

Evaluating the Impact of Universal Free School Meals on Child Blood Pressure

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Abstract

Evaluating the Impact of a Universal Free School Meals Policy on High Blood Pressure in
Children

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High blood pressure in children is linked to negative health outcomes in adulthood. The Community Eligibility Provision, a federal universal free school meals policy, has the potential to reduce high blood pressure in children by expanding access to free breakfast and lunch to all students in low-income schools, who are at increased risk of developing high blood pressure. The purpose of this dissertation research is to describe school characteristics associated with CEP participation, and to use this information to evaluate the effectiveness of this policy in reducing high blood pressure in children. Specifically, the three aims of this dissertation research are to 1) Assess school and area characteristics associated with CEP participation and how these associations have changed over time 2) Estimate the association of CEP with blood pressure outcomes 3) Assess heterogeneity in the association of CEP and high blood pressure prevalence by age and race and ethnicity.

CHAPTER 1: INTRODUCTION

Over the past several decades, high blood pressure (BP) in children has emerged as a pressing public health concern for which population-level solutions are lacking.¹⁻³ This dissertation research examines the Community Eligibility Provision (CEP), a federal universal free school meals (UFM) policy, as a potential population-level approach to address high BP in children. Grounded in fundamental cause theory and using an implementation-effectiveness hybrid design, this research aims to assess barriers and facilitators to CEP participation among eligible schools. It then uses this information to test whether CEP impacted high BP in a sample of low-income youth, and whether these impacts varied by demographic group.

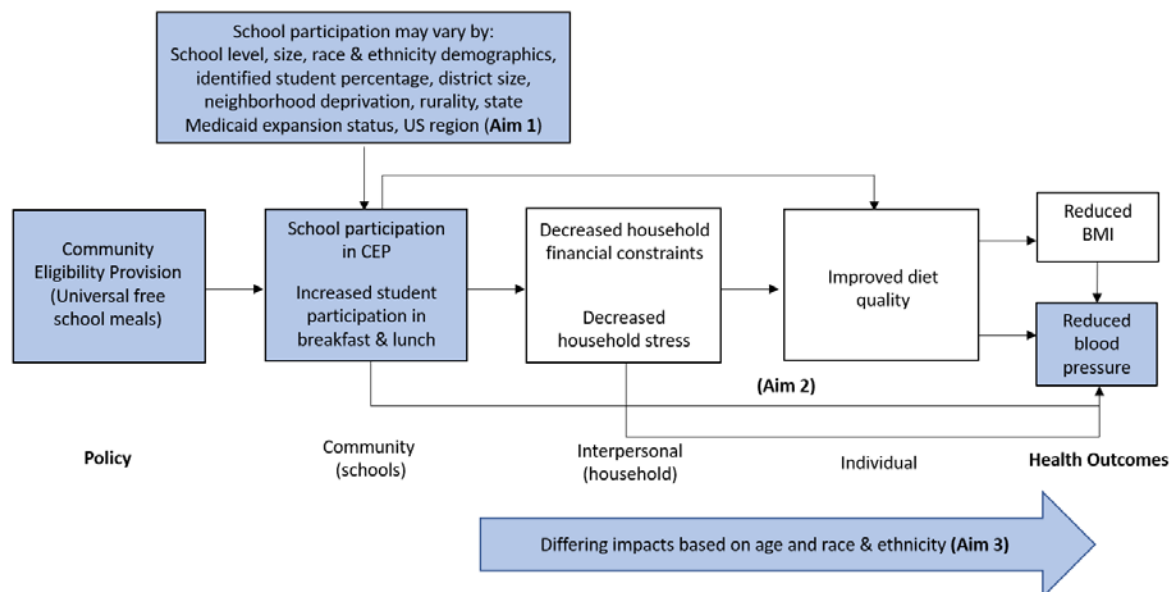
High BP includes both elevated BP (systolic or diastolic BP between the 90th and 95th percentiles for age, sex, and height based on normal-weight children) and hypertension (systolic or diastolic BP at or above the 95th percentile).¹ Approximately 11% of children are estimated to have high BP, but prevalence is higher among boys compared to girls and adolescents compared to younger children.^{1,3} Children with high blood pressure are significantly more likely to develop hypertension as young adults, a leading cause of heart disease and stroke.^{4,5} Common risk factors for high BP in children include obesity and unhealthy diet.^{1,2} These risk factors, however, are downstream of fundamental causes of disease like socioeconomic status and structural racism.^{6,7} These fundamental drivers result in disparities in high BP by race and ethnicity and socioeconomic status, with Black, Hispanic, and low-income children being disproportionately affected.⁸

Efforts to control hypertension have recently been emphasized by the US Surgeon General, underscoring the need for large-scale interventions that target social determinants of health.⁹ The Dietary Approaches to Stop Hypertension or DASH diet, which is high in fruits, vegetables, and low-fat dairy and low in saturated and trans-fat and sodium is recommended as the primary non-pharmacological intervention to address high BP,¹ and has been shown to

reduce pediatric high BP in short-term clinical interventions.^{10,11} However, implementing such clinical interventions at a population-level would be unfeasible, given limited coverage by health insurers for such behavioral health interventions and the inequities inherent in access to preventive healthcare in the US.

Schools represent a promising setting for delivering population-level public health interventions. CEP, authorized by the 2010 Healthy, Hunger-Free Kids Act (HHFKA), became available to eligible schools nationwide beginning in 2014, and allows schools in low-income areas to provide free breakfast and lunch to all students. As CEP became available, the HHFKA also improved nutrition standards for school meals, requiring that they align with the US Department of Agriculture Dietary Guidelines for Americans, which promotes a diet similar to DASH. As of 2023, this policy reached nearly 20 million children - 40% of all school-age children nationwide.¹²

CEP is hypothesized to reduce child blood pressure through several mechanisms as displayed in the conceptual model below. The conceptual model integrates the Social Ecological Model and Fundamental Cause Theory to elucidate the pathways through which CEP may influence BP outcomes and disparities.^{6,13} CEP is a policy enacted at the federal level, and is



Conceptual Model of the mechanisms by which the Community Eligibility Provision may reduce high blood pressure. Model is adapted from the Social Ecological Model of Health (McLeroy et al. 1988) and informed by Fundamental Cause Theory (Link and Phelan 1995).

made available to eligible, low-income schools nationwide. By providing federal funding to low-income schools, CEP targets access to economic resources, a fundamental cause of disease, which impacts risk factors for high BP at multiple levels of influence, including institutional, interpersonal, and individual.^{6,13,14} At the institutional level, schools that adopt CEP experience increased participation in school meals.¹⁵ CEP eliminates the need for individual meal applications, reduces the stigma associated with receiving free meals, and extends free meals to students from middle and lower-middle income households who fall above the eligibility threshold for free meals.^{16,17} I also hypothesize that school CEP participation may vary by school- and area-level characteristics (Aim 1).

At the household level, CEP may alleviate financial constraints by saving families grocery expenses, which could result in increased household spending on health-promoting goods or services.¹⁸ This could also lead to decreased household financial stress, and stress is linked to high blood pressure.^{19–21} At the individual level, CEP leads to improved diet quality by increasing participation in school meals. Research has repeatedly shown that the improved school meal nutrition standards introduced by the HHFKA resulted in improved dietary quality of school meals, and that school meals are on average healthier than alternatives.^{22–25} When schools adopt CEP, students may be substitute up to half of their weekly diet with more nutritious options. The health impacts from these various levels of influence may result in decreased BP directly, or indirectly through reduced obesity (Aim 2). Emerging evidence suggests that CEP is associated with reductions in obesity.^{26,27} Finally, I hypothesize that CEP may impact child blood pressure differentially by age group and by race and ethnicity, since BP outcomes differ by these demographic categories (Aim 3).

Motivated by the theoretical model described above, this dissertation research assesses the nationwide implementation of CEP and whether CEP affects child BP overall and in populations disproportionately burdened by its health consequences. The first paper, titled “Characteristics Associated with Participation in the Community Eligibility Provision, a Universal

Free School Meals Policy: 2014-2020”, uses data on CEP participation nationwide to describe trends in adoption during the first six years of the policy’s rollout leading up to the COVID-19 pandemic. As shown in the above model, I hypothesize that school-level factors such as school type, school size, and percent of students eligible for free or reduced-price meals, as well as area-level factors such as neighborhood deprivation, and rurality may affect both selection into a CEP-participating school, as well as BP outcomes. Selection of characteristics included in the analysis was guided by findings from prior research as well as the Consolidated Framework for Implementation Research.^{28–31} By describing associations of CEP participation with key school characteristics and how these associations have changed over time, important barriers and facilitators to policy adoption can be identified. Further, this information aids in designing the natural experiment used in the subsequent two dissertation papers.

The second paper, titled “School Participation in the Community Eligibility Provision and Blood Pressure Outcomes among Children and Adolescents who Visited Community Health Centers between 2013 and 2020” assesses the overall association of attending a CEP-participating school and blood pressure outcomes obtained from the electronic health record in an open cohort of patient ages 4-18. I use a difference-in-differences methodological approach, balancing on factors associated with CEP participation reported in the first paper, to assess whether BP decreased in CEP-participating compared to non-participating students. The third paper, titled “Heterogeneous Associations of the Community Eligibility Provision with High Blood Pressure by Child Age and Race or Ethnicity” uses a similar difference-in-differences approach for staggered policy adoption that allows for assessment of heterogeneous associations by group. In this analysis, I test the association of CEP participation and high blood pressure by demographic category.

This dissertation research aims to contribute to understanding of the implementation and effectiveness of a large-scale federal nutrition assistance policy and its potential impacts on

child health. Further, through linking school data to child medical record data, this research provides a unique opportunity to examine the impacts of a social safety net nutrition policy on blood pressure outcomes. Previous research on high blood pressure been limited to clinical settings. In the wake of the COVID-19 pandemic when waivers allowed all schools nationwide to provide universal free meals, some states have since adopted universal free school meals policies while others are considering doing so. Therefore, this research is highly relevant and has the potential to inform decision-making regarding the future of school meal policies.

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CHAPTER 2

Title:

Characteristics Associated with Participation in the Community Eligibility Provision, a Universal Free School Meals Policy: 2014-2020

Authors:

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Abstract:

We assessed the association of participation in the Community Eligibility Provision, a universal free school meals policy, with school and area-level characteristics, and how these associations changed over time. Using logistic generalized estimating equations models, in 53,391 eligible schools nationwide between 2014-2020, adjusted prevalence of participation was 6.2 percentage points (pp) lower among high schools relative to elementary schools (95% CI: 5.3, 7.1), 8.3pp lower in small relative to large school districts (95% CI: 7.3, 9.3), 7.4 pp lower in suburban relative to urban schools (95% CI: 6.5, 8.3), and 18.91 pp lower in Mountain Plains schools relative to those in the Southeast (95% CI: 17.1, 20.7). Time trends reveal a lower change in prevalence of participation in majority Hispanic relative to majority Black schools. As evidence mounts showing the benefits of universal free school meals for child well-being, addressing these barriers will be important to increase participation.

Background:

The Community Eligibility Provision (CEP), a federal universal free school meals (UFM) policy authorized by the 2010 Healthy, Hunger-Free Kids Act (HHFKA), allows eligible low-income schools to provide free breakfast and lunch to all students. CEP increases participation in school meals,¹ which are healthier than alternatives, particularly after the HHFKA improved nutrition standards.² CEP reduces the stigma associated with receiving free meals³ and eliminates the need for applications. It also extends access to children whose household falls above the income eligibility threshold (\$39,000 annually for a family of four as of 2023).⁵ CEP is associated with improvements in student academic, behavioral, and health outcomes, as well as increased disposable income for low-income families.^{1,6-8}

CEP is administered through the School Breakfast Program (SBP) and National School Lunch Program (NSLP). In schools not participating in CEP, SBP and NSLP provide free and reduced-price meals to qualifying students from low-income households. To qualify for free or reduced-price meals in non-CEP schools, students must either apply or are directly certified via participation in a federal assistance program like the Supplemental Nutrition Assistance Program (SNAP). Students identified as homeless, migrant, or in foster care or Head Start are also directly certified for free meals, and some states use Medicaid for direct certification. To be eligible for CEP, schools must have an identified student percentage (ISP) of 40% or greater. ISP is calculated using the proportion of directly certified students in a school. ISP is multiplied by 1.6 to determine percent of meals reimbursed at the federal free rate; schools with an ISP of 62.5% or higher are reimbursed at the free rate for 100% of meals served.

In 2014 when CEP became an option for eligible schools nationwide, about 14,000 schools participated.⁹ By 2020, participation increased to over 30,000 schools.⁹ The COVID-19 pandemic led to the US Department of Agriculture (USDA) issuing nationwide waivers allowing all schools to implement UFM for two years, however these have since expired. As of 2023,

40,235 schools were participating in CEP (82% of eligible schools), reaching 19.9 million children.⁹

Several studies have examined factors associated with CEP participation. Turner and colleagues assessed schools in California between 2013-2017 using repeated cross-sectional analyses,¹⁰ and Rogus and colleagues assessed school districts cross-sectionally in school year 2015-16 in a sample representing approximately 60% of all districts nationwide.¹¹ Hecht and colleagues conducted a cross-sectional analysis of schools nationwide in school year 2017-18.¹² Authors consistently found CEP participation was positively associated with larger school districts and higher ISP.¹⁰⁻¹² However, other findings were conflicting; for example, school-level analyses found inconsistent relationships of CEP with school size, level, and rurality^{10,12} which could have implications for how resources are allocated and where outreach efforts are focused. Additionally, no studies have examined longitudinal trends in CEP participation, allowing for evaluation of how characteristics of CEP-participating schools have changed over time. From this, we can identify both longstanding and emerging barriers and facilitators to participation. For example, a higher change in participation over time could indicate the introduction of a successful strategy for policy adoption, whereas a lower change in participation could signal that certain types of schools are failing to successfully adopt. Therefore, the purpose of this study is to 1) assess the overall association of CEP participation with school- and area-level characteristics, and 2) how these associations have changed over time.

Methods:

Conceptual Framework

Selection of characteristics was based on existing evidence and guided by the Consolidated Framework for Implementation Research (CFIR). CFIR provides a menu of constructs associated with effective implementation, organized into five domains: innovation

(policy being implemented), outer setting (broader contextual environment in which the policy is implemented), inner setting (specific setting where the policy is implemented), individuals (characteristics of individuals who implement, receive, or otherwise influence/are influenced by the intervention), and implementation process (activities and strategies used to implement the innovation).¹³

Independent Variables

Table 1 shows school- and area-level characteristics hypothesized to be associated with CEP participation, organized by constructs. Some measures capture more than one construct. We selected a total of 11 variables. School-level variables include ISP (categorized into deciles), percent Black, Hispanic, and White students (the largest race and ethnicity groups represented), enrollment (categorized as fewer than 400 students, 400-699, 700-999, or 1000 or more), and school level (elementary, middle, high, or other (e.g. K-12)).

Community-level variables include school district size (fewer than 10 schools, 10-20 schools, 21-30 schools, or greater than 30 schools), neighborhood deprivation measured by the Social Deprivation Index (SDI), a composite score with a scale from 0 to 100 with 100 indicating the highest deprivation,¹⁴ and locale (urban, suburban, town, or rural). Regional characteristics include state Medicaid expansion status (binary) and USDA region (Western, Mountain Plains, Southwest, Midwest, Mid-Atlantic, Northeast, and Southeast). All data came from the National Center for Education Statistics (NCES) common core of data,¹⁵ except for neighborhood deprivation from the Robert Graham Center,¹⁴ Medicaid expansion status from KFF (formerly the Kaiser Family Foundation),¹⁶ and regions from USDA.¹⁷ Table 1 describes rationale for selection of variables.

Construct: Innovation Cost	Construct Definition: Degree to which the innovation purchase and operating costs are affordable	Measures: School ISP ^a School Size District Size Region	Rationale: CEP adoption is most affordable for schools with ISP above 62.5% - the threshold at which all meals are reimbursed at the free rate, which is associated with CEP adoption ^{1,2} Larger schools and/or districts may benefit from economies of scale, for whom the policy may be more affordable ¹⁻⁴ Food and labor costs vary by region, which could impact program affordability ^{1,2,4}
Construct: Local Attitudes	Construct Definition: Degree to which sociocultural values and beliefs encourage the Outer Setting to support implementation and/or delivery of the innovation	Measures: Locale State Medicaid Expansion	Rationale: Local attitudes differ by urbanicity which may impact policy adoption Schools in states that have expanded Medicaid may be more amenable to adopting other safety net programs ¹
Construct: Local Conditions	Construct Definition: Degree to which economic, environmental, political, and/or technological conditions enable the Outer Setting to support implementation and/or delivery of the innovation	Measures: Locale Neighborhood Deprivation	Rationale: Rural areas experience higher poverty relative to urban areas ⁵ , which could drive CEP adoption. ³ Schools in high-poverty areas may be incentivized to adopt CEP to address higher rates of food insecurity
Construct: Partnerships & Connections	Construct Definition: Degree to which the Inner Setting is networked with external entities	Measure: Region	Rationale: Outreach and support to schools and districts occurs at the regional level and may impact CEP participation rates ^{1,2,6}
Construct: Policies & Laws	Construct Definition: Degree to which legislation, regulations, etc. support implementation and/or delivery of the innovation	Measure: State Medicaid Expansion	Rationale: Medicaid expansion increases direct certification in some states, ⁷ which could increase school meal participation and incentivize CEP adoption
Construct: Need	Construct Definition: Degree to which the individuals have deficits related to survival, well-being, or personal fulfillment, which will be addressed by the innovation	Measures: School ISP Race and Ethnicity Neighborhood Deprivation	Rationale: ISP reflects student economic need; schools with higher ISP may adopt CEP to address unmet student nutrition needs ^{1,2} Racially and ethnically minoritized students are more likely to experience food insecurity ⁸ ; schools with more minoritized students may be driven adopt CEP to address need Neighborhood deprivation may reflect student need beyond ISP, which could drive adoption
Construct: Innovation Recipients	Construct Definition: Individuals who are directly or indirectly receiving the innovation	Measures: School level Race and ethnicity	Rationale: School meal participation rates are higher among elementary school students, ⁹ which may drive adoption Meal participation rates are higher among Black and Hispanic compared to White students, ⁹ which may drive adoption.

Table 1. Variables hypothesized to be associated with CEP adoption using the Consolidated Framework for Implementation Research (CFIR). Table includes study measures hypothesized to be associated with CEP adoption, their data source, and the rationale for the hypothesized association. The measures are organized according to the Consolidated Framework for Implementation Research, which includes five domains (innovation, outer setting, inner setting, individuals, and implementation process). Selected constructs and their definition are included under selected domains. Variables were assigned to the underlying construct they are intended to measure. Some variables capture more than one construct.

Dependent Variable

Binary school-level CEP participation data, measured yearly between 2014-2020, were obtained from state departments of education, NCES, and replication data from another researcher⁸.

Inclusion Criteria

The analysis included all schools nationwide with an ISP of 40% or higher in any year during the study period, which was used as a proxy for school CEP eligibility. ISP was obtained from state departments of education, NCES, and Food Research and Action Committee (FRAC).

Statistical Analysis

Data were assessed for missingness which ranged from 0-2% among all variables except ISP, for which 19% of observations were missing. To address missingness, we used multiple imputation by chained equations. We used logistic generalized estimating equations (GEE) models with an exchangeable correlation structure and cluster-robust standard errors. This model produces valid standard errors even if within-group correlations are not exchangeable. To assess the overall association of school and area-level characteristics with CEP participation, we fit the following model (Model 1):

$$\begin{aligned} \text{logit}(E[Y_{ij}|X_{ij}]) = & \beta_0 + \beta_1 \text{SchType}_i + \beta_2 \text{ISP}_i + \beta_3 \text{SchSize}_i + \beta_4 \text{PercHis}_i + \\ & \beta_5 \text{PercBlack}_i + \beta_6 \text{PercWhite}_i + \beta_7 \text{DistSize}_i + \beta_8 \text{SDI}_i + \beta_9 \text{UrbRur}_i + \beta_{10} \text{MedicaidExp}_i + \\ & \beta_{11} \text{Region}_i + \beta_{12} \text{Year}_j \end{aligned}$$

Y_{ij} represents the log-odds of CEP participation for year i and school j , conditional on covariates. For ease of interpretability, from this model we computed predicted probabilities, multiplied by 100 to obtain estimated prevalence of CEP participation. β 's of independent variables (β_1 - β_{11})

represent the association of characteristics with CEP participation, adjusted for covariates including time trends (β_{12}). We performed Wald tests for all categorical variables to test the null hypothesis that coefficients for all category levels were equal to zero. To assess time trends in these associations, we added interactions with time for all covariates (Model 2). In Model 2, β 's of independent variables interacted with year represent the change in associations over time. We initially modeled time as an indicator variable to allow for flexible time trends. However, plots based off this specification showed approximately linear increases in participation over time. Therefore, in the final models we include time as a continuous variable. We conducted all analyses using StataMP 18.

Results:

Table 2 displays characteristics by year of 53,391 distinct schools eligible for CEP between 2014-2020. Not all schools report measurements in all years, as some opened or closed during this period; Table 2 displays number of distinct schools contributing measurements in each year. Time-varying characteristics remained stable with the exception of schools in Medicaid expansion states, which increased during the study period as more states expanded Medicaid, and ISP category, which fluctuated across years. Depending on the year, 21-29% of schools reported an ISP less than 40%. However, because CEP eligibility is redetermined every four years, most of these schools remained eligible to participate.

Figure 1 displays adjusted estimates and 95% confidence intervals of overall prevalence of CEP participation by school and area characteristics. After adjusting for covariates, elementary schools had the highest prevalence of participation (6.20 percentage points (pp) higher than high schools (95% CI: 5.27 pp, 7.14 pp)). School size was positively associated with participation; schools with more than 1,000 students had a 3.48 pp higher prevalence of participation than schools with fewer than 400 students (95% CI: 2.26 pp, 4.69 pp). ISP also was positively associated with participation; relative to schools with ISP of 40-50%, schools with

	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019	2019-2020
Total Unique Schools = 53,391	N Schools = 49,168	N Schools = 49,165	N Schools = 48,922	N Schools = 48,898	N Schools = 48,588	N Schools = 47,941
School-Level Characteristics						
School Level (N (%))						
Elementary	29,239 (59%)	29,181 (59%)	29,148 (60%)	29,271 (60%)	29,184 (60%)	28,995 (60%)
Middle/Jr. High	7551 (15%)	7,490 (15%)	7,502 (15%)	7,519 (15%)	7,454 (15%)	7,362 (15%)
High	7745 (16%)	7,906 (16%)	7,802 (16%)	7,809 (16%)	7,844 (16%)	7,610 (16%)
Other (e.g. K-12)	4633 (9%)	4,588 (9%)	4,471 (9%)	4,299 (9%)	4,107 (8%)	3,975 (8%)
School Enrollment (N (%))						
Small (< 400 students)	22,476 (46%)	22,604 (46%)	22,670 (46%)	22,793 (47%)	22,857 (47%)	22,739 (47%)
Medium (400-699 students)	17,443 (35%)	17,459 (36%)	17,273 (35%)	17,277 (35%)	17,135 (35%)	16,777 (35%)
Large (700-999 students)	6,087 (12%)	5,949 (12%)	5,859 (12%)	5,742 (12%)	5,533 (11%)	5,344 (11%)
Very Large (≥ 1000 students)	3,162 (6%)	3,152 (6%)	3,120 (6%)	3,087 (6%)	3,063 (6%)	3,082 (6%)
Identified Student Percentage (ISP) (N (%))						
Less than 40%	12,035 (24%)	10,868 (22%)	13,947 (29%)	10,030 (21%)	10,683 (22%)	12,585 (26%)
40-50%	15,486 (31%)	15,352 (31%)	12,403 (25%)	12,152 (25%)	12,014 (25%)	11,960 (25%)
50-60%	8,921 (18%)	9,638 (20%)	8,779 (18%)	10,094 (21%)	9,830 (20%)	9,152 (19%)
60-70%	6,695 (14%)	7,397 (15%)	6,963 (14%)	8,839 (18%)	8,344 (17%)	7,240 (15%)
70-80%	3,603 (7%)	3,569 (7%)	3,940 (8%)	4,464 (9%)	4,587 (9%)	4,138 (9%)
80-90%	1,663 (3%)	1,630 (3%)	2,014 (4%)	2,383 (5%)	2,369 (5%)	2,058 (4%)
90-100%	765 (2%)	711 (1%)	877 (2%)	935 (2%)	762 (2%)	808 (2%)
Percent Students by Race and Ethnicity (mean (sd))						
White	38% (0.15%)	38% (0.15%)	37% (0.15%)	36% (0.15%)	36% (0.15%)	35% (0.15%)
Hispanic	30% (0.14%)	31% (0.14%)	31% (0.14%)	32% (0.14%)	32% (0.14%)	33% (0.14%)
Black	24% (0.13%)	23% (0.13%)	23% (0.13%)	23% (0.13%)	23% (0.13%)	22% (0.13%)
Asian	3% (0.03%)	3% (0.03%)	3% (0.03%)	3% (0.03%)	3% (0.03%)	3% (0.03%)
Native American or Alaska Native	2% (0.05%)	2% (0.05%)	3% (0.06%)	3% (0.06%)	3% (0.05%)	3% (0.06%)
Pacific Islander or Native Hawaiian	0.3% (0.01%)	0.3% (0.01%)	0.3% (0.01%)	0.3% (0.01%)	0.3% (0.01%)	0.3% (0.01%)
Multiple Races	3% (0.02%)	3% (0.02%)	3% (0.02%)	3% (0.02%)	4% (0.02%)	4% (0.02%)
Area-Level Characteristics						
School District Size (N (%))						
Small (≤ 10 schools)	19,906 (40%)	20,040 (41%)	19,839 (41%)	19,715 (40%)	20,142 (41%)	19,903 (42%)
Medium (11-20 schools)	7,140 (15%)	7,080 (14%)	7,132 (15%)	7,180 (15%)	6,997 (14%)	6,921 (14%)
Large (21-30 schools)	4,294 (9%)	4,278 (9%)	4,275 (9%)	4,238 (9%)	4,126 (8%)	4,027 (8%)
Very Large (≥ 31 schools)	17,828 (36%)	17,767 (36%)	17,676 (36%)	17,765 (36%)	17,323 (36%)	17,090 (36%)
Urbanicity/Rurality (N (%))						
Urban	18,106 (37%)	18,125 (37%)	18,100 (37%)	18,090 (37%)	18,064 (37%)	17,903 (37%)
Suburban	11,959 (24%)	11,891 (24%)	11,799 (24%)	11,838 (24%)	11,768 (24%)	11,649 (24%)
Town	7,333 (15%)	7,380 (15%)	7,258 (15%)	7,193 (15%)	7,066 (15%)	6,877 (14%)
Rural	11,770 (24%)	11,768 (24%)	11,766 (24%)	11,777 (24%)	11,690 (24%)	11,512 (24%)
Social Deprivation Index (mean (sd))*	68 (10)	68 (10)	68 (10)	68 (10)	68 (10)	68 (11)
Medicaid Expansion State (N (%))	26,233 (53%)	27,212 (55%)	28,345 (58%)	28,329 (58%)	29,127 (60%)	29,049 (61%)
USDA Region (N(%))						
Western	7731 (16%)	7,750 (16%)	7,687 (16%)	7,699 (16%)	7,822 (16%)	7,774 (16%)
Southwest	10674 (22%)	10,693 (22%)	10,674 (22%)	10648 (22%)	10,686 (22%)	10,560 (22%)
Mountain Plains	2717 (6%)	2,733 (6%)	2,749 (6%)	2745 (6%)	2,709 (6%)	2,653 (6%)
Midwest	8330 (17%)	8,283 (17%)	8,294 (17%)	8357 (17%)	8,348 (17%)	8,261 (17%)
Southeast	10656 (22%)	10,626 (22%)	10,534 (22%)	10586 (22%)	10,355 (21%)	10,106 (21%)
Mid-Atlantic	4054 (8%)	4,033 (8%)	4,013 (8%)	3982 (8%)	3,786 (8%)	3,722 (8%)
Northeast	5006 (10%)	5,047 (10%)	4,971 (10%)	4881 (10%)	4,882 (10%)	4,865 (10%)

Table 2. Characteristics of schools eligible for the Community Eligibility Provision by year. Table includes characteristics for 53,391 unique public schools nationwide that were ever eligible for CEP between 2014-2020. Social Deprivation Index score is a composite measure of area-level deprivation ranging from 1 to 100 with 100 corresponding to highest level of deprivation¹⁰

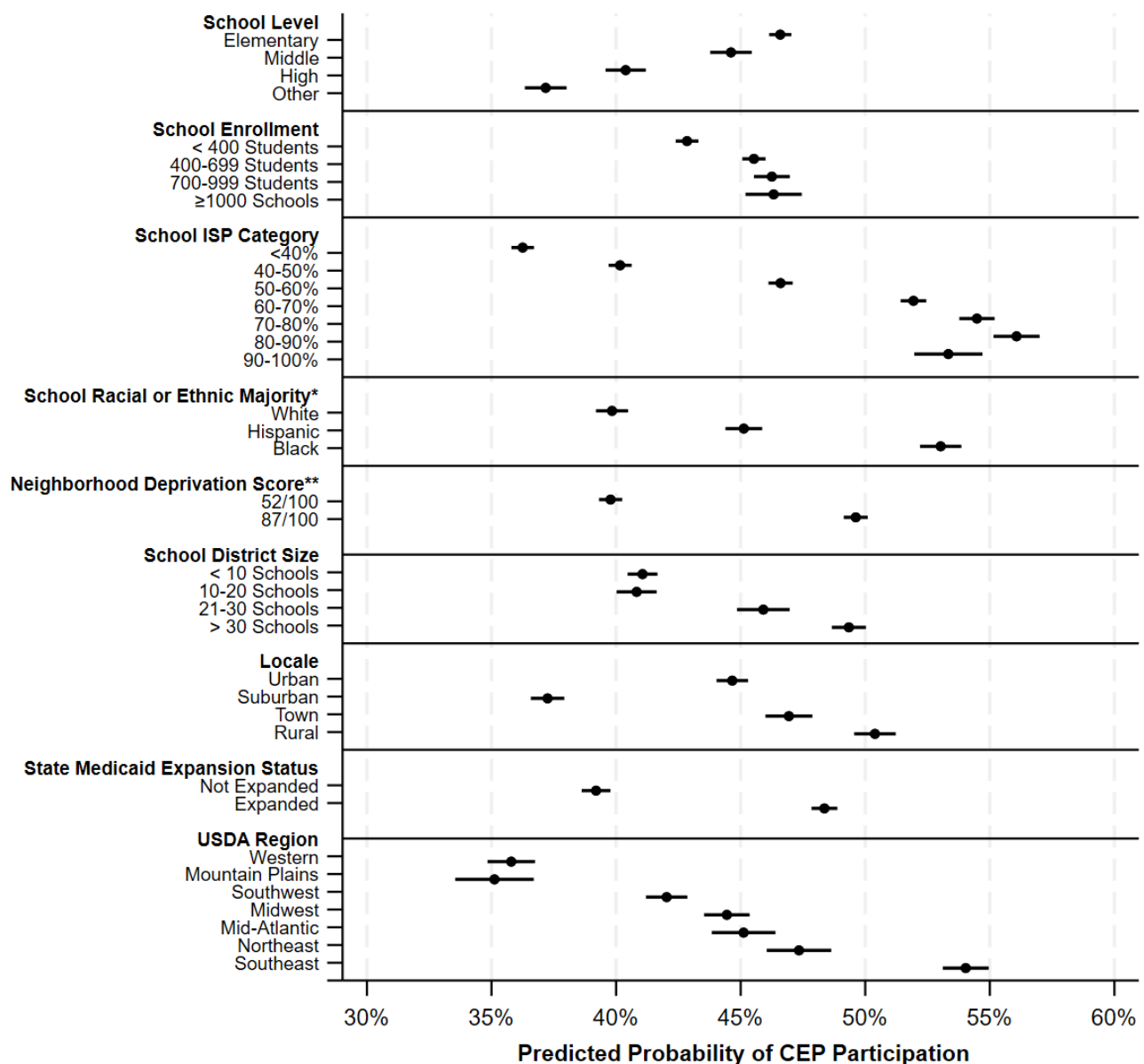


Figure 1. Adjusted associations of school and area characteristics with prevalence of participation in the Community Eligibility Provision. Figure shows point estimates and 95% confidence intervals of prevalence of CEP participation by school and area characteristics, relative to base category, adjusted for covariates for 53,391 schools eligible for CEP between 2014-2020. Results of joint tests for all categorical variables that all categories are equal to zero were statistically significant at the $p < .001$ level.

*Each race or ethnicity variable (White, Hispanic, Black) was set to 75% while the other two were each simultaneously set to 10%

**Scores represent the 25th percentile and 75th percentile of the distribution of the Social Deprivation Index¹⁰

ISP of 80-90% had a 15.91 pp higher prevalence of participation (95% CI: 14.89 pp, 16.92 pp). By school race and ethnicity demographics, prevalence of participation was 3.78 pp higher for each 25-pp increase in percent Black students (95% CI: 3.53 pp, 4.30 pp), 0.88 pp higher for each 25-pp increase in percent Hispanic students (95% CI: 0.19 pp, 1.56 pp). Prevalence was 1.10 pp lower for each 25-pp increase in percent White students (95% CI: -1.87 pp, -0.34 pp).

School districts with more than 20 schools had a higher prevalence of CEP participation than districts with 20 or fewer schools (8.28 pp higher for the largest districts relative to the smallest (95% CI: 7.26 pp, 9.30 pp)). A 25-point increase in neighborhood deprivation score was associated with a 6.75 higher prevalence of participation (95% CI: 6.34 pp, 7.17 pp). By locale, suburban schools had the lowest prevalence of participation (7.41 pp lower than urban schools, 95% CI: -8.31 pp, -6.52 pp) and rural schools had the highest (5.75 pp higher than urban schools, 95% CI: 4.56 pp, 6.89 pp). State Medicaid expansion was associated with a 9.17 pp higher prevalence of participation relative to non-expansion states (95% CI: 8.30 pp, 10.03 pp). By region, schools in the Southeast had the highest overall prevalence of participation (18.24 pp higher than Western states, 95% CI: 16.27 pp, 19.76 pp) followed by schools in the Northeast (11.55 pp higher than Western states, 95% CI: 10.03 pp, 13.07 pp), whereas schools in the Mountain Plains and West had the lowest. Results of joint tests for all categorical variables that all categories were equal to zero were statistically significant ($p < 0.001$), indicating that variables were associated overall with CEP participation.

Adjusted trends in prevalence of CEP participation over time are shown by school (Figure 2) and area characteristics (Figure 3). For percent race and ethnicity variables, we computed change in prevalence of participation for an average school comprised of a majority (75%) of each race or ethnicity group, setting the other race or ethnicity variables to 10% each (Figure 2).

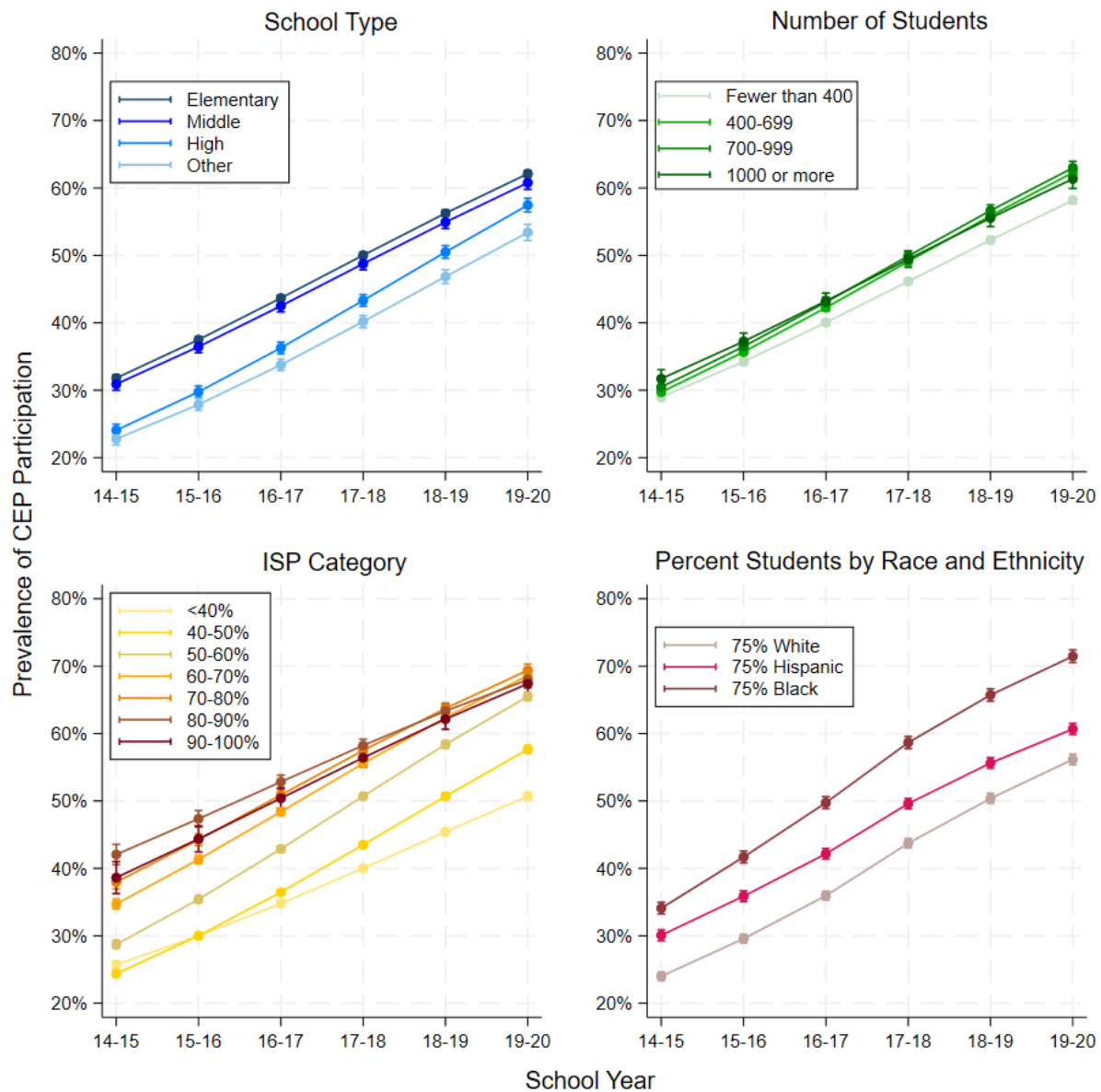


Figure 2. Adjusted associations of school-level characteristics with annual prevalence of participation in the Community Eligibility Provision. Figures show prevalence of CEP participation for 53,391 schools eligible for CEP between 2014-2020, by year and category, adjusted for covariates. ISP is the school identified student percentage. For school level, “other” represents a combination of primary and secondary school grades not captured by elementary, middle, or high (e.g. K-12). For each graph, all covariates are set to their means. For graph of percent students by race or ethnicity, each race/ethnicity variable (White, Hispanic, Black) was set to 75% while the other two were each simultaneously set to 10%.

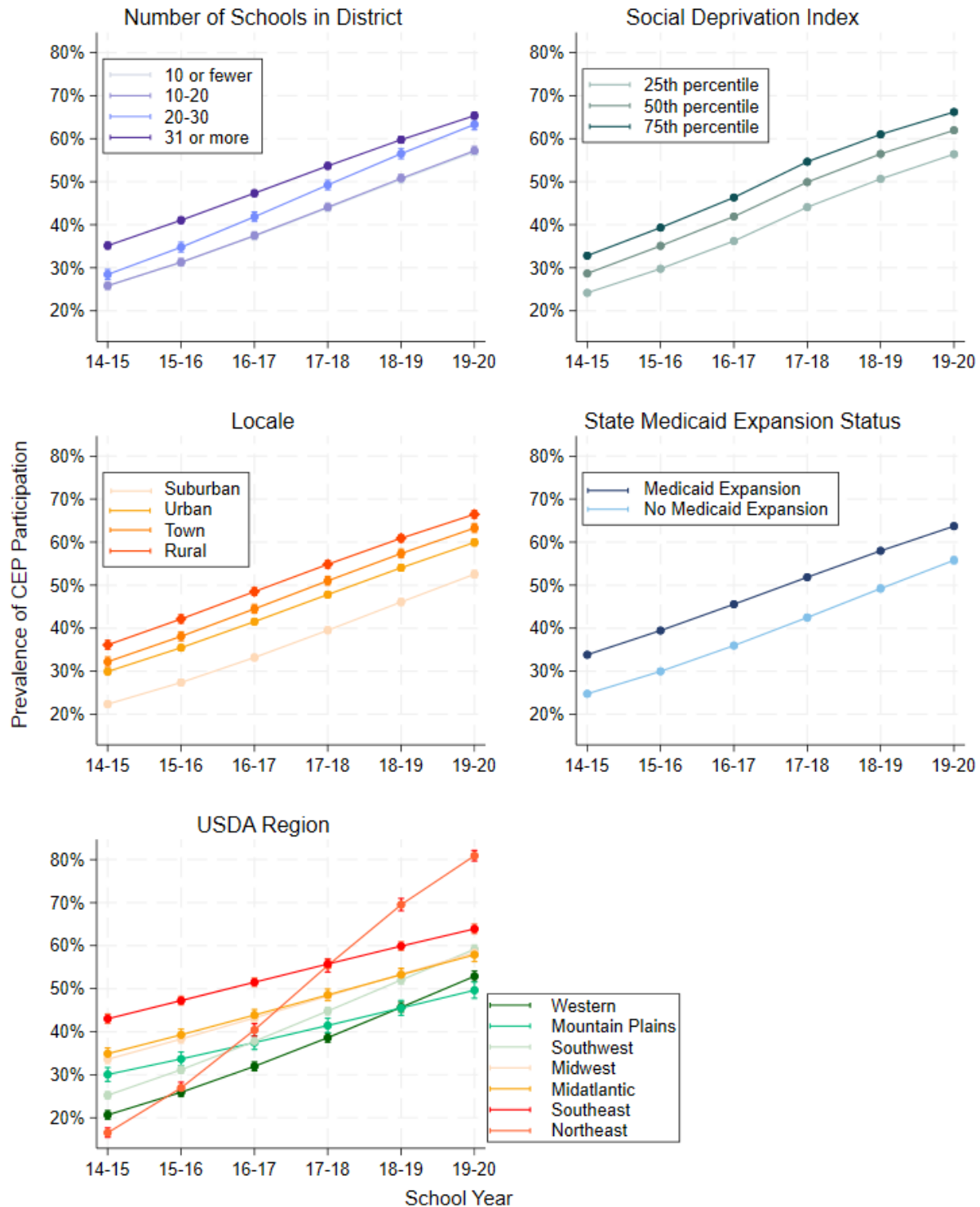


Figure 3. Adjusted associations of area-level characteristics with annual prevalence of participation in the Community Eligibility Provision. Figures show prevalence of CEP participation for 53,391 schools eligible for CEP between 2014-2020, by year and category, adjusted for covariates. For Social Deprivation Index, the 25th percentile corresponds to a score of 52/100, 50th percentile to a score of 72/100, and 75th percentile to a score of 87/100.

For SDI, we modeled change in participation for schools in zip codes with an SDI score at the 25th, 50th, and 75th percentiles of the sample, which correspond to scores of 52, 72, and 87, respectively (Figure 3). Between 2014-2020, overall change in prevalence of participation was higher in high schools (33.39 pp, 95% CI: 32.26 pp, 34.52 pp) than elementary schools (30.31 pp, 95% CI: 29.78 pp, 30.84 pp). Change in prevalence was higher among medium-sized (32.55 pp, 95% CI: 31.84 pp, 33.26 pp) and large schools (32.51 pp, 95% CI: 31.30 pp, 33.72 pp) than small schools (29.18 pp, 95% CI: 28.54 pp, 29.82 pp). By ISP, change in prevalence was highest among schools in the 50-60% range (36.79 pp, 95% CI: 35.84 pp, 37.73 pp vs. 33.28 pp for schools with ISP 40-50%, 95% CI: 32.53 pp, 34.02 pp). Large school districts had a higher change in prevalence (34.85 pp, 95% CI: 33.43 pp, 36.27 pp) than small districts (31.04 pp, 95% CI: 30.26 pp, 31.81 pp). Change in prevalence was highest in the Northeast (64.38 pp, 95% CI: 62.98 pp, 65.77 pp, vs. 32.23 pp in the West, 95% CI: 31.03 pp, 33.42 pp). Among schools with a majority of Black students, change in prevalence of participation was 36.32 pp for (95% CI: 35.32 pp, 37.32 pp), vs. 29.60 pp for schools with a majority of Hispanic students (95% CI: 28.70 pp, 30.51 pp).

Discussion:

This study describes overall associations and trends over time in characteristics of schools nationwide eligible for the Community Eligibility Provision between 2014 and 2020. We found lower adjusted prevalence of CEP participation in high schools, small schools and districts, schools with ISP below 50%, predominantly Hispanic and predominantly White schools, suburban schools, schools in non-Medicaid expansion states, and schools in the Mountain Plains and Western US. We observed relatively higher participation in elementary schools, predominantly Black schools, large schools and districts, rural schools, and schools in the Northeastern and Southeastern US. Strengths of this study are its inclusion of all CEP-eligible schools nationwide and its examination of longitudinal trends in school CEP

participation, which allowed us to evaluate how characteristics of CEP-participating schools changed over time and identify emerging barriers to participation.

Some differences in CEP participation are likely driven by food costs. For example, participation remains relatively low in the Mountain Plains region, which was associated with the highest food costs nationally.¹⁸ Schools in the Southeast had relatively high participation, likely facilitated by lower food costs.¹⁸ Lower participation among small schools and districts likely reflects higher per-meal costs than larger schools and districts which can take advantage of economies of scale.¹⁸ Trends in participation over time revealed schools with ISP over 60% adopted CEP earlier, likely because 62.5% is the threshold at which all meals served are reimbursed at the free rate. However, the gap in participation for schools with ISP between 50-60% and higher ISP schools lessened over time. Relatively lower participation among schools with ISP between 40-50% likely indicates a lack of affordability. For schools with these characteristics, additional allocation of resources may be needed to increase participation.

Other differences in CEP participation may be attributed to demand. Elementary schools were positively associated with participation and appear to have adopted the policy earlier than middle, high, or other school levels. This is likely driven by higher school meal participation.¹⁹ However, the gap in participation between elementary and high schools lessened over time as more high schools adopted the policy. High schools have historically had lower school meal participation,¹⁹ possibly due to lower satisfaction with school meals²⁰, despite improvements in quality.² However CEP adoption increases school meal participation.¹ Particularly for students who eat lunch off campus, switching to school meals could have additional benefits like reduced absenteeism and improved nutrition, but school meal acceptability could remain a barrier in this age group. This is an area for future research.

Drivers of other observed differences in CEP participation remain uncertain. While both predominantly Black and predominantly Hispanic schools were positively associated with

participation, only predominantly Black schools were associated with a higher change in prevalence of participation, and the gap in participation widened over time. These findings are policy-relevant as US schools remain highly segregated; nearly half of White students, one-third of Hispanic students, and one-quarter of Black students attend a school where the majority of students are the same race or ethnicity.²¹ Black students face higher risk of food insecurity than their White counterparts due to structural racism,²² and CEP represents a potential strategy to address food insecurity. However, Hispanic children are also at increased risk of food insecurity.²² Research is needed to determine barriers to adoption for schools serving this population.

We also observed that rural schools had the highest adjusted prevalence of CEP participation by locale, which is promising since poverty is higher in rural compared to urban areas.²³ Although rural areas face higher food transportation costs, use of food purchasing cooperatives may facilitate adoption.^{18,24} Suburban schools lagged behind urban and rural schools in participation. Poverty in the suburbs is increasing at a faster rate than in other locales, yet the suburban social safety net remains less developed.²⁵ Schools in the Northeast had a higher change in prevalence of participation than any other region during this period. This may be due to the concerted effort of a large coalition of stakeholders to implement CEP in all New York City public schools by 2017.²⁶ Such strategies could be modified to increase participation in suburban areas. Finally, we found that Medicaid expansion states were associated with participation, which could be due to local attitudes, as stakeholders in expansion states may be more amenable to adopting other social safety net policies. This could also be facilitated by increased school meal participation in states that use Medicaid for direct certification.

Our findings were mostly consistent with those from previous research^{10–12} but sometimes differed. Specifically, Hecht and colleagues found associations of CEP participation

with school size, school level, and locale that conflicted with ours (though ours were consistent with those from Turner and colleagues¹⁰). However other takeaways such as associations of participation with larger school districts and higher percent Black students were consistent with our findings.¹² Hecht and colleagues included more variables in their analysis¹² while we attempted to limit the number of variables in our model capturing a single construct. Additionally, the estimates reported by Hecht et al. are from school year 2017-18 only,¹² whereas ours are from school year 2014-15 through 2019-20, and some associations changed over time.

As of 2023, several states including California, Maine, Colorado, Minnesota, and New Mexico have implemented universal free school meals for all public schools. This will likely aide schools in implementing UFM by reducing cost-related barriers. However, other barriers, such as lower school meal participation may require targeted approaches to be successful. However, until all states implement UFM policies, CEP remains the most common mechanism for schools to provide free, nutritious meals for low-income children.

Limitations

This study has several limitations. Reported estimates can only be interpreted as associations as this study was not designed to determine causal relationships. Although our selection of variables was guided by CFIR and existing literature, we may not have captured important determinants of CEP adoption such as other political dimensions or measures of institutional capacity. There is also likely heterogeneity in adoption that this study design did not capture. Finally, given the structure of CEP participation data sources, we treated all schools as if they remained participating after adoption. However, up to 6% of schools in the sample de-adopted the policy, so participation may be slightly over-estimated.

Conclusion

In an analysis of schools eligible for the Community Eligibility Provision between 2014-2020, higher school identified student percentage, elementary schools, larger schools and districts, and schools with higher percentages of Black and Hispanic students were positively associated with CEP participation. Additionally, participation was associated with higher neighborhood deprivation, rural schools, schools in states that expanded Medicaid, and schools in the Southeastern and Northeastern US. Time trends reveal potential barriers to participation among schools with an ISP of 40-50%, majority Hispanic schools, suburban schools, and schools in the West and Mountain Plains. As CEP and other universal free school meals policies continue to expand, understanding barriers to participation in these schools will be critical to successful policy implementation.

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CHAPTER 3

Title:

School Participation in Universal Free Meals Policy and Blood Pressure Outcomes in Children and Adolescents

Authors:

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Abstract:

Background: The Community Eligibility Provision is a federal universal free school meals policy for schools in low-income areas. We assessed whether school-level adoption of this policy is associated with childhood blood pressure outcomes.

Methods: Patients ages 4-18 who received care from community health organizations in the OCHIN network were matched to a school based on address. Using a balanced sample of schools, we assessed change in blood pressure outcomes, obtained from medical records, among patients matched to schools that participated in the policy to those matched to eligible, nonparticipating schools. We used doubly robust difference-in-differences estimation for staggered policy adoption, conditional on covariates and weighted by number of patients per school to assess the association between the policy and prevalence of a high blood pressure measurement, a hypertensive blood pressure measurement, and mean systolic and diastolic blood pressure percentiles.

Results: The sample included 155,778 patients matched to 1,052 schools eligible for the Community Eligibility Provision between 2013-14 and 2018-19. Patients were on average 10 years old and 50% were male, 48% Hispanic, 22% White, and 16% Black. Mean number of patients per school was 47. Baseline prevalence of a high blood pressure measurement was 25%. Schools were located in 12 US states, but the majority (64%) were in California or Oregon. School participation in the Community Eligibility Provision was associated with a 2.73 percentage point net reduction in prevalence of a high blood pressure measurement (95% CI: -4.76, -0.70, $p=0.01$), corresponding to an 11% net reduction given baseline prevalence. School participation in the policy was also negatively associated with prevalence of a hypertensive blood pressure measurement and mean diastolic blood pressure percentile.

Conclusion: Compared to eligible nonparticipating schools, participation in the Community Eligibility Provision was associated with a net reduction in high blood pressure among patients who received care from community health organizations.

Background:

Pediatric high blood pressure (BP) is a pressing public health concern; children and adolescents who exhibit high BP have an increased risk of hypertension in early adulthood, which is a leading cause of heart disease, heart attack, stroke, and kidney disease.¹⁻⁵ High BP, which includes both elevated BP (formerly “prehypertension”) and hypertension, is defined as systolic or diastolic BP at or above the 90th percentile for age, sex, and height based on normal-weight children.¹ Overall youth prevalence is estimated at 11% but increases with age and adiposity.^{1,2,6} Known causes of pediatric high BP include obesity, unhealthy diet, sedentary lifestyle, tobacco use, chronic stress, genetic and perinatal factors, and underlying disease.^{1,7} Many of these downstream causes are influenced by upstream fundamental causes of disease like socioeconomic status and structural racism.^{8,9} As such, high BP disproportionately burdens low-income and racially and ethnically minoritized children, particularly Black and Hispanic children.^{1,6} Racial and ethnic disparities in high BP persist even after adjusting for weight status.⁶

Currently, the recommended non-pharmacological treatment for pediatric high BP is the Dietary Approaches to Stop Hypertension (DASH) diet, which is high in fruits, vegetables, and low-fat dairy, and low in sodium and saturated and trans fats.¹ Randomized controlled trials demonstrate that a DASH dietary intervention lowered systolic BP among adolescents with high BP within 3-6 months (change in z-score -0.3).^{10,11} However, this intervention included regular nutrition and behavioral counseling and incentives for meeting dietary goals.^{10,11} Most health insurers do not cover such behavioral interventions.¹⁰ Further, observed decreases in BP were not fully sustained 18 months post-intervention, and the greatest attrition occurred among children with poorer baseline dietary quality, suggesting that such an approach may not be sustainable, particularly for children at greatest risk.¹⁰ Finally, this intervention targets children who already have high BP.¹⁰ In order to effectively reduce hypertension and its associated health consequences in adulthood, experts emphasize the importance of strategies that prevent

the development of high BP in childhood.⁷ Population-level approaches that address social determinants of health and create an environment in which individuals' default decisions are healthy have the greatest potential to address rising rates of high BP in children.¹²

School meals offer an opportunity to provide a DASH-type diet to the majority of children nationwide. The 2010 Healthy, Hunger-Free Kids Act (HHFKA) enacted strict nutrition standards for school meals, requiring schools to serve meals aligned with the Dietary Guidelines for Americans.^{13,14} Several studies demonstrate that the stricter nutrition standards were reflected in improved nutritional quality of school meals.^{15–17} Evidence also shows that school meals are healthier than alternatives and that they are children's most nutritious food source.^{18,19} The Community Eligibility Provision (CEP), also authorized by the HHFKA, is a universal free meals (UFM) policy, allowing schools in low-income areas to provide free breakfast and lunch to all students. CEP reduces the stigma associated with participating in free meals,²⁰ eliminates the need for applications, and extends free meals to children from low-middle income households above the eligibility threshold (\$39,000 annually for a family of four as of 2024).²¹ Several studies have shown that CEP increases school meal participation and improves student diet quality by substituting up to half of their weekly diet with healthier options.²²

CEP has the potential to improve population health, as supported by emerging evidence showing associations of CEP with obesity reduction.^{23,24} CEP may reduce pediatric high BP, not only through improved nutrition and obesity reduction, but also through reduced household income constraints (families that switch from full-price to free school meals save up to \$850 per child per year)²⁵ and reduced food insecurity,²² which are both linked to high BP in children.^{26,27} Further, CEP has a wide reach; as of 2023, over 40,000 schools have adopted the policy, reaching nearly 20 million children nationwide.²⁸ This study assessed whether attending a school that participated in CEP was associated with change in BP outcomes in a sample of low-income children who visited community health organizations across the US between 2013-2019.

Methods:

This study follows an open cohort of children and adolescents ages 4-18 who received care from community health organizations across the US between 2013 and 2019. Youths were matched to neighborhood schools based on address. Because the majority of students were only observed for one year and some students switched schools during the study period, we followed a balanced sample of schools longitudinally, allowing individual children to enter and exit the sample each year, and treated student-level observations as repeated-cross sections. We assessed the difference in BP outcomes among students matched to CEP-participating schools compared to those matched to eligible, non-participating schools. The University of Washington Institutional Review Board determined the research exempt from oversight.

Inclusion Criteria:

Figure 1 depicts a flow chart of exclusion criteria used to create the final sample of schools. Patient data were obtained from the OCHIN Epic electronic health record (EHR) system; OCHIN is a national nonprofit health IT consultancy that provides a fully hosted and shared EHR platform for a nationwide network of community health organizations.²⁹ The sample included schools matched to patients in kindergarten through 12th grade who visited a clinic in the OCHIN network during the school year (August 15th through June 30th) between 2013 and 2019. Patients were matched to their neighborhood school based on address at the time of visit. If patients were matched to multiple neighborhood schools, we chose the school closest to their address. Beginning with 11,534 schools, we excluded 6,774 schools from the sample that were ineligible for CEP between 2014 (when CEP became available nationwide) and 2019. Schools were considered eligible for CEP if they had an identified student percentage (ISP) of 40% or greater. ISP is determined by the proportion of students directly certified for free meals through household participation in a federal assistance program such as the Supplemental Nutrition Assistance Program, or who are identified as in foster care, homeless, migrant, or Head Start. ISP was obtained directly from state departments of education and Food Research & Action Center.

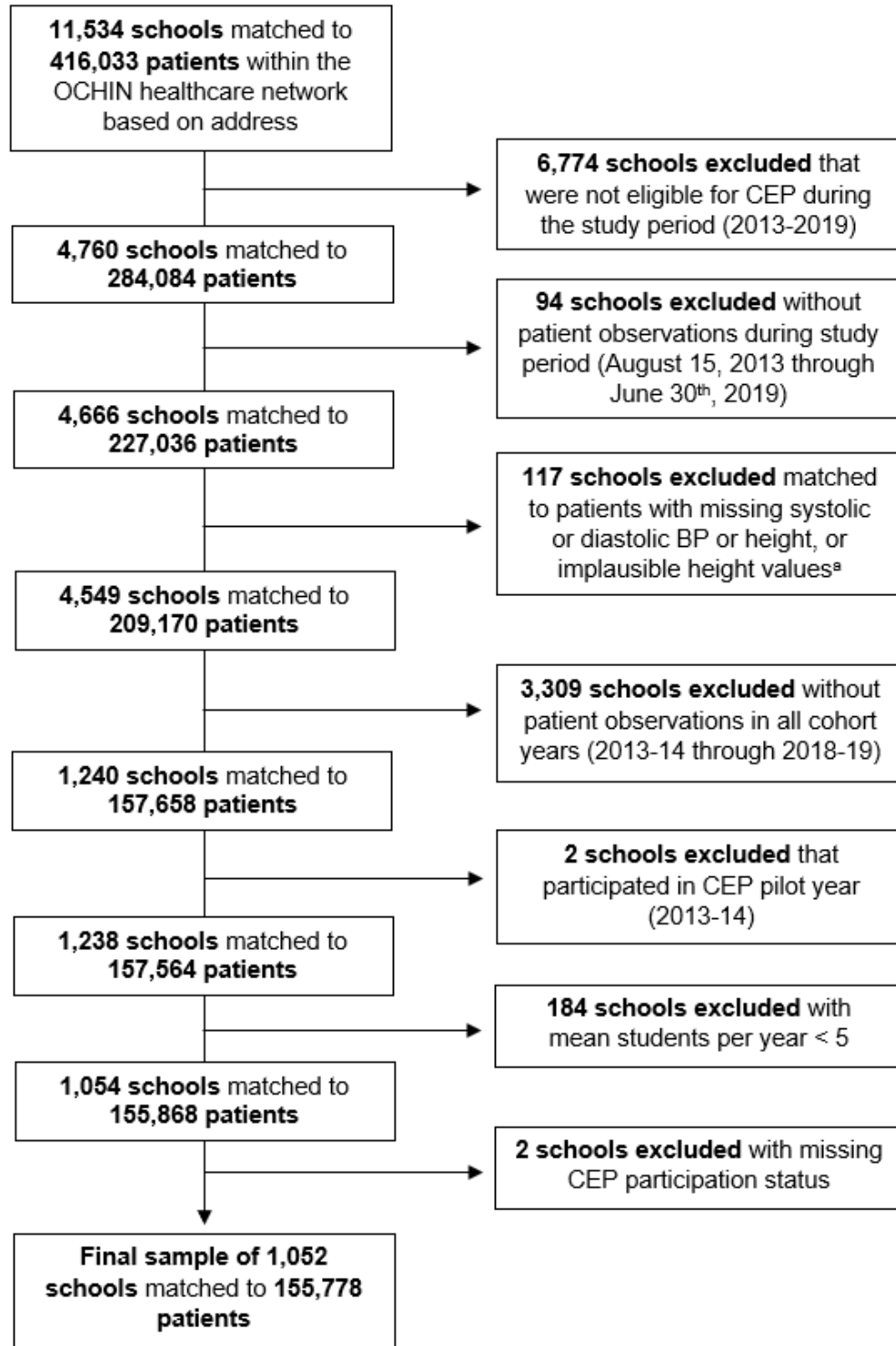


Figure 1. Flow Chart of Inclusion and Exclusion Criteria to Create Sample of Schools Matched to Patient Observations. ^aImplausible height values determined via two algorithms: one for cleaning child growth data from the electronic health record data,¹ and another for computing blood pressure percentiles based on age, sex, and height using normative blood pressure tables based on normal-weight children^{2,3}

We excluded 94 schools without patient observations during the study period (August 15th, 2013 through June 30th, 2019). We excluded 117 schools that matched only to patients with missing or implausible height or BP values. We used two algorithms to identify implausible measurements: one for cleaning child growth data from EHR data (e.g. very extreme values, duplicates, carried forward)³⁰, and one for computing blood pressure percentiles based on CDC growth charts and normative BP tables.^{1,31} To obtain a balanced sample of schools and ensure that observed results are not due to changes in sample composition, we excluded 3,309 schools without patient observations in all school years 2013-14 through 2018-19. The majority of these excluded schools (75%) had only one year of data or no untreated reference year (both required for our analytic approach). We excluded 2 schools that participated in a pilot version of CEP in 2013-14 as our analytic strategy required all schools to have an untreated reference year. In order to obtain reliable school-level outcome measurements, we excluded 184 schools with an average of fewer than five patient measurements per year. Finally, we excluded 2 schools with missing CEP participation status.

Outcomes:

The unit of analysis for all outcomes was the school-year. The primary outcome was prevalence of a high BP measurement, defined as a systolic or diastolic BP measurement at or above the 90th percentile based on age, sex, and height for normal-weight children. Secondary outcomes included prevalence of a hypertensive BP measurement (at or above the 95th percentile), and mean systolic and diastolic BP percentiles. All BP measurements were collected after the beginning of the school year. If there was more than one visit in which BP was measured, we used the visit nearest to the end of the school year. If more than one BP measurement was taken within a visit, we used the average from that visit.

Exposure:

Schools were considered treated if they participated in CEP in a given year. Once schools were treated, we assumed they remained treated. CEP participation status was

obtained directly from state departments of education, the National Center for Education Statistics Common Core of Data,³² and replication data from another researcher.³³

Covariates:

Our models included time-varying mean patient characteristics by school and year that could cause both selection into a CEP-participating school and BP outcomes (but were not hypothesized to be on the causal pathway), in order to account for compositional changes in patient-level demographics between years. These characteristics included age, percent of patients with public health insurance, percent Hispanic patients, percent White patients, and percent Black patients. We also included state Medicaid expansion status as a time-varying covariate.

Statistical analysis:

We used a prediction model to impute values for the 1% of observations missing ISP data which was used to determine CEP eligibility and inclusion in the sample (for details see Supplemental Exhibit A). To assess the association of CEP participation and BP outcomes, we used a difference-in-differences approach for staggered policy adoption which allows for heterogeneous treatment effects over time. This approach, described by Callaway and Sant'anna (2021), computes estimates for each cohort (year schools adopt the policy) for each school year.³⁴ These estimates calculate multiple weighted difference-in-difference estimates for each year and each group to compare change in the outcome in the treated group to change in the outcome in the control group, using one year prior to treatment as the reference year (described in more detail below). The difference-in-differences estimator controlled for all observed and unobserved time-invariant school-level confounders.

The analysis included five cohorts of schools that adopted CEP: schools that adopted in school year 2014-15 (the first year CEP became available to eligible schools nationwide), in 2015-16, in 2016-17, in 2017-18, and in 2018-19. Schools that were eligible for but did not participate in CEP during the study period were also included in the analysis. For each cohort,

the difference in outcomes between each year and one year prior to policy adoption was compared to the same difference in outcomes for a control group of schools that were not yet treated. This control group included schools that would adopt the policy in later cohorts as well as schools that did not adopt the policy during the study period. These estimates were then aggregated into an overall treatment effect estimate (average treatment effect on the treated), as well as treatment effect estimates by cohort and by number of years since policy adoption. This approach avoids the potential biases of applying traditional two-way fixed effects models (linear regression models that include fixed effects for unit and time) to settings where policy adoption is staggered.³⁵

Models used doubly robust estimation based on stabilized inverse probability of treatment weighting (IPTW) and generalized least squares regression.^{34,36} The IPTW model uses propensity scores to derive inverse probability weights using stabilized weights to reduce the distribution of the range of weights to prevent very large weights from having undue influence on results.^{36,37} If either the IPTW or outcome regression model (but not both) is misspecified, the analysis will still yield valid results.³⁸ All models estimated school cluster-robust standard errors.³⁹ Models also used heteroskedasticity weights by mean number of patients per school. Assumptions of this model include irreversibility of treatment (treated schools remain treated), no anticipation (no treatment effect prior to policy adoption), and conditional parallel trends (in the absence of treatment, the difference in outcomes between the treated and control group is constant over time, conditional on covariates).³⁴

Sensitivity analyses:

We conducted several sensitivity analyses to check assumptions and robustness to model specifications. In one model, we dropped all schools with a predicted (vs actual) ISP value to assess whether results were robust to this imputation method. Additionally, we repeated analyses in further-restricted models, limiting the sample to schools with at least 10 students and at least 20 students on average per year, to confirm that results do not change

with more restricted cutoffs of patients per school. We also repeated the analyses in a larger unbalanced sample of schools to ensure that results remained similar. Finally, because obesity is both a hypothesized moderator and mediator in the relationship between CEP and child BP, we did not include percent of patients with obesity in our primary models, but conducted a sensitivity analysis where we included this as a covariate. Body mass index (BMI) was calculated using height and weight in the EHR and used to compute percent of patients with obesity. Obesity in children is defined as BMI at or above the 95th percentile for age and sex according to CDC growth charts.⁴⁰ All analyses were conducted using StataMP 18 and R version 4.3.2.

Results:

The final sample included 1,052 schools followed from school year 2013-14 through 2018-19, matched to 155,778 distinct patients. Table 1 displays summary characteristics of these patients and schools overall and by year schools first adopted the policy. Mean number of patients per school was 47. On average, patients were 50% male, 10 years old, 48% identified as Hispanic, 22% as non-Hispanic White, and 16% as Non-Hispanic Black. Eighty-six percent (86%) of patients had public health insurance, and 19% had a BMI in the EHR that corresponded with the definition of obesity.⁴⁰ Among schools, 67% were elementary, 16% were middle, and 15% were high schools. Mean number of students per school was 694 and on average 78% of students were eligible for free or reduced-price meals. Schools came from 12 states across the US, but 64% of all schools were located in California and Oregon.

Figure 2 displays unadjusted time trends in mean prevalence of a high blood pressure measurement by cohort, weighted by number of patients per school. Mean baseline prevalence of a high blood pressure measurement was 25% overall but varied by cohort: 20% among never-treated schools, 28% in the 2014-15 cohort, 23% in the 2015-16 cohort, 24% in the 2016-17 cohort, 35% in the 2017-18 cohort, and 23% in the 2018-19 cohort.

	Overall	Year Schools Adopted CEP					
		Never	14-15	15-16	16-17	17-18	18-19
PATIENT CHARACTERISTICS							
Number of Patients per school (mean, sd)	46.6 (74.9)	46.0 (84.7)	45.9 (61.1)	33.9 (42.1)	59.1 (97.9)	95.5 (114.2)	38.5 (63.3)
Percent Male (mean, sd)	50.4% (16.6%)	49.8% (17.2%)	50.9% (16.4%)	50.9% (18.4%)	50.9% (12.7%)	51.2% (13.0%)	49.5% (17.3%)
Age (mean, sd)	10.2 (3.0)	10.5 (3.2)	9.6 (2.7)	10.7 (3.2)	9.7 (2.7)	9.6 (2.6)	11.1 (3.3)
Race or Ethnicity (mean, sd)							
Hispanic	47.6% (34.0%)	36.1% (30.6%)	55.8% (32.5%)	38.1% (33.7%)	30.8% (37.2%)	59.3% (36.0%)	62.8% (30.1%)
Non-Hispanic White	22.4% (27.3%)	34.6% (30.8%)	16.6% (21.9%)	27.1% (30.7%)	18.8% (25.2%)	9.0% (17.7%)	11.1% (20.5%)
Non-Hispanic Black	15.5% (25.5%)	12.8% (22.9%)	13.3% (21.1%)	24.8% (36.6%)	41.1% (36.0%)	23.6% (33.6%)	9.8% (19.7%)
Asian	3.7% (9.0%)	4.2% (9.9%)	4.2% (9.5%)	1.4% (4.8%)	2.0% (6.6%)	2.0% (6.3%)	2.8% (7.5%)
American Indian or Alaskan Native	0.4% (2.0%)	0.5% (2.8%)	0.3% (1.1%)	0.5% (1.5%)	0.1% (0.8%)	0.7% (3.1%)	0.3% (2.1%)
Native Hawaiian or Other Pacific Islander	0.5% (2.8%)	0.7% (2.5%)	0.7% (3.6%)	0.3% (2.0%)	0.1% (0.4%)	0.1% (0.5%)	0.3% (1.5%)
Multiple races	1.2% (4.1%)	1.8% (5.7%)	0.9% (2.9%)	1.3% (2.9%)	1.2% (2.6%)	0.6% (1.6%)	0.7% (2.9%)
Unknown	8.7% (12.0%)	9.3% (12.7%)	8.1% (10.8%)	6.5% (10.1%)	5.8% (7.4%)	4.8% (7.2%)	12.2% (15.6%)
Percent health insurance type (mean, sd)							
Public (e.g. Medicaid)	86.2% (17.4%)	82.6% (19.4%)	89.0% (14.7%)	81.2% (19.2%)	86.1% (12.7%)	92.4% (12.8%)	87.8% (19.1%)
Private	6.8% (11.5%)	9.7% (14.3%)	4.9% (8.9%)	8.4% (11.8%)	6.1% (8.8%)	3.7% (7.2%)	5.3% (10.3%)
Uninsured	7.0% (13.0%)	7.6% (13.3%)	6.1% (11.4%)	10.3% (15.2%)	7.7% (9.2%)	4.0% (9.7%)	6.9% (16.8%)
Percent with Obesity (mean, sd) ^a	18.8% (9.1%)	17.6% (8.6%)	19.4% (9.5%)	17.4% (9.7%)	18.9% (8.0%)	20.6% (6.0%)	20.2% (9.7%)
SCHOOL CHARACTERISTICS							
Total Schools (N)	1,052	351	405	57	72	29	138
School Type (%)							
Elementary	67.2%	59.8%	77.0%	64.9%	77.8%	69.0%	52.2%
Middle	16.0%	19.9%	11.9%	14.0%	6.9%	20.7%	22.5%
High	14.9%	18.5%	10.1%	19.3%	11.1%	3.5%	22.5%
Other	1.9%	1.7%	1.0%	1.8%	4.2%	6.9%	2.9%
Number of Students (mean, sd)	694.4 (537.4)	737.4 (666.1)	616.1 (366.2)	632.7 (478.4)	550.8 (208.6)	624.4 (329.4)	929.6 (670.3)
Percent Students Eligible for Free or Reduced-Price Meals (mean, sd)	78.1% (14.9%)	68.3% (15.0%)	83.1% (11.4%)	77.5% (14.7%)	87.4% (13.7%)	81.8% (11.2%)	85.4% (9.5%)
Social Deprivation Index Score (mean, sd) ^b	76.9 (19.7)	68.5 (21.2)	82.2 (17.2)	76.6 (20.2)	80.5 (17.5)	77.2 (20.3)	81.0 (15.7)
Rurality (mean, sd) ^c	1.8 (1.5)	2.0 (1.7)	1.7 (1.4)	2.0 (1.6)	1.5 (1.1)	1.7 (1.0)	1.5 (1.1)
State (%)							
California	36.9%	30.5%	33.8%	15.8%	22.2%	65.5%	72.5%
Oregon	26.8%	36.8%	29.6%	43.9%	1.4%	6.9%	3.6%
Texas	10.0%	4.8%	14.1%	8.8%	2.8%	3.5%	16.7%
Indiana	6.1%	6.3%	6.4%	10.5%	2.8%	0%	5.8%
Ohio	6.1%	6.0%	0.3%	0%	52.8%	6.9%	1.5%
Massachusetts	5.7%	1.4%	11.4%	0%	12.5%	0%	0%
Washington	4.4%	11.4%	0.7%	5.3%	0%	0%	0%
Minnesota	2.1%	0.9%	0.5%	15.8%	4.2%	17.2%	0%
North Carolina	1.0%	0%	2.2%	0%	1.4%	0%	0%
Alaska	0.6%	1.4%	0.3%	0%	0%	0%	0%
Montana	0.3%	0.3%	0.5%	0%	0%	0%	0%
Wisconsin	0.2%	0.3%	0.3%	0%	0%	0%	0%

Table 1. Patient and School Characteristics by Year Schools Adopted the Community Eligibility Provision. Characteristics of 1,052 schools eligible for the Community Eligibility Provision matched to 155,778 patients followed from school year 2013-14 through 2018-19. ^aObesity in children is defined as body mass index at or above the 95th percentile for age and sex according to CDC growth charts. ^bSocial deprivation index score is a composite measure of area-level deprivation ranging from 1 to 100 with 100 corresponding to highest level of deprivation⁵ ^cRurality measure from the 2013 US Department of Agriculture rural-urban continuum; continuum is a scale from 1-9 with 9 indicating most rural.

Table 2 shows results of the overall post-treatment average association of CEP and blood pressure outcomes from the adjusted difference-in-differences models. School CEP participation was associated with a 2.73 percentage point (pp) net decrease in prevalence of a high BP measurement (at or above the 90th percentile based on age, sex, and height for normal-weight children) relative to eligible nonparticipating schools (95% CI: -4.76 pp, -0.70 pp, $p=0.01$). This corresponds to an 11.10% net decrease given prevalence at baseline (95% CI: 19.34%, 2.85%).

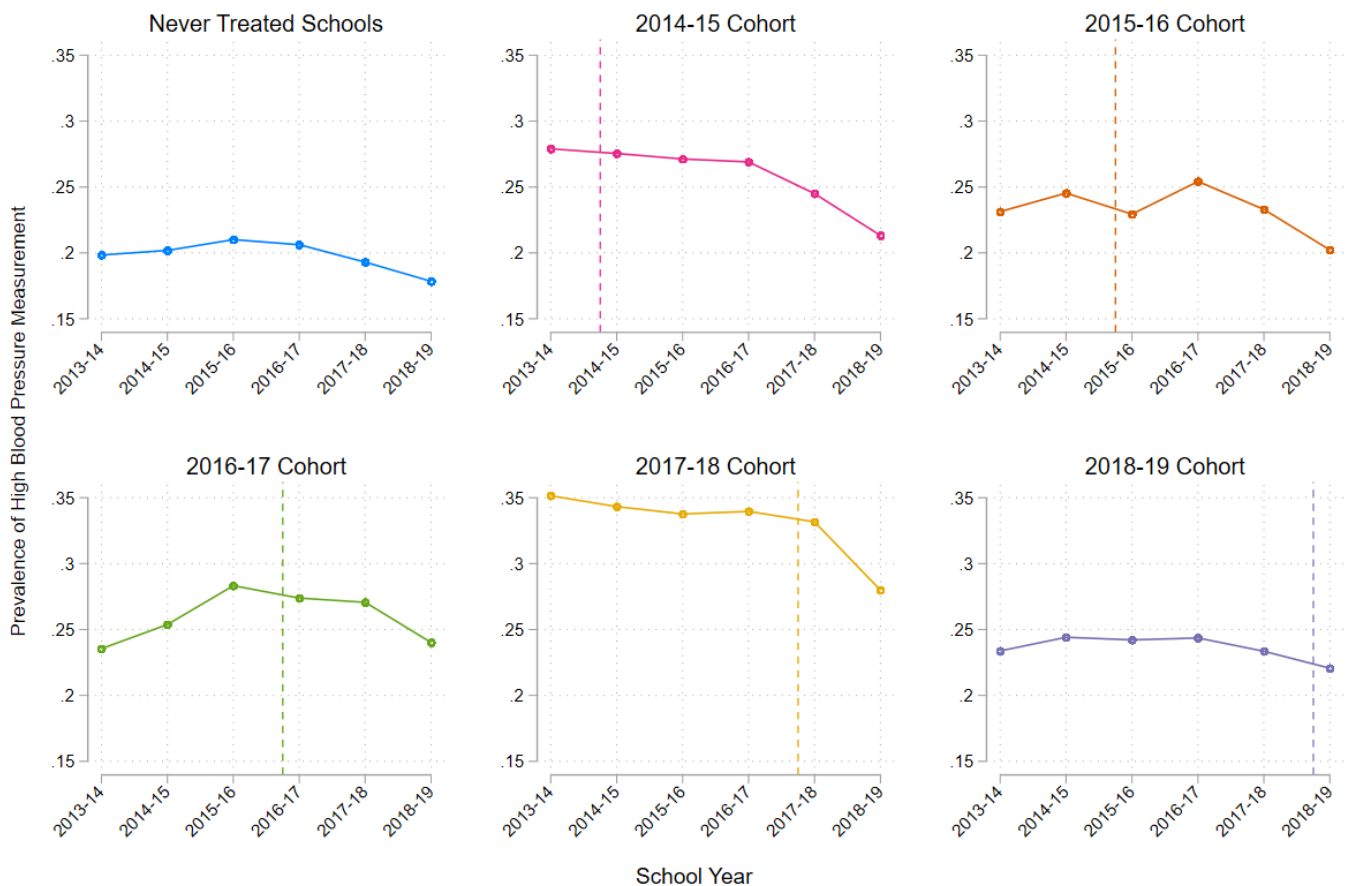


Figure 2. Unadjusted Trends in Prevalence of High Blood Pressure Measurement by Year Schools Adopted the Community Eligibility Provision. Trends in yearly mean prevalence of a high blood pressure measurement among 1,052 schools followed from school year 2013-14 through 2018-19. Blood pressure measurements were from 155,778 unique patients. Dashed lines indicate when the policy was first adopted by each cohort of schools. High blood pressure measurement is defined as systolic or diastolic blood pressure at or above the 90th percentile for age, sex, and height based on normal-weight children.²

Participation in CEP was associated with a 2.48 pp net reduction in prevalence of a hypertensive BP measurement (at or above the 95th percentile) (95% CI: -4.43, -0.52, p=0.01). CEP participation was associated with a 1.99 pp net reduction in mean diastolic blood pressure percentile (95% CI: -3.66 pp, -0.31 pp, p=0.02). This corresponds to a change in mean z-score of -0.07 (95% CI: -0.13, -0.02). CEP was also negatively associated with mean systolic blood pressure percentile, but the estimate was not statistically significant (point estimate=-0.92 pp, 95% CI: -2.44, 0.61, p=0.24). This corresponds to a change in z-score of -0.04 (95% CI: -0.09, 0.02).

	Difference-in-Differences Point Estimate	95% Confidence Interval
Primary Outcome		
Prevalence of High Blood Pressure Measurement	-2.73***	-4.76, -0.70
Secondary Outcomes		
Prevalence of Hypertensive Blood Pressure Measurement	-2.48**	-4.43, -0.52
Mean Diastolic Blood Pressure Percentile	-1.99**	-3.66, -0.31
Mean Systolic Blood Pressure Percentile	-0.92	-2.44, 0.61

Table 2. Association of Participation in the Community Eligibility Provision with School-level Blood Pressure Outcomes. Estimates expressed as percentage points. Sample includes 1,052 schools matched to 155,778 patients followed from school year 2013-14 through 2018-19. High blood pressure measurement is defined as systolic or diastolic blood pressure at or above the 90th percentile for age, sex, and height based on normal-weight children; hypertensive blood pressure measurement is defined as a measurement at or above the 95th percentile.² Treatment effects were estimated using Callaway/Sant’anna doubly robust difference-in-differences estimator,⁶ weighted by mean number of patients per school, conditional on covariates.

Figure 3 shows difference-in-differences estimates of the association of CEP and prevalence of a high BP measurement by time since policy adoption. All post-policy treatment effect estimates were negative and statistically significant at the p<0.05 level, except for year one, which was significant at p<0.1. The joint test that pre-policy treatment effect estimates were not statistically significant (p=0.59) indicates that prior to policy adoption, differences in trends in prevalence of high BP for CEP-participating vs. nonparticipating schools were not

different from zero, lending support to the parallel trends and no anticipation assumptions.

Figure 4 displays difference-in-differences estimates of the association of CEP and prevalence of a high BP measurement aggregated by cohort and pooling all post-treatment years for each cohort. Treatment effect estimates were negative for all cohorts except for schools that adopted in 2017-18 (point estimate = 1.80, 95% CI: -4.48, 8.08, $p=0.57$). However, only the estimate for the cohort that adopted CEP in 2014-15 was statistically significant (point estimate = -2.92 pp, 95% CI: -4.99 pp, -0.84 pp, $p=0.006$).

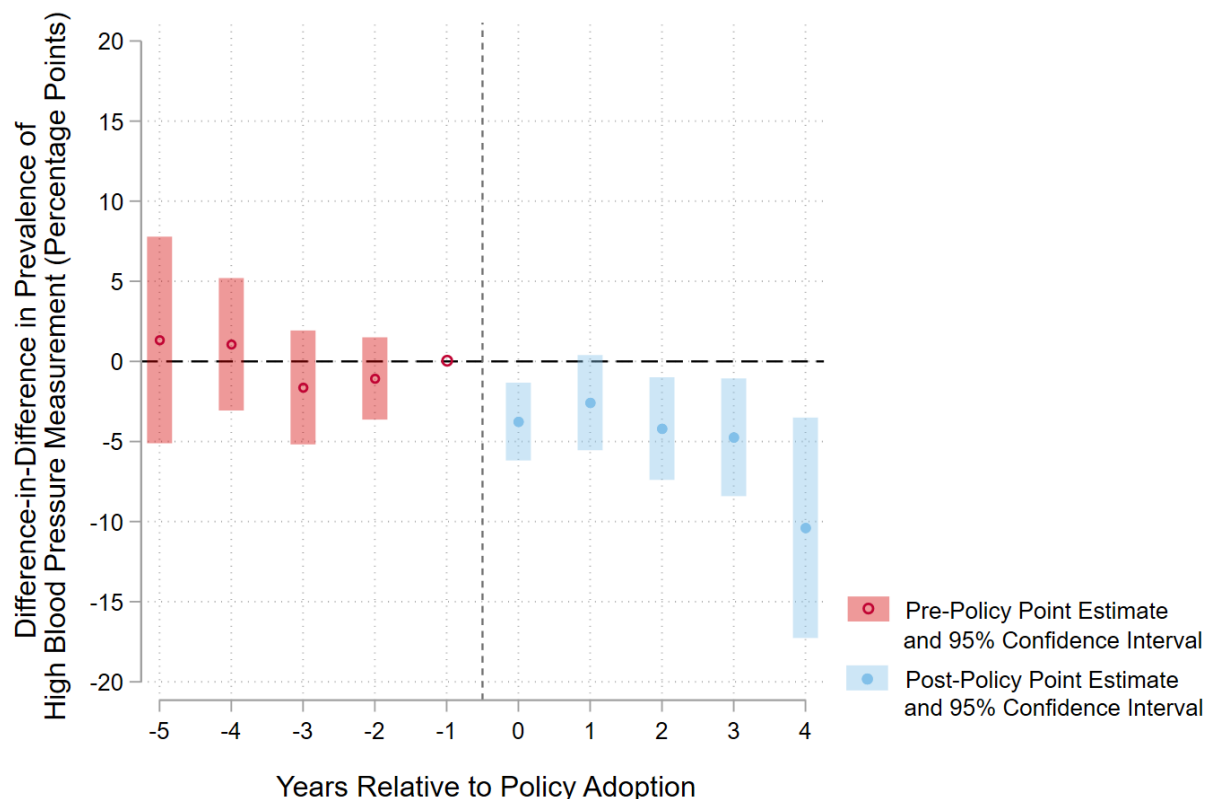


Figure 3. Difference-in-Differences Estimates of the Association of Participation in the Community Eligibility Provision with Prevalence of a High Blood Pressure Measurement, Aggregated by Years Relative to Policy Adoption. Sample includes 1,052 schools matched to 155,778 patients followed from school year 2013-14 through 2018-19. High blood pressure measurement is defined as systolic or diastolic blood pressure at or above the 90th percentile for age, sex, and height based on normal-weight children.² Pre- and post-policy difference in differences were estimated using Callaway/Sant’anna doubly robust difference-in-differences estimator,⁶ weighted by mean number of patients per school, conditional on covariates. Estimates are aggregated by time since policy adoption (first year of policy adoption = 0, years prior to policy adoption are negative numbers and years after policy adoption are positive numbers). Reference group is eligible, non-participating schools (including both not-yet and never-participating schools): reference year is one year prior to policy adoption (years relative to policy adoption = -1).

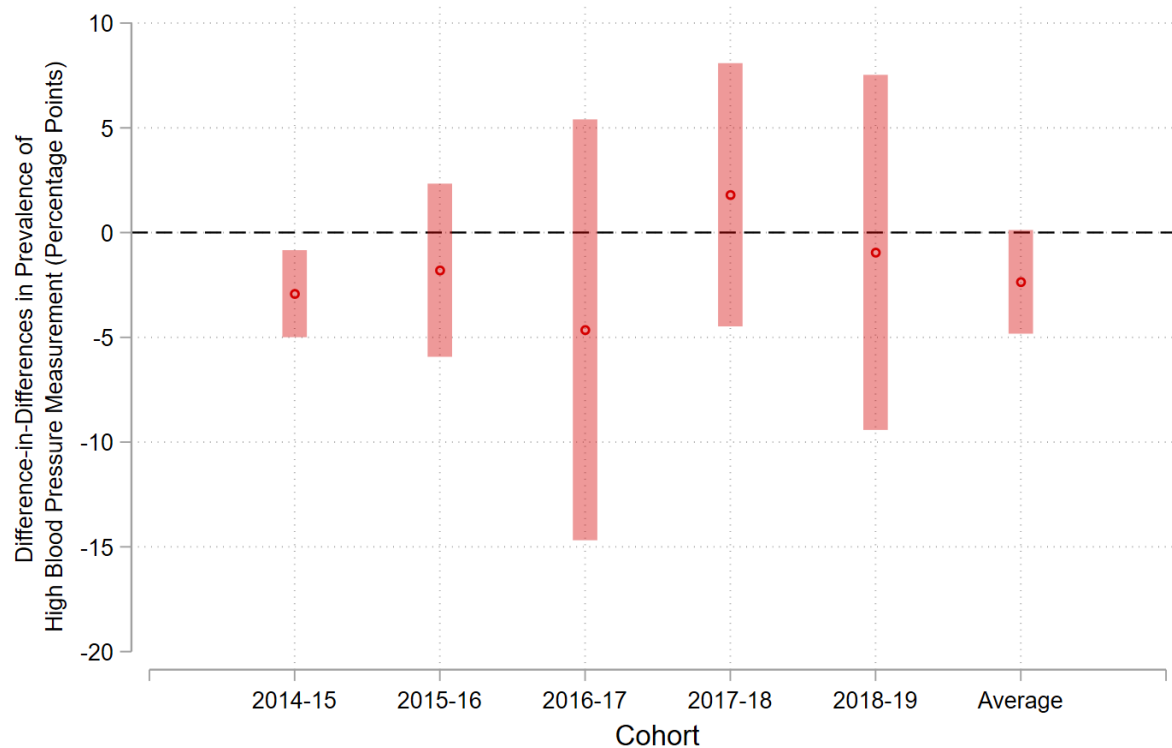


Figure 4. Difference-in-Differences Estimates of the Association of Participation in the Community Eligibility Provision with Prevalence of a High Blood Pressure Measurement, Aggregated by Year of Policy Adoption. Sample includes 1,052 schools matched to 155,778 patients followed from school year 2013-14 through 2018-19. High blood pressure measurement is defined as systolic or diastolic blood pressure at or above the 90th percentile for age, sex, and height based on normal-weight children.² Treatment effects were estimated using Callaway/Sant'anna doubly robust difference-in-differences estimator,⁶ weighted by mean number of patients per school, conditional on covariates. Reference group is eligible, non-participating schools (including both not-yet and never-participating schools); reference year is one year prior to policy adoption.

Results of sensitivity analyses are displayed in Table A of the Supplemental Materials. Estimates and confidence intervals were similar when we dropped the 11 schools with missing ISP values that were imputed for our main analyses. When we further restricted the sample to schools with mean patients per school of 10 or more or 20 or more, all estimates remained negative, but most point estimates were slightly attenuated and the strength of associations weakened. Results were similarly modestly attenuated in a larger unbalanced sample with 556 additional schools that had at least two observation years and an untreated reference year.

When we included obesity status as a covariate in our models, all estimates remained negative, but point estimates were slightly attenuated and the strength of associations weakened.

Discussion:

In a balanced sample of 1,052 schools followed from school year 2013-14 through 2018-19 that were matched to patients observed in community health organizations across the US, school participation in universal free meals via the Community Eligibility Provision was associated with an 11% net decrease in prevalence of a high blood pressure measurement. CEP was also associated with relative reductions in prevalence of a hypertensive blood pressure measurement and mean diastolic blood pressure. Strengths of this study include its longitudinal design, use of a comparison group of not yet and never participating schools, and analytic approach which allowed treatment effects to vary over time and employed doubly robust estimation to control for potential confounders. Additionally, evaluating pre-treatment trends suggested that the parallel trends and no anticipation assumptions were reasonable.

By cohort, the observed association was strongest for schools that adopted the policy in school year 2014-15, the first year it became available nationwide. This may be because schools in this cohort had the longest length of exposure to the policy. Although CEP-participating schools were associated with larger reductions in high BP measurements than eligible nonparticipating schools, trends in high BP decreased overall in this sample among both CEP-participating and nonparticipating schools. While several studies note an increase in prevalence of high BP in children between 1988 and the early 2000s,^{41,42} more recent trends indicate that prevalence of pediatric high BP in the US may actually be declining.² Future research should assess whether these overall declines in high BP were associated with the timing of the improved school meal nutrition standards of the HHSFKA, which took effect in school year 2012-13.

While few studies have examined the effects of dietary interventions on child BP outcomes, Couch and colleagues found in two studies that a clinical DASH dietary and

behavioral intervention reduced systolic BP in a sample of patients with high BP after 6 months.^{10,11} While these authors observed a larger decrease in BP in their sample than we did, this is to be expected when comparing results of a small clinical intervention to those of a population-level intervention. Cohen and colleagues observed in a nationally-representative repeated cross-sectional survey that higher accordance with the DASH diet was also associated with lower systolic BP.⁴³ Our study builds on these findings, demonstrating that switching to universal free school meals, which are aligned with a DASH-style diet, was associated with a net reduction in prevalence of a high BP measurement. A reduction in this metric is meaningful for both children with existing high BP, as well as those at risk of developing high BP. In our secondary analyses, we found CEP was associated with a relative decrease in both systolic and diastolic BP, but only the latter was statistically significant. Current evidence suggests that both measures are important predictors of cardiovascular outcomes in those younger than 50.⁴⁴

Recent studies have demonstrated that CEP was also associated with relative reductions in obesity.^{23,24} That CEP is associated with a net reduction in high BP is consistent with this evidence, since obesity is a cause of high BP.¹ However, when we added obesity prevalence as a covariate in our models, our results were slightly attenuated but remained negative, indicating that CEP may impact child BP independent of its potential impact on obesity. Our findings add to this literature suggesting that CEP may be a health-promoting intervention. Given that the policy reaches nearly 20 million children nationwide,²⁸ investments in this or similar school meals policies may have the potential to result in meaningful population-level improvements in child health.

This study has several limitations. Data in this sample were not nationally representative and schools were concentrated predominantly in California and Oregon. However, the sample was created using data from health clinics in low-income and racially and ethnically diverse areas, which are priority populations for such interventions. Future research, however, should assess this association in other settings, including in nationally representative samples. We

further decreased generalizability by limiting the analysis to a balanced sample of schools, but by doing so increased internal validity. Prevalence of a high blood pressure measurement observed in this study was higher than national estimates of pediatric high BP.¹ However, the observed prevalence of a high BP measurement is still likely to be an overestimate of “persistently elevated” BP, which requires measurements to be taken on three separate occasions.¹ This is because BP varies over time, particularly within children.⁴³ Additionally, patients were matched to their closest neighborhood school based on address. There is likely to be some error in this assignment, however we have no reason to believe that students were assigned to schools differentially by treatment status.

Conclusion:

In a school-matched sample of pediatric patients who visited community health organizations in 12 US states between 2013 and 2019, school participation in the Community Eligibility Provision was associated with a net decrease in prevalence of a high blood pressure measurement. The policy was also associated with a net decrease in prevalence of a hypertensive measurement, and mean diastolic blood pressure percentile. These associations remained after adjusting for obesity prevalence. Universal Free School Meals policies like the Community Eligibility Provision represent promising strategies for improving population-level child health.

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CHAPTER 4

Title:

Heterogeneous Associations of the Community Eligibility Provision with High Blood Pressure by Child Age and Race or Ethnicity

Authors:

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Abstract:

Objective: The purpose of this study is to assess whether the association between the Community Eligibility Provision, a federal universal free school meals policy, and high blood pressure varied by age group or race and ethnicity.

Methods: Schools eligible for the Community Eligibility Provision were matched to patient medical records from community health organizations in the OCHIN healthcare network. Schools were followed longitudinally from 2013 through 2019. To assess heterogeneous associations of the policy with high blood pressure, we used a difference-in-differences approach for staggered policy adoption with an adjusted linear regression model including interactions between all covariates and hypothesized effect modifiers with cohort, year, and a treatment indicator variable. The model included school and year fixed effects and was weighted by number of patients per school. We computed marginal effects by age group and race and ethnicity.

Results: A total of 1,052 Schools matched to 155,668 patients were included in the analysis. Demographically, 48% of patients were Hispanic, 22% of patients were non-Hispanic White, 16% of patients were non-Hispanic Black, 86% of patients had public health insurance, and 19% had obesity. Elementary schools comprised 67% of the sample. Schools were located in 12 US states but the majority were in California (37%) or Oregon (27%). School participation in the Community Eligibility Provision was associated with a 3.7 percentage point reduction in prevalence of high blood pressure in elementary schools (95% CI: -6.5, -0.9, $p < .01$), which was significantly greater ($p < .05$) than the observed 2.6 percentage point reduction in middle schools (95% CI: -5.1, -0.1, $p < .05$) and the 1.2 percentage point reduction in high schools (95% CI: -3.8, 1.4, $p > .05$). By race and ethnicity, participating schools with a majority of Hispanic students had a 4.0 percentage point relative reduction in prevalence of high blood pressure (95% CI: -6.8, -1.1) which was significantly greater ($p < .01$) than the estimated 2.0 percentage point reduction in majority White schools (95% CI: -4.9, 0.8). The observed 1.0 percentage point relative decrease in majority Black schools was not statistically significant (95% CI: -3.4, 1.5).

Conclusion: In a sample of schools matched to patient medical records from community health centers in low-income areas, school participation in the Community Eligibility Provision was associated with the greatest reduction in prevalence of high blood pressure in elementary schools and in majority Hispanic schools.

Background:

Prevalence of high blood pressure (BP) in US children is approximately 11%, but varies widely by age and race and ethnicity.^{1–3} High BP, defined as systolic or diastolic BP at or above the 90th percentile for age, sex, and height, poses a threat to child health and is associated with development of hypertension and cardiovascular disease in adulthood^{1,4} High BP is more prevalent among adolescents compared to younger children, as risk increases with longer exposure to risk factors like unhealthy diet, sedentary lifestyle, and obesogenic environments.^{1,5,6} Children from racially or ethnically minoritized groups including Black and Hispanic, particularly Mexican American, are disproportionately burdened by high BP due to structural racism and socioeconomic disparities driving exposure to unhealthy environments.^{1,3} Obesity is a major direct cause of high BP in children via several biological mechanisms.⁷ However, children without obesity can also develop high BP.¹ While differences in high BP by age and race and ethnicity are partially attributable to obesity, disparities remain even after adjusting for weight status.³

Dietary interventions like the DASH (Dietary Approaches to Stop Hypertension) diet are recommended to reverse high BP in children, while a healthy diet high in fruits and vegetables is suggested for prevention of high BP.¹ However, the majority of American children do not consume a sufficiently healthy diet.⁸ Behavior change is challenging, particularly within economically deprived environments; therefore, interventions which address social determinants of health and create contexts in which default choices are healthy have the greatest potential to impact health on a population level.⁹ The Community Eligibility Provision (CEP), a federal universal free school meals policy, enacted as part of the Healthy, Hunger-Free Kids Act (HHFKA), allows schools in low-income areas to provide free breakfast and lunch to all students. CEP increases participation in school meals, which are on average healthier than alternatives and are children's most nutritious food source.^{10–12} This is particularly true since the

HHFKA improved school meal nutrition standards, which are now required to be in alignment with the Dietary Guidelines for Americans.^{13–15} Previous research described in Dissertation Chapter 3 showed that CEP may be associated with reduction in the prevalence of high BP. However, given disparities in adoption of CEP at the school level identified in Chapter 2, as well as differences in participation rates in school meals at the child level,¹⁶ combined with differences in prevalence of high blood pressure by child demographics,³ the effects of the policy may differ by subgroups.

CEP may lead to larger reductions in prevalence of high BP in younger children because they are more likely to participate in school meals.¹⁶ However, because high BP is more prevalent in older children and adolescents,¹ it is possible the policy may have a greater effect in this population due to their higher risk profile. Black and Hispanic children are disproportionately burdened by high BP and are also more likely than their White counterparts to attend a CEP-participating school.^{3,17} Therefore, they may benefit more from this policy than White children. However, schools with larger White populations on average have fewer students already eligible for free or reduced-price meals.¹⁸ Therefore, it is possible that predominantly White schools may experience a greater shift of students moving from not participating to participating in school meals, thereby increasing their probability of experiencing a reduction in high BP associated with the policy.¹⁹ Given these questions, the purpose of this analysis is to test whether there is heterogeneity in the association of CEP with high BP by age group or race or ethnicity.

Methods:

This analysis used patient data from the OCHIN Epic electronic health record (EHR) system. OCHIN is a national nonprofit health IT consultancy that provides a fully hosted and shared EHR platform for a nationwide network of community health organizations.²⁰ Medical records from patients in kindergarten through 12th grade were matched to schools based on patient address. Schools were included in the analysis if they were eligible for CEP between

2014 (when the policy became available nationwide) and 2019. Schools, groups of schools, or districts are eligible for CEP if they have an identified student percentage (ISP) of 40% or higher. ISP is determined by the proportion of students directly certified to receive free meals through participation in a means-tested safety net program. We used a school ISP of 40% or higher as a proxy for CEP eligibility. More details on inclusion criteria for this sample of schools can be found in Chapter 3. In this previous study, we examined overall change in BP outcomes by school CEP participation status and found that CEP participation was associated with a relative reduction in prevalence of high BP in this population between 2013 and 2019.

In the present study, we used the same sample of patient-matched schools to examine heterogeneity in prevalence of high BP by 1) school level (elementary, middle, and high schools) and 2) majority patient race/ethnicity, in this same sample of school-matched patients. For this analysis, we use a two-way fixed effects model for staggered policy adoption described by Wooldridge 2021 (colloquially called “extended two-way fixed effects”) that interacts all covariates and hypothesized effect modifiers with cohort (year schools first adopted the policy) and year, and an indicator variable for treatment.²¹ We estimated treatment effects for each category of each hypothesized effect modifier. Further, we conducted joint tests to determine whether associations differed by hypothesized effect modifiers overall, as well as Wald tests to determine whether the association of CEP with high BP differed by categories of age group or race or ethnicity group. The University of Washington Institutional Review Board determined the research exempt from oversight.

Outcome:

The outcome of interest was school-level prevalence of high BP, defined as number of patients in a school with a systolic or diastolic BP measurement at or above the 90th percentile based on age, height, and sex for normal-weight children over total number of patients in a school. Prevalence was specified in the models as a continuous school-level variable with

values ranging from 0-100. BP measurements were obtained from patient medical records and were assigned to a given school year if they were measured between August 15th and June 30th. For patients with more than one visit in a given school year, we used the BP measurement closest to the end of the school year. If more than one BP measurement was taken within a visit, we took the average of these measurements.

Exposure:

The exposure was school participation in CEP. Policy adoption was staggered (schools could choose to adopt the policy each year beginning in 2014). We assumed that once school were treated they remained so. Schools maintain eligibility for CEP for four years regardless of whether their ISP changes during this time. In Chapter 2 we estimated de-adoption of CEP to be lower than 6%. Additionally, irreversibility of treatment is a required assumption for our analytical approach. We obtained CEP participation data from the National Center for Education Statistics. For states with missing CEP participation data, we obtained data directly from state departments of education and used replication data from another researcher.²²

Hypothesized Effect Modifiers:

Effect modifiers included school level, defined as elementary, middle, high, or other, and school-level patient majority race or ethnicity group, defined as majority non-Hispanic White, non-Hispanic Black, Hispanic, or another race or ethnicity category. For example, if a school had 40% Hispanic patients, 30% Black patients, 20% White patients, and 10% other patient race/ethnicity groups, the school would be considered majority Hispanic.

Additional Covariates:

In addition to the hypothesized effect modifiers, the model adjusted for percent of patients with public health insurance, and state Medicaid expansion status. We included these covariates to account for compositional changes in patient-level demographics between years

or statewide policy change. These characteristics were hypothesized to cause both selection into CEP-participating schools and high BP, but were not hypothesized to be on the causal pathway between the exposure and outcome.

Statistical Analysis:

To assess whether the association of CEP participation and prevalence of high BP differed by age and race or ethnicity, we used a difference-in-differences approach for staggered policy adoption. This approach, described by Wooldridge (2021, 2023), expands on the traditional two-way fixed effects model, which includes time and unit fixed effects in a regression model, by adding an indicator variable for cohort, and interacting the time and cohort indicator variables with all covariates, thus creating a fully saturated model.^{21,23} This approach estimates a treatment effect for each time period and cohort, thereby avoiding the potential biases of using traditional two-way fixed effects models for staggered policy adoption.²⁴

In our models, the time indicator variable is school year (2013-2014 through 2019-2020) and the cohort variable is year of policy adoption. We used linear regression models and estimated cluster-robust standard errors at the level of treatment assignment (school).²⁵ Models used heteroskedasticity weights by mean number of patients per school. Models included school fixed effects, which control for all observed and unobserved school-level time-invariant characteristics. Because the model interacts each hypothesized effect modifier with treatment, from these estimates we computed separate marginal treatment effects for each level of age and majority patient race or ethnicity group. We also conducted Wald tests to determine whether the various categories of each variable were different from one another. Assumptions of this model include irreversibility of treatment (treated schools remain treated), no anticipation (no treatment effect prior to policy adoption), and conditional parallel trends (in the absence of treatment, the difference in outcomes between the treated and control group is constant over

time, after controlling for covariates).^{21,23} All analyses were conducted using StataMP 18 and R version 4.3.2.

Secondary Analysis

As a secondary analysis we assessed whether treatment effects varied by school-level patient obesity prevalence. We did not include this variable in our primary analyses as to not adjust away the effect of obesity, a major cause of high BP.¹ We hypothesize obesity status to both moderate and mediate the relationship between school CEP participation and child blood pressure. Therefore, we included a separate model with obesity prevalence as a covariate to estimate whether the association of school CEP participation with prevalence of high BP differed by school obesity prevalence. Obesity prevalence was a dichotomous variable equal to one if more than 20% of patients in a school had obesity (the mean prevalence in our sample). To determine obesity prevalence, we used body mass index (BMI) calculated from height and weight in the EHR, and designated patients with BMI at or above the 95th percentile for age and sex according to CDC growth charts to have obesity.²⁶

Results

The sample included 1,052 schools matched to 155,668 distinct patients. All schools were followed from school year 2013-14 through 2018-19. Table 1 shows demographic characteristics of patients and schools by school CEP participation status (participated or did not participate in CEP during the study period). Mean patient age was 10 years and on average 86% of patients had public health insurance, 19% had obesity, 48% were Hispanic, 22% were non-Hispanic White, and 16% were non-Hispanic Black. Mean number of patients per school was 47. Among schools matched to patients, 67% were elementary schools, mean school size was 695 students, and 78% of students within schools were eligible for free or reduced-price lunches on average prior to CEP adoption. Schools were located in 12 US states however the majority of schools were located in California (37%) or Oregon (27%). Schools that adopted

	Overall	CEP Participating ^a	Not CEP Participating ^a
PATIENT CHARACTERISTICS			
Number of patients per school (mean, sd)	46.6 (74.9)	46.9 (69.4)	46.0 (84.7)
Percent male (mean, sd)	50.4% (16.6%)	50.7% (16.3%)	49.8% (17.2%)
Age (mean, sd)	10.2 (3.0)	10.0 (2.9)	10.5 (3.2)
Race or Ethnicity (mean, sd)			
Hispanic	47.6% (34.0%)	53.3% (34.2%)	36.1% (30.6%)
Non-Hispanic White	22.4% (27.3%)	16.3% (23.1%)	34.6% (30.8%)
Non-Hispanic Black	15.5% (25.5%)	16.8% (26.6%)	12.8% (22.9%)
Asian	3.7% (9.0%)	3.4% (8.5%)	4.2% (9.9%)
American Indian or Alaskan Native	0.4% (2.0%)	0.3% (1.5%)	0.5% (2.8%)
Native Hawaiian or Other Pacific Islander	0.5% (2.8%)	0.5% (2.9%)	0.7% (2.5%)
Multiple races	1.2% (4.1%)	0.9% (2.9%)	1.8% (5.7%)
Unknown	8.7% (12.0%)	8.4% (11.6%)	9.3% (12.7%)
Percent health insurance type (mean, sd)			
Public (e.g. Medicaid)	86.2% (17.4%)	88.0% (16.0%)	82.6% (19.4%)
Private	6.8% (11.5%)	5.3% (9.4%)	9.7% (14.3%)
Uninsured	7.0% (13.0%)	6.6% (12.8%)	7.6% (13.3%)
Percent with Obesity (mean, sd) ^b	19.1% (13.6%)	19.7% (13.4%)	17.9% (13.8%)
SCHOOL CHARACTERISTICS			
Total Schools (N)	1,052	701	351
School Type (%)			
Elementary	67.2%	70.9%	59.8%
Middle	16.0%	14.0%	19.9%
High	14.9%	13.1%	18.5%
Other	1.9%	2.0%	1.7%
Number of Students (mean, sd)	694.4 (537.4)	672.8 (458.2)	737.4 (666.1)
Percent Students Eligible for Free or Reduced-Price Meals (mean, sd)	78.1% (14.9%)	83.4% (11.8%)	68.3% (15.1%)
Social Deprivation Index Score (mean, sd) ^c	76.9 (19.7)	81.0 (17.5)	68.3 (21.5)
Rurality (mean, sd) ^d	1.8 (1.5)	1.6 (1.3)	2.0 (1.7)
State (%)			
California	36.9%	40.1%	30.5%
Oregon	26.8%	21.8%	36.8%
Texas	10.0%	12.6%	4.8%
Indiana	6.1%	6.0%	6.3%
Ohio	6.1%	6.1%	6.0%
Massachusetts	5.7%	7.9%	1.4%
Washington	4.4%	0.9%	11.4%
Minnesota	2.1%	2.7%	0.9%
North Carolina	1.0%	1.4%	0%
Alaska	0.6%	0.1%	1.4%
Montana	0.3%	0.3%	0.3%
Wisconsin	0.2%	0.1%	0.3%

Table 1. Demographic Characteristics of Patients and Schools by School CEP Participation Status.

^aRefers to whether schools participated in CEP during the study period (between 2014 when the policy became available to eligible schools nationwide, through 2019. ^bObesity in children is defined as body mass index at or above the 95th percentile for age and sex according to CDC growth charts. ^cSocial deprivation index score is a composite measure of area-level deprivation ranging from 1 to 100 with 100 corresponding to highest level of deprivation. ^dRurality measure from the 2013 US Department of Agriculture rural-urban continuum; continuum is a scale from 1-9 with 9 indicating most rural.

CEP during the study period on average had more Hispanic and Black patients and fewer White patients. The percentage of elementary schools was higher among participating (71%) than non-participating schools (60%) and had more students eligible for free or reduced-price meals (83% among CEP-participating vs. 68% among non-CEP-participating schools).

Table 2 shows number of schools and mean patients per school by CEP participation status and by hypothesized effect modifiers: age group, race or ethnicity, and obesity prevalence. CEP-participating elementary schools had higher mean patients per school (45) than those that did not participate (29), while CEP-participating high schools had lower mean patients per school (51 vs. 100 among non-CEP participating high schools).

Category	Number of Schools		Mean Patients Per School	
	CEP Participating	Not CEP Participating	CEP Participating ^a	Not CEP Participating ^a
Age Group				
Elementary	497	210	45.4	28.5
Middle	98	70	50.9	50.1
High	92	65	51.2	100.2
Majority Race or Ethnicity				
Non-Hispanic White	133	190	52.7	58.1
Hispanic	441	127	47.5	34.6
Non-Hispanic Black	120	26	38.5	23.8
Obesity Prevalence				
≤20%	634	338	43.4	50.6
>20%	625	283	50.8	38.8

Table 2. Number of Schools and Mean Patients per School by CEP Participation Status and Age Group, Obesity Prevalence, and Race or Ethnicity. ^aRefers to whether schools participated in CEP during the study period (between 2014 when the policy became available to eligible schools nationwide, through 2019).

Table 3 shows baseline mean prevalence of high BP by school CEP participation status and hypothesized effect modifiers. Baseline prevalence was higher among CEP-participating elementary (29%) and middle schools (25%) than among those that did not participate (21% elementary, 20% middle). Among schools with greater than 20% obesity prevalence, prevalence of high BP was higher among CEP-participating (31%) than non-participating schools (22%). By race or ethnicity, high BP prevalence was higher among majority Hispanic CEP-participating

schools (30%) than non-participating schools (19%) and majority Black participating (24%) than non-participating schools (16%).

Category	CEP Participating ^a	Not CEP Participating ^a
Age Group		
Elementary	28.7%	20.9%
Middle	25.4%	19.8%
High	21.4%	19.7%
Majority Race or Ethnicity		
Non-Hispanic White	22.4%	20.6%
Hispanic	29.6%	18.9%
Non-Hispanic Black	24.2%	16.1%
Obesity Prevalence		
≤20%	23.4%	19.8%
>20%	31.3%	21.5%

Table 3. Baseline Mean Prevalence of High BP by School CEP Participation Status and Age Group, Obesity Prevalence, and Race or Ethnicity. Prevalence estimates weighted by number of patients per school. ^aRefers to whether schools participated in CEP during the study period (between 2014 when the policy became available to eligible schools nationwide, through

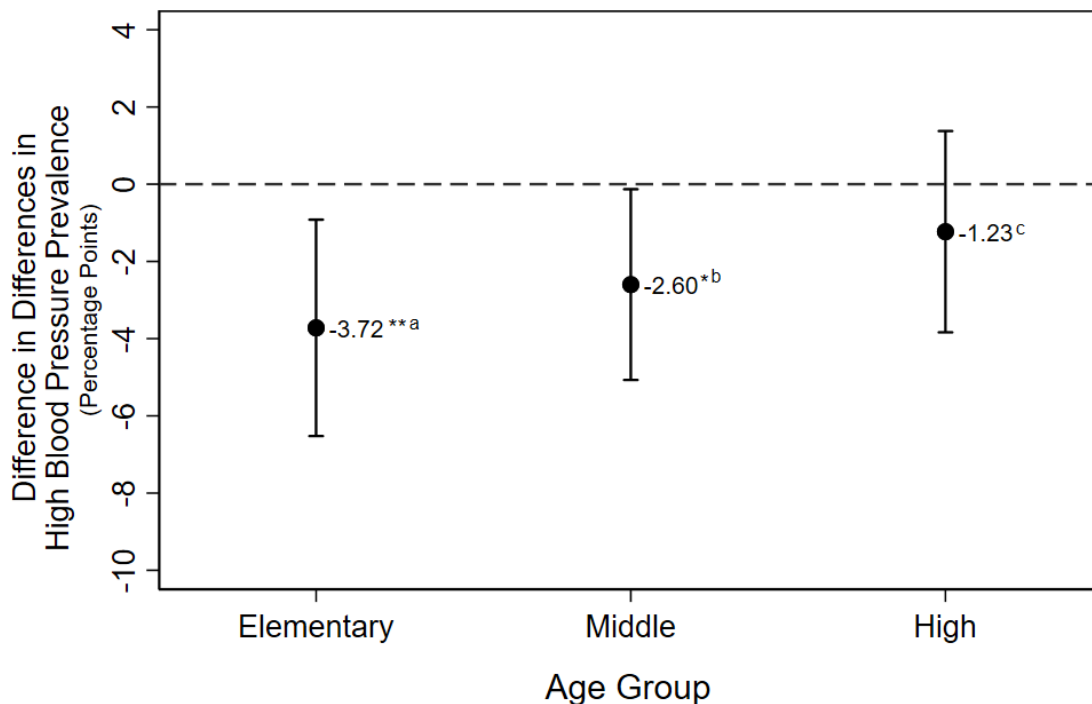


Figure 1. Difference-in-Differences Estimates of the Association of School CEP Participation with Prevalence of High BP by Age Group. Difference in differences estimates and 95% confidence intervals of the association of CEP participation with prevalence of high blood pressure by age group. Estimates are shown in percentage points. Estimates with different letters are statistically different from one another. Estimate is statistically significantly different from zero: *p<.05, **p<.01.

Figure 1 depicts adjusted difference-in-differences point estimates and confidence intervals of the association of school CEP participation with prevalence of high BP by age group. CEP was associated with a 3.72 percentage point (pp) lower prevalence of high BP among elementary schools (95% CI: -6.53, -0.91, $p=0.01$), and a 2.60 pp lower prevalence among middle schools (95% CI: -5.07, -0.14, $p=0.04$). CEP participation was also negatively associated with high BP prevalence in high schools, but the association was not statistically significant (point estimate = -1.23 pp, 95% CI: -3.83, 1.37, $p=0.35$). The association of CEP and high BP prevalence varied significantly by age group ($p=0.03$). CEP-participating elementary schools were associated with a significantly greater relative reduction in prevalence of high BP than CEP-participating middle schools ($p=0.02$) and high schools ($p=0.008$).

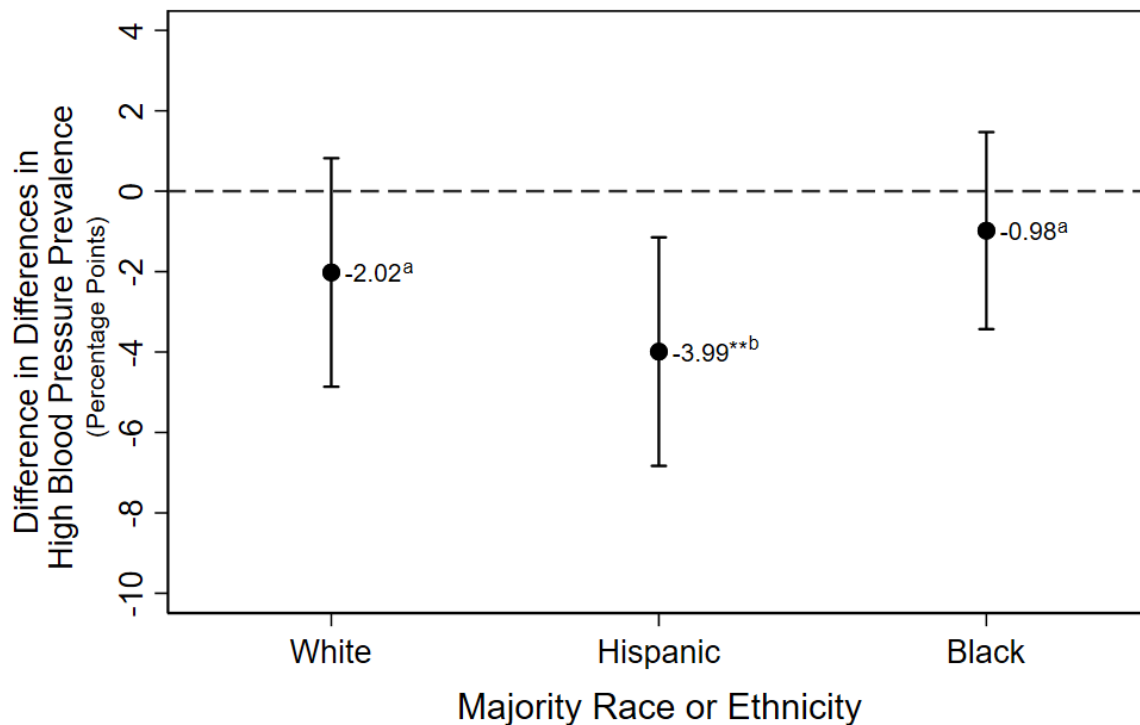


Figure 2. Difference-in-Differences Estimates of the Association of School CEP Participation with Prevalence of High BP by Majority Race or Ethnicity. Difference in differences estimates and 95% confidence intervals of the association of CEP participation with prevalence of high blood pressure by majority patient race or ethnicity group. Estimates are shown in percentage points. Estimates with different letters are statistically different from one another. Estimate is statistically significantly different from zero: * $p<.05$, ** $p<.01$.

Figure 2 depicts adjusted difference-in-differences point estimates and confidence intervals of the association of school CEP participation with prevalence of high BP by majority patient race or ethnicity. CEP participation was associated with a 3.99 pp lower prevalence of high BP among schools with a majority of Hispanic patients (95% CI: -6.84, -1.14, $p=0.006$). While CEP was negatively associated with high BP in both schools with a majority of White patients and schools with a majority of Black patients, estimates did not reach traditional levels of statistical significance (schools with majority White patients: point estimate = -2.02, 95% CI: -4.86, 0.81, $p=0.16$) (schools with majority Black patients: point estimate = 0.98, 95% CI: -3.44, 1.48, $p=0.43$). The association of CEP and high BP prevalence varied significantly by patient majority race or ethnicity ($p=0.009$). CEP-participating schools with a majority of Hispanic patients had a significantly greater relative reduction in prevalence of high BP than CEP-participating schools with a majority of White patients ($p=0.005$). In a secondary analysis in which obesity prevalence was included as a covariate, CEP was associated with a 4.27 pp net reduction in prevalence of high BP among schools with 20% or fewer patients with obesity (95% CI: -7.02, -1.51, $p=0.002$) and a 4.04 pp relative decrease among schools with more than 20% of patients with obesity (95% CI: -6.60, -1.47, $p=0.002$). However, these estimates were not significantly different from one another ($p=0.47$).

Discussion:

In a predominantly low-income sample of schools matched to patient health records, we observed that school participation in the Community Eligibility Provision was associated with greater relative reductions in prevalence of high blood pressure in elementary schools compared to middle or high schools, and schools with a majority of Hispanic patients compared to those with a majority of White or Black patients. This study was longitudinal at the school level, used a novel approach of linking patient medical records to school policy data, and used an analytic approach designed for both assessing treatment effects of a policy with staggered adoption as well as assessing heterogeneous treatment effects by subgroups of interest.

The greater relative reduction in prevalence of high BP observed in CEP-participating elementary schools compared to middle or high schools could be due to higher school meal participation rates in this age group.¹⁶ Thus, more students in this age group likely experience the dietary benefits of switching to school meals.^{10,12} Qualitative evidence suggests that lower participation rates in adolescents may be due to lower satisfaction with school meal quality and freshness, despite improvements in nutrition quality in recent years.²⁷ Future research should investigate how school meal participation can be improved in older age groups who are at higher risk of developing high BP.¹ This could include research on farm to school programs, which have the potential to increase access to fresh fruits and vegetables.²⁸ However, that we observed more pronounced potential health benefits of the policy in elementary-aged children is promising. By intervening in early childhood, CEP may help children to develop healthier eating habits which can be protective against developing high BP and the associated health consequences as they age.⁶ In this sample, baseline prevalence of high BP was higher among elementary-aged patients in CEP-participating schools than in older age groups, which is not consistent with population-level trends.¹ However, any time-invariant school-level differences, both observed and unobserved, were controlled for in our study design. Therefore, even if this particularly group of patients had higher BP at baseline, this difference at baseline is unlikely to have impacted observed results.

By majority patient race or ethnicity group, we observed that CEP participation was more negatively associated with prevalence of high BP in schools with a majority of Hispanic patients than schools with a majority of White or Black patients. Hispanic patients comprised the largest demographic group in this sample, and had the highest prevalence of high BP at baseline. A recent study found that majority Hispanic schools have lower access to competitive foods (e.g. a la carte options and vending machine products) and were more likely to have a school wellness policy than majority White schools, indicating a potentially more healthful school

food environment.²⁹ Researchers, however, did not observe differences in school meal nutrition quality by school majority race or ethnicity.²⁹ Future research should investigate factors that may facilitate potential health benefits of the policy in this population.

In general, many school-based health interventions to address nutrition, physical activity, and healthy lifestyle have been education-focused, which have limited efficacy on a population level compared to interventions that address social determinants of health.^{9,30} While some have demonstrated modest health improvements, many school-based interventions could not be sustained over time due to insufficient resources and staff turnover.^{30,31} Evidence suggests that joint interventions between schools and governmental policies are most effective.³⁰ With continued federal funding, CEP represents a sustainable government-school partnership with demonstrated academic, behavioral, and health benefits.^{10,22,32,33} Few studies on school-based nutrition interventions have shown heterogeneous impacts by race or ethnicity³⁴ and little is known about how school-based interventions may vary in efficacy by age group.³⁰ Additional qualitative research may be particularly useful to better elucidate ways in which school-based policies can better serve children of varying age groups and with different racial and ethnic identifies.

Limitations

Results of this study are not nationally representative but do come from a population of children in low-income areas who attend CEP-eligible schools and who are disproportionately burdened by high BP. Nevertheless, future studies should assess heterogeneous impacts of school meals programs on health in larger, nationally representative samples. We were unable to assess heterogeneity in outcomes by income level due to high rates of missing income data. Although socioeconomic status is another important predictor of high BP in children,³ the majority of children in this sample came from low-income households, as exhibited by the vast majority qualifying for public health insurance. However, future studies should assess

heterogeneous impacts of school meals policies by household income. High BP is officially diagnosed after measurements are found to be consistently high on three separate occasions.¹ Because we had only one measurement occasion from most patients in the study, observed prevalence in this study is likely an overestimate of true prevalence of persistent, elevated BP.

Conclusion:

In a sample of schools linked to patient medical records from community health organizations in low-income areas, we assessed heterogeneity in the associations between school participation in the Community Eligibility Provision and prevalence of high blood pressure by age group and race and ethnicity. We observed greater relative reductions in high blood pressure in elementary schools participating in the policy than in middle or high schools. We also observed greater net decreases in participating schools with a majority of Hispanic patients than schools with a majority of White or Black patients. While our findings highlight that CEP may positively impact health in important demographic groups, more research is needed to determine how the policy can better serve other groups disproportionately burdened by high blood pressure, including Black children and adolescents.

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CHAPTER 5: CONCLUSION

This dissertation research assessed factors associated with the implementation of the Community Eligibility Provision, a federal universal free school meals policy reaching over 20 million children nationwide, and the potential effectiveness of this policy in improving population health.¹ This effectiveness-implementation hybrid design allowed us to identify barriers and facilitators to participation in the policy over time and to utilize this information to determine whether the policy was associated with change in blood pressure outcomes. High BP in children is a pressing public health concern and precursor to leading causes of morbidity and mortality in the United States.²⁻⁶ By assessing both implementation and effectiveness of the policy in addressing pediatric high BP, this research provides critical information to researchers and policymakers and makes important contributions to the public health literature.

In Aim 1, we examined the association of school and area-level characteristics with CEP participation and how these associations changed over time. We found relatively lower prevalence of participation in small schools and school districts, high schools, majority Hispanic schools, schools below the threshold for 100% federal reimbursement for meals served (specifically, an identified student percentage below 50%), suburban schools, schools in non-Medicaid expansion states, and schools in the Western and Mountain Plains regions of the US. Based on prior research and the underlying constructs that characteristics measured identified a priori, we determined that these findings reveal potential barriers to CEP participation included cost of policy implementation (particularly among schools that fall below the threshold for 100% federal reimbursement for meals served), low student demand among high school-aged students, and political environments/beliefs that are not amenable to social safety net policy adoption. We identified a successful stakeholder-led effort to adopt CEP in all New York City public schools (over 1,800) in a relatively short time period. This was likely, at least in part, responsible for the observed dramatic change in prevalence of participation in the Northeastern

US over time, higher than any other region.⁷ Such community organizing efforts represent a potential facilitator to CEP adoption that could be adapted to other environments with lower CEP participation such as suburban areas.

Other facilitators to CEP adoption will require policy changes such as increased funding for small schools and districts or a lower threshold for 100% federal reimbursement of meals served. For example, although CEP eligibility was technically expanded in school year 2023-24 when the eligibility threshold was decreased from an identified student percentage of 40% to 25%, our findings suggest that this expansion is unlikely to substantially increase CEP participation. This is because unless the threshold at which 100% of meals are federally reimbursement is also lowered, making up this cost difference will not be affordable to many eligible schools. The reason for other observed disparities in participation by school and area characteristics remain unclear. For example, majority Hispanic schools had lower participation in CEP than majority Black schools, and this gap in participation widened over time. Because Hispanic children face disproportionate rates of food insecurity,⁸ more research, including qualitative research, into why these schools had lower participation will be critical.

In Aim 2, we estimated the association between school participation in CEP and school-level BP outcomes. We followed a balanced sample of CEP-eligible schools longitudinally that were matched to patient medical records from the OCHIN network of community health organizations based on address. We found that school participation in CEP was associated with a net decrease in prevalence of high BP. This is supported by evidence that CEP increases participation in school meals, which are healthier than alternatives.^{9,10} Our rigorous, quasi-experimental approach allowed us to assess trends in the outcome prior to policy adoption, which were not statistically different between treated and untreated schools, lending support to the assertion that the observed net decrease in high BP can be attributed to the policy. This study represents a paradigm shift in research into interventions to address high BP in children.

Prior research into pediatric high blood pressure has focused on small clinical educational interventions focused on individual behavior change.^{11,12} Due to the widespread nature of the health problem and its major contribution to leading causes of death in the US,² population-level approaches that address social determinants of health and provide a context in which default decisions are healthy hold the most potential for meaningful change.¹³

Finally, in Aim 3 we assessed whether the association of school CEP participation with high BP varied by age group and race/ethnicity. In this sample of schools matched to patients from community health organizations in low-income areas, we found that the association of school CEP participation and prevalence of high BP varied significantly by both age group and majority patient race or ethnicity. The association was greater (more negative) in elementary-aged children than in middle or high school-aged children. We also found that the association was greater (more negative) in majority Hispanic schools than majority White or majority Black schools. The greater reduction observed among younger children is likely explained by higher rates of school meal participation in this age group.¹⁴ CEP may have induced more children in this age group to participate, while barriers to participation in older students such as dissatisfaction with school meal quality and taste may prevent them from participating in school meals even when they are universally free.¹⁵ Additionally, majority Hispanic schools are less likely to provide competitive foods and more likely to have a school wellness policy than majority White schools.¹⁶ When schools switch to CEP within the context of a healthier food environment where there are fewer unhealthy alternatives available, this could create a greater potential for students to participate in the more nutritious, free meal options.

However, both findings from this study raise questions for future research. For example, how can schools increase meal participation among adolescents who are at higher risk of developing high blood pressure than younger children? What are the factors that facilitate health benefits of school meals among Hispanic students? Can these factors be modified to enhance

participation among other minoritized groups (e.g. schools serving predominantly Black students) who are also disproportionately burdened by high blood pressure? Qualitative research focused on eliciting feedback directly from students in these groups may be particularly beneficial in helping to answer these questions. Nevertheless, this research contributes to the goal of enhancing equity in public health interventions. It is critical that researchers move beyond assessing overall effectiveness of public health policies, which often differ significantly by subgroups. Assessing heterogeneous effects of public health policies provides crucial understanding for how such policies can be improved to better serve communities most negatively impacted.

Findings from this dissertation research, taken as a whole, have important implications for public health policy and practice. One such implication is the contribution to the growing body of literature highlighting the potentially beneficial impacts of CEP for child health; specifically in reducing child BMI/obesity.^{17,18} This is in addition to findings that CEP may also improve child academic and behavioral outcomes.^{19,20} Further, findings from this research can be used to guide future policymaking and funding decisions regarding CEP. For example, our implementation-related findings could inform how additional funding could be strategically allocated to improve CEP participation. Additionally, our findings on the potential effectiveness of CEP for improving child health could inform whether state and/or federal policymakers decide to continue to fund or expand funding for CEP. These findings are particularly timely for states considering implementing their own permanent universal free meals policies in the wake of the recent expiration of pandemic-related nationwide universal free meals waivers. These waivers allowed all schools to temporarily implement universal free meals between 2020 and 2022. Finally, the promising findings reported in this dissertation research may help to shift research into interventions to address hypertension and high blood pressure away from those focused on individual behavior change via education and counseling and towards policies and programs

that address social determinants of health. Such large-scale initiatives will be necessary in order to effectively address high blood pressure and similarly prevalent chronic conditions for which effective population-level solutions have been challenging to identify and enact.

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