 1964. We excluded individuals born outside the United States or in states without CSLs during this period (Alaska and Hawaii). We excluded individuals who were top-coded on age (whereby ages above a certain threshold are censored and replaced with a maximum value to protect confidentiality of individuals in small groups), given we could not define the correct CSL corresponding to their birth year (detail in eAppendix 1, https://links.lww.com/EDE/C350). To match the age distribution in the population data, we excluded individuals born before 1926 in the mortality data. Our final sample represented a population of 85.1 million adults born 1926–1964 (eFigure 1, https://links.lww.com/EDE/C350).

PUMS data are publicly available. The use of restricted death certificate data underwent review and approval by the National Center for Health Statistics; data were handled in compliance with the Data Use Agreement. The IRB at the University of California, San Francisco, determined this did not constitute human subjects research.

Exposure Data and Measures

Our exposures were state-level mandatory years of education based on CSLs. In our main analysis, we defined the number of mandatory years of education by subtracting mandatory school enrollment age from the legal dropout age. To estimate schooling measures that would most likely apply to a given individual, we lagged mandatory enrollment age by 6 years after birth and lagged dropout and work permit age by 14 years. CSL data from 1907 to 1961 were previously compiled from US federal education reports usually published biennially.[12,24–26] (Detail and data access in eAppendix 1, https://links.lww.com/EDE/C350.)

Our datasets did not capture changes in state of residence during childhood. Therefore, individuals were linked to CSLs corresponding to their birth state, with the assumption of minimal interstate migration between birth and school-age. Prior research has demonstrated interstate migration among children during this period was relatively low and unrelated to CSL implementation.[24,27] Therefore, any measurement error would likely tend to slightly bias results toward the null.

Covariates

We included both individual- and state-level characteristics, including year of birth (linear and quadratic terms) to account for secular trends, birth state fixed effects to account for other state-level factors, sex, and race and ethnicity (details in eAppendix 1, https://links.lww.com/EDE/C350). Time-varying state-level factors included (1) percent urban, percent Black, and percent foreign-born in the respondent's birth state when they were 6 years old and (2) average manufacturing wages and manufacturing jobs per capita in their birth state when they were 14 years old (details in eAppendix 1, https://links.lww.com/EDE/C350).

Statistical Analysis

Creation of Main Analytic Dataset

We stacked mortality and population data to create a single dataset representing both our target population and decedents. Individuals from the population dataset were assigned their ACS population weight and a death outcome of 0. Individuals from the mortality dataset were assigned a weight of 1 and a death outcome of 1. Roughly 1% of the decedents will also be present in the ACS data as non-decedents; because mortality is rare, this negligibly affects estimates (details in eAppendix 1, https://links.lww.com/EDE/C350).

Statistical Methods

Using logistic regression, we estimated odds ratios (ORs) for mortality associated with each level of mandated schooling under the CSLs, compared to a reference of 9 years of mandatory schooling (the most common level).

We adjusted for all covariates above (see conceptual diagram in eFigure 2, https://links.lww.com/EDE/C350). We examined potential effect modification by the intersection of sex and Black versus White racial identity based on prior research highlighting differential impacts of CSLs on health outcomes by race and sex.[24] We focused on Black and White individuals due to small cell sizes and lack of evidence regarding how CSLs may have been enforced for other racial/ethnic groups.[24,26] We examined jointly stratified estimates.

We examined all-cause mortality in three time periods: pre-pandemic (March 2019–February 2020), pandemic year 1 (March 2020–February 2021), and pandemic year 2 (March 2021–December 2021), and COVID-19 mortality in pandemic years 1 and 2.

Secondary Analyses

To help disentangle mechanisms related to an individual's own education versus community-level education, we compared results between individuals residing inside versus outside their birth state at the time of death/ACS completion. We additionally examined an alternative CSL definition calculated by subtracting mandatory enrollment age from the age students were allowed to receive a work permit (rather than from the legal dropout age).[12] To examine the robustness of our findings to the right-truncated year 2, we included a sensitivity analysis specifying alternative time periods (details in eAppendix 1, https://links.lww.com/EDE/C350). To examine the robustness of our results to the inclusion of ACS replicate weights, we included models with replicate person weights via the successive difference replication method.[22,28] Given potential for multicollinearity due to correlation between state-level factors and the potential for state-level factors to be influenced by CSLs, we included a sensitivity analysis excluding state-level covariates (details in eAppendix 1, https://links.lww.com/EDE/C350). To examine the robustness of our findings to alternative approaches to adjusting for birth year, we additionally included models with varying birth year specifications, including birth year fixed effects and 5-year cohort bins. To evaluate the potential for birth year model misspecification, we regressed CSLs on linear and quadratic birth year in the ACS population data and plotted the average residuals by 5-year birth cohort.

To further examine the robustness of the overall relationship between CSLs and pandemic-era mortality, we additionally included an analysis of a single-year CSL discontinuity leveraging difference-in-differences (DiD) analysis in a restricted geographic and temporal setting. Following Liu[29], we exploited a CSL policy change in 1946 in Southern states. In 1946, four states (Georgia, Louisiana, Missouri, and North Carolina) increased the minimum legal dropout age from 14 to 16 years old, while the mandatory school entry age remained unchanged. Our exposure was defined as the interaction between being in a treatment state and being in a birth cohort affected by the policy change (detail in eAppendix 1, https://links.lww.com/EDE/C350). We also included a falsification test with a nearby year without policy changes.

Analysis used Stata version 17, with code review on all statistical code, which is available on GitHub.

RESULTS

Sample Characteristics

The weighted sample represented a US population of 78.7 million individuals and 6.4 million all-cause deaths between March 2019 and December 2021 (502,779 COVID-19 deaths) (Table). Compared to nondecedents, decedents were older, and more likely to be male, Black, and have less education. Compared to decedents of all causes, individuals who died of COVID-19 were similarly aged, but more likely to be male, Black, and have lower education.

Applicable CSLs ranged from 6 to 12 years across states; 32 states changed their CSLs during the study period (see eFigure 3 https://links.lww.com/EDE/C350), with 1–5 policy changes per state (average = 1.2, total changes = 60). CSL requirements typically increased over time, but this was not universally true. The average number of mandatory years of schooling by state was 9.1.

Effect of CSLs on COVID-19 Mortality

Each additional year of mandatory schooling was associated with lower odds of COVID-19 mortality (Figure, eTable 1 https://links.lww.com/EDE/C350). For example, in pandemic year 1, individuals mandated to complete only 8 rather than 9 years of education (reference) based on birth state had higher odds of COVID-19 mortality (OR: 1.16; 95% confidence interval [CI]: 1.11, 1.20). The magnitude of this estimate was nearly identical for pandemic year 2 (OR: 1.13; 95% CI: 1.08, 1.17). Conversely, individuals mandated to complete 10 rather than 9 years of education had lower odds of COVID-19 mortality in both pandemic year 1 (OR: 0.96; 95% CI: 0.93, 0.98) and pandemic year 2 (OR: 0.97; 95% CI: 0.95, 1.00). Detailed results for all years of mandatory education are presented in eTable 1, https://links.lww.com/EDE/C350. The gradient of lower mortality with additional years of mandated schooling was present across all levels.

Effect of CSLs on All-cause Mortality

We also observed a dose–response relationship between CSLs and all-cause mortality, with no evidence of a differential effect when contrasting the pre-pandemic year with pandemic years 1 and 2 (Figure, eTable 1, https://links.lww.com/EDE/C350). In the year preceding the pandemic, being mandated to

TABLE. Sample Characteristics of Population and Decedents, Weighted

	Population at Risk (n = 78.7M)		Decedents (All Causes) (n = 6.4M)		Decedents (COVID-19) (n = 502,779)	
	N/ Mean	(%/ SD)	N/ Mean	(%/ SD)	N/ Mean	(%/ SD)
Age	67.4	(8.8)	75.8	(10.4)	75.0	(10.2)
Sex						
Male	36,707,418	(46.6%)	3,311,290	(51.9%)	275,419	(54.8%)
Female	41,997,790	(53.4%)	3,063,213	(48.1%)	227,360	(45.2%)
Race/ethnicity						
White	65,112,435	(82.7%)	5,308,793	(83.3%)	386,430	(76.9%)
Black	8,613,861	(10.9%)	795,042	(12.5%)	78,474	(15.6%)
Asian	296,698	(0.4%)	11,063	(0.2%)	919	(0.2%)
Hispanic	3,421,597	(4.3%)	202,270	(3.2%)	29,328	(5.8%)
Mixed/Other	1,260,617	(1.6%)	57,335	(0.9%)	7,628	(1.5%)
Reported education						
≤8th grade	2,209,088	(2.8%)	389,058	(6.1%)	37,010	(7.4%)
9–12th grade, no diploma	5,082,624	(6.5%)	613,098	(9.6%)	51,189	(10.2%)
HS diploma/GED	24,715,801	(31.4%)	2,853,916	(44.8%)	232,233	(46.2%)
≥Some college	46,697,695	(59.3%)	2,451,884	(38.5%)	176,163	(35.0%)
Missing	0	(0.0%)	66,547	(1.0%)	6,184	(1.2%)
CSLs based on dropout age	9.2	(0.9)	9.1	(0.9)	9.2	(0.9)
CSLs based on work permit age	8.1	(1.1)	7.9	(1.2)	7.9	(1.1)
State of birth characteristics, age 6						
Percent urban	66.8	(16.4)	60.7	(18.6)	60.7	(18.5)
Percent Black	10.8	(10.1)	11.3	(11.4)	12.0	(11.6)
Percent foreign	5.8	(4.8)	6.6	(6.0)	6.2	(5.9)
State of birth characteristics, age 14						
Manufacturing jobs per capita	68.8	(25.6)	70.5	(30.2)	69.7	(30.1)
Avg. manufacturing wages	40765.3	(8387.2)	34615.5	(9046.7)	34918.7	(8908.2)

Population from ACS PUMS 1% 2019 and decedents from March 2019 - December 2021 US death certificates, born before 1964.
Weighted N = 85.1M.
GED indicates General Education Development; HS, high school; M, million.

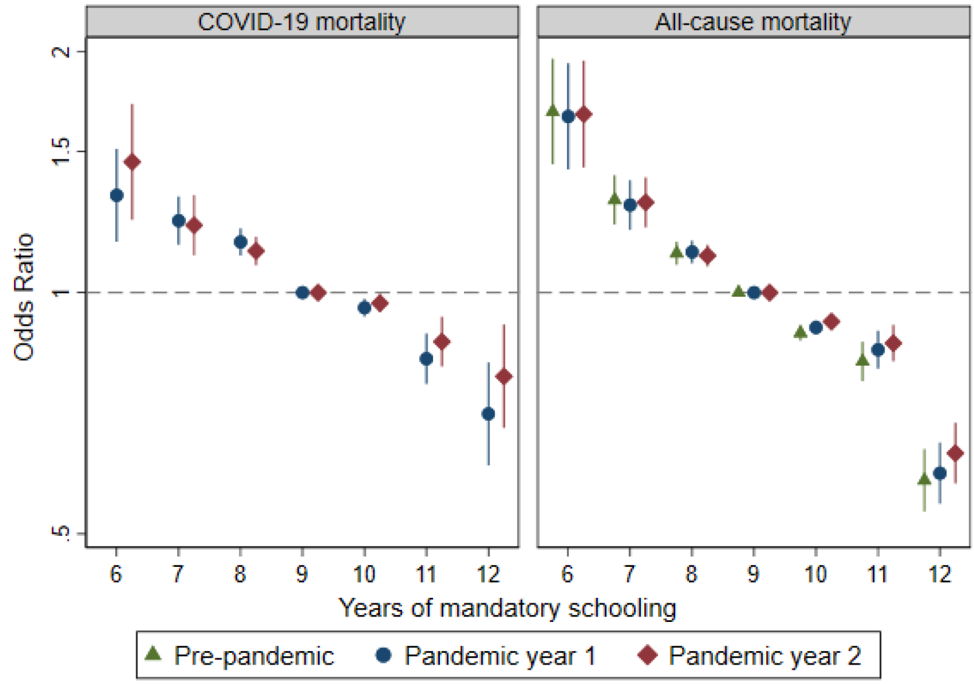

FIGURE. Effect of CSLs on COVID-19 and all-cause mortality, March 2019–December 2021. Source: Population from ACS PUMS 1% 2019 and decedents from March 2019–December 2021 US death certificates, born before 1964. Years are defined as pre-pandemic: Mar 2019–Feb 2020, pandemic year 1: Mar 2020–Feb 2021, pandemic year 2: Mar 2021–Dec 2021. Models adjusted for sex, race, ethnicity, year of birth (linear and quadratic terms), state of birth fixed effects, and time-varying state-level factors. Reference group = 9 years of mandatory schooling. Weighted N = 85.1M. M indicates million. Group sizes by years of mandatory schooling are as follows: 6: 0.05%, 7: 0.25%, 8: 11.9%, 9: 67.4%, 10: 11.1%, 11: 3.5%, 12: 5.7%.

complete only 8 (vs. 9) years of schooling was associated with higher odds of all-cause mortality (OR: 1.12; 95% CI: 1.08, 1.16), nearly identical to the OR for all-cause mortality during the pandemic (year 1 OR: 1.12; 95% CI: 1.09, 1.16; year 2 OR 1.11; 95% CI: 1.08, 1.15). Being mandated to complete 10 (vs. 9) years was associated with lower odds of all-cause mortality pre-pandemic (OR: 0.89; 95% CI: 0.87, 0.91) and during the pandemic (year 1 OR: 0.90; 95% CI: 0.89, 0.92; year 2 OR: 0.92; 95% CI: 0.90, 0.94). A dose–response gradient was present across all mandated schooling levels (eTable 1, https://links.lww.com/EDE/C350).

Subgroup Analyses

The stratified analysis provided evidence of effect modification by sex and racial identity. The gradient between state-level CSLs and COVID-19 in pandemic year 1 and all-cause mortality across all periods appeared steepest among Black women and steeper among women versus men within both Black and White individuals in the CSL range of 8–10 years of schooling, where estimates were most precise (eTable 2, eFigure 4, eAppendix 2, https://links.lww.com/EDE/C350). Across most periods, we observed differences in stratified trends between Black women versus White men, Black men, and White women, as well as between White women versus White men.

Secondary Analyses

In analyses separately estimating CSL effects among individuals residing inside versus outside their birth state, we found evidence of effect modification. Results showed similar patterns but were attenuated among individuals residing outside their birth state (eFigure 5, eAppendix 2, https://links.lww.com/EDE/C350).

Overall trends were similar when coding CSLs using work permit age rather than legal dropout age, but the pattern in the most common mandated schooling years (7, 8, or 9) was relatively flat (eFigure 6, eAppendix 2, https://links.lww.com/EDE/C350).

Our results were robust to alternative dates (eFigure 7, eAppendix 2, https://links.lww.com/EDE/C350) and to the use of replicate weights (eTables 3A and 3B, eAppendix 2, https://links.lww.com/EDE/C350).

We identified modest to strong correlation between some state-level factors (eTable 4, https://links.lww.com/EDE/C350). When excluding state-level factors, we identified a similar overall pattern, although the dose–response pattern was not as consistent (eFigure 8, eAppendix 2, https://links.lww.com/EDE/C350).

When comparing models with varying birth year specifications (eTable 5, https://links.lww.com/EDE/C350), we found that the overall gradient appeared across specifications, with slight differences, for example, 10 (vs. 9) years of mandatory schooling showed higher mortality for 5-year cohort bins and birth year fixed effects specifications. We found model fit statistics were strongest for birth year fixed effects, followed by linear and quadratic continuous birth year terms, followed by a categorical variable reflecting 5-year birth year bins.

We did not find evidence of any discernible trend in the residuals from CSLs and our birth year specification across 5-year birth cohorts that would suggest misspecification of the birth year control in our primary analysis (eFigure 9, https://links.lww.com/EDE/C350).

In the DiD analysis of the 1946 CSL discontinuity, we found the CSL increase was associated with lower all-cause mortality. While the estimate for COVID-19 mortality was also negative in magnitude, we did not find statistical evidence of an association. The falsification test did not identify any associations with lower mortality (eTable 6, eAppendix 2, https://links.lww.com/EDE/C350).

DISCUSSION

Combining information on historical state-level schooling laws, national mortality, and population estimates, we demonstrated that people who were born into states with longer mandated schooling requirements had lower COVID-19 mortality and all-cause mortality decades after the policies were enacted. Longer education mandates were associated with lower mortality across the range of required schooling from 6 to 12 years. The relative effects on all-cause mortality were similar before and during the pandemic. While the dose–response patterns were evident across sex and race subgroups, CSLs reduced mortality more strongly among women than men and particularly among Black women.

Our findings implicate policies adopted decades ago in shaping COVID-19 mortality. Individual educational attainment is likely a major pathway connecting CSLs and mortality risk. Our findings are thus consistent with existing evidence that more years of attained education reduce mortality, including a 2024 meta-analysis finding a dose–response relationship between completed education and adult all-cause mortality globally.[19] Pre-pandemic research documented a long-standing educational gradient in mortality, using both traditional and instrument-based methods, including CSLs,[8–10] and research during the pandemic also found evidence of stark disparities in COVID-19 mortality by educational attainment.[4,5]

Our results are broadly consistent with fundamental cause theory, in that education is a highly flexible resource that influences the patterning of disease outcomes. We did not find evidence that the educational gradient in COVID-19 mortality was drastically different from the existing gradient in all-cause mortality. Our findings align with Case and Deaton's work, finding a relatively stable association between greater educational attainment and decreased all-cause mortality before and during the COVID-19 pandemic.[18] In contrast, other research found relative and absolute disparities in all-cause mortality by educational attainment were somewhat stable from 2017 to 2019 but increased from 2019 to 2020.[30] While these studies analyzed educational attainment, our research is novel in leveraging CSLs rather than traditional confounder control. The disease preventability and preventability shifts approaches of fundamental cause theory would suggest that the extent of social patterning of COVID-19 mortality would depend on the preventability of the disease itself, compared with all-cause mortality and over time. However, we also did not find evidence that educational inequalities grew as the pandemic evolved and a larger repertoire of preventative and treatment strategies became available.[20] This may reflect the fact that, essentially, in the first weeks of the pandemic, there was a known preventive strategy—physical isolation—differentially available to highly educated individuals. Against this backdrop of a highly effective preventive strategy, additional evidence and tools for prevention and treatment may not have substantially increased the educational advantage. It is also possible that there were differing educational gradients in disease transmission across the pandemic period that are not apparent when examining mortality.

Existing research on education and pandemic-era mortality generally has not accounted for community-level education. The attenuated associations among individuals residing outside their birth state could indicate that CSLs influence mortality partially via community-level pathways such as average educational attainment or local economic growth. Pathways could include disease protection behaviors (e.g., masking and distancing) or socioeconomic factors (e.g., ability to work remotely) in the local community. Attenuated results could be due to individuals moving before exposure to their birth state's CSLs, although the vast majority of US children live in their birth state at least through secondary school.[24,27]

We did not evaluate why longer school mandates affect mortality, but hypothesize several mechanisms. Effects extended to older adults unlikely to be in the labor force, so direct occupational exposures are unlikely to be fully responsible, though indirect effects via co-resident working-age adults are possible. Additional mechanisms include literacy/numeracy to sift through health information,[14] institutional trust amid political polarization, financial security, and accumulation of comorbidities.[31] Although CSLs predict individual educational attainment,[9,24,25] the associations are too small to fully explain the large effects of CSLs on mortality. We hypothesize that changes in enrollment and dropout age policies coincided with other educational investments—such as longer school term lengths, higher teacher pay, smaller class sizes, and greater school resources[26]—which may have enhanced student benefits.[14]

Our use of CSLs effectively ruled out individual-level confounders for the relationship between educational attainment and mortality, such as childhood socioeconomic status or intellectual ability. Moreover, by incorporating state fixed effects, we demonstrated that this is not merely a geographic pattern of mortality. Even after accounting for state fixed effects, birth cohorts with longer required schooling experienced lower mortality. However, we cannot rule out other state policy changes that may have been adopted in tandem with increases in compulsory education. Additionally, historical factors influencing migration and residence patterns shaped where people live; for example, one of the Oregon Black exclusion laws was not repealed until 1926.[32] Individual characteristics such as racialized identity are historically linked to the state of birth and therefore CSL exposure. While we adjusted for race/ethnicity and sex in our model, other individual-level factors may have a role.

CSLs included exemptions for several reasons, such as mental or physical disability, distance from school, poverty, lack of schools, and work permits; CSLs likely did not benefit all populations equally.[24] While we separately examined the impact of work permits and examined heterogeneity by race/ethnicity and sex, we did not examine other exemptions that may have influenced CSLs' impact, such as poverty or rural residence. Our main results, therefore, average across populations more and less likely to experience CSL benefits.

The race and sex variations in associations are somewhat consistent with the limited available prior evidence. Prior research also shows greater health benefits from additional education for women,[33,34] particularly Black women.[34,35] The theory of resource substitution posits that individuals with lower access to flexible resources (e.g., education) due to structural racism and sexism will benefit more from additional education.[33] The steeper benefits for Black women may also reflect broader changes during this period, including increased employment opportunities for Black women following the Civil Rights Act of 1964, which may have led to greater returns on education.[35,36] On the other hand, CSLs may have been less enforced for Black children, who also may have been more likely to be exempt based on poverty or lacking school access.[24] Partly in contrast to our observed results, we might therefore expect a less steep gradient for Black men and women.

Research on how childhood policies impact age-related health outcomes faces inherent challenges in isolating policy effects from birth cohort effects and heterogeneous or dynamic policy effects. CSLs demonstrate largely (though not exclusively) monotonic increases over time, which creates collinearity with birth cohort. We examined the robustness of our results to alternative birth cohort specifications. Comparing these specifications is valuable when balancing accounting for confounding versus restricting variation or encountering multicollinearity. While models including birth year fixed effects may improve control for potential confounding due to birth year cohort, these fixed effects can also remove variation of interest.[37] An overall gradient appeared to be present across our specifications, although some models differed on whether mortality was higher for 10 (vs. 9) years of mandatory schooling. Examination of residuals from CSLs and our birth year specification by 5-year birth cohorts also did not provide evidence of misspecification of birth year control. We also examined results across populations; if results were driven mainly by birth cohort effects, we would expect similar dose–response mortality gradients for all settings with monotonic policy changes. However, we observed differences in the gradients between people residing in and outside of their state of birth based on the interaction term and stratified results, suggesting there may be effects via specific pathways from CSLs. Finally, the inclusion of DiD analysis of a single-year CSL discontinuity provides a different perspective on the relationship of interest with differing model assumptions. Observing an impact due to a single year CSL change in a restricted 10-year birth cohort supports our overall findings of a relationship between CSLs and pandemic-era mortality.

Strengths of this study include rich data and linkage to CSLs using the state and year of birth for every individual. Prior instrumental variable analysis shows mixed effects of CSLs,[13] potentially due to limited power or heterogeneity.[38] We addressed prior challenges using a 1% population sample and comprehensive death data. We adopted intent-to-treat rather than instrumental variables analysis as CSLs may influence mortality via mechanisms beyond individual education, for example, community-level education or economic growth. By combining weighted ACS data with national death records, we emulated a national cohort and derived fairly precise estimates.

This study has several limitations. We restricted to US-born individuals born 1926–1964. CSLs may be less relevant for recent cohorts; research examining recent education policies is needed. We used 2019 ACS data to define the population at-risk of mortality at the pandemic outset; however, population characteristics may have changed given deaths among older adults. We may face measurement error due to age rounding and race/ethnicity misclassification in death certificates (see eAppendix 1, https://links.lww.com/EDE/C350). We did not assess heterogeneity by cohorts and birthplace, as found in prior research.[8] We cannot rule out state-level confounding by co-occurring policies; however, our approach circumvents individual-level confounders.

In conclusion, state policies mandating compulsory schooling, implemented decades ago, continued to offer survival benefits even through the pandemic. Middle-aged and older adults born into states that required longer schooling experienced markedly lower mortality during the pandemic compared with individuals born into states requiring less schooling. Our findings suggest likely benefits of policies expanding education access (such as to pre-kindergarten or post-secondary education) in protecting long-term population-level health.

ACKNOWLEDGMENTS

MLC is grateful for support from the Schmidt Center of MIT-Harvard Broad Institute through the doctoral fellowship program.

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