



Healthier school food and physical activity environments are associated with lower student body mass index

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ABSTRACT

School food and physical activity (PA) environments can influence children's dietary and physical activity behaviors. However, evidence on whether school environment is associated with students' weight status is less definitive. In this study, we examined the association between students' body mass index (BMI) and measures of school food and PA environments. We calculated BMI from nurse-measured data collected on 19,188 6–19-year-old students from 90 public schools in four low-income cities in New Jersey in 2015–2016. Based on a questionnaire administered to school nurses, we constructed 6 food and 3 PA indices capturing the healthfulness of key dimensions in the school food and PA environment domains. Multilevel linear models, stratified by school level (elementary and secondary), examined the association between BMI z-scores and indices of the school environment. The food and PA domains were modeled separately and then combined. Joint significance of indices within each domain was tested. Analyses were conducted in 2019–2020. In the combined model for elementary schools, indices in both the food and PA domains were jointly significant ($p = 0.005$ and $p < 0.001$, respectively). With regard to specific indices in the model, students' BMI z-score was 0.03 units lower for each additional outdoor PA facility (95% CI $[-0.06, -0.00]$; $p = 0.036$). Similarly, for secondary schools, both the food and PA domains were jointly significant ($p = 0.004$ and $p = 0.020$, respectively). Each additional unhealthy item in vending machines was associated with a 0.12 unit increase in BMI z-score (95% CI $[+0.00, 0.23]$; $p = 0.042$). Overall, healthier food and PA environments were associated with lower student BMI.

1. Introduction

Childhood obesity continues to be a major public health problem in the United States, with 18.5% of children and adolescents aged 2–19 years living with obesity in 2015–2016 (Hales et al., 2017). The prevalence of obesity among children is concerning because it is linked to adverse psycho-social and health outcomes during childhood and later in life (Abarca-Gómez et al., 2017). School policies and practices can play an important role in addressing obesogenic behaviors. Children consume up to two meals and a snack at school, which can amount to 58% of their total daily caloric intake (Cullen and Chen, 2017). Similarly, adolescents accumulate 42% of their daily physical activity (PA) in school settings (Carlson et al., 2016).

Research has suggested a positive impact of interventions to promote healthier school environments on targeted dietary and PA

behaviors (Micha et al., 2018; Masini et al., 2020). Some studies have also examined the relationship between school environments and students' weight status directly. In a nationally representative sample, Terry-McElrath et al. (2015) found that specific healthier components of the school food environment were associated with lower risk of self-reported overweight or obesity among high schoolers, but not middle schoolers. Using data from the same nationally representative study, O'Malley et al. (2009) and Hood et al. (2014) found only a few significant associations between healthier physical activity environments and lower weight status among middle and high school students using student-reported weight data.

To date, most studies examining the relationship of school environments with students' weight address either food or PA environments in their analysis, tend to focus on narrow age/grade ranges, and often rely on student reports of heights and weights. The current study

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leverages data from a large cohort of children covering grades 1–12 from multiple school districts using nurse-measured heights and weights. We examine the association between children’s weight status and school food and PA environment measured using validated indices, first individually and then simultaneously.

2. Methods

2.1. Data

New Jersey State Board of Education requires all public schools to measure students’ heights and weights in grades K through 12 annually (NJ Department of Education, 2019). These nurse-measured heights and weights were collected as part of the New Jersey Child Health Study (NJCHS) from 6–19 year-old students in four New Jersey cities (Camden, New Brunswick, Newark, and Trenton) in school year 2015–2016. Of the 124 elementary and secondary schools in the NJCHS, 102 provided student measurement data for a response rate of 82%. Measurement records also included data on student sex, race, and date of birth/age. All data were de-identified. Age- and sex-specific Body Mass Index (BMI) z-scores were calculated following standard Centers for Disease Control and Prevention procedures (Centers for Disease Control and Prevention, 2019) and were used as the outcome in our analysis. Sensitivity analyses were conducted using the BMI percentile-for-age, another commonly used measure for obesity surveillance.

Key exposure variables were 9 indices capturing the healthfulness of different aspects of the school environment, categorized into two domains: food environment (6 indices) and PA environment (3 indices). These indices were created using data collected for the NJCHS from a school survey of the food and PA environment, which had a response rate of 90%. Food environment indices are counts of healthy and unhealthy items offered in school lunches, vending machines, and a la carte. Physical activity environment indices are counts of indoor and outdoor facilities such as gymnasiums, pools, sports courts, or multi-purpose fields; and counts of PA opportunities such as intra- and extramural sports, recess, and physical education. The complete list of items included in each index is reported in Appendix Table A.1. Missing data on items used in index construction were handled with multiple imputations based on a chained equations procedure (Royston and White, 2011). More details about the school survey and index construction are available elsewhere (Acciai et al., 2019).

Student age, sex, and race/ethnicity were obtained from nurse records and included as covariates in the analysis. Race/ethnicity was categorized as Hispanic, non-Hispanic black, non-Hispanic white, and others. School-level covariates were drawn from the National Center for Education Statistics (NCES) common core data repository (NCES, 2018). NCES variables included in the analyses were: number of enrolled students, proportion of students eligible for free or reduced-price lunch, and school level, classified as elementary vs. secondary (middle and high) schools.

Of the 110 schools that responded to the school food and PA environment survey, 90 schools had also provided nurse-measured heights and weights of their students. After excluding biologically implausible measurements ($n = 107$) and missing information on race ($n = 426$), the analytic sample included 19,188 students from 67 public elementary and 23 secondary schools.

Table 1

Description of Sample: Individual and School-Level Characteristics. Mean (or percentage) and standard deviation in parentheses.

Variables	All Schools	Elementary	Secondary
<i>Individual Level</i>			
BMI z-score	<i>N</i> = 19,188	<i>N</i> = 12,722	<i>N</i> = 6,466
	0.85 (1.1)	0.84 (1.1)	0.88 (1.1)
Sex (% Male)	50.9 (0.5)	52.3 (0.5)	48.2 (0.5)
Age (years)	10.9 (3.4)	9.1 (2.3)	14.5 (2.1)
Race/Ethnicity (%)			
Black	42.6 (0.5)	38.2 (0.5)	51.1 (0.5)
Hispanic	54.2 (0.5)	57.9 (0.5)	47.0 (0.5)
White	1.5 (0.1)	2.0 (0.1)	0.6 (0.1)
Other	1.7 (0.1)	1.9 (0.1)	1.3 (0.1)
<i>School Level</i>			
	<i>N</i> = 90	<i>N</i> = 67	<i>N</i> = 23
Students Enrolled	648 (353.8)	546 (207.6)	848 (475.6)
Eligible for Free and Reduced-price Lunch (%)	72.5 (15.4)	73.7 (14.5)	70.2 (16.8)
Food Environment Indices [Observed range]			
NSLP – Healthy [4,9]	7.4 (1.3)	7.1 (1.3)	8.0 (1.1)
NSLP – Unhealthy [0,5]	3.1 (1.4)	3.1 (1.4)	3.1 (1.5)
Vending Machine – Healthy [0,4]	0.7 (1.3)	0.5 (1.1)	1.2 (1.4)
Vending Machine – Unhealthy [0,8]	0.7 (1.6)	0.6 (1.6)	1.0 (1.5)
A La Carte – Healthy [0,9]	4.2 (3.3)	3.2 (3.1)	6.0 (3.0)
A La Carte – Unhealthy [0,10]	3.5 (3.3)	2.6 (2.3)	5.1 (2.2)
PA Environment Indices [Observed range]			
Indoor Facilities [0,4]	2.0 (0.8)	1.9 (0.7)	2.3 (0.8)
Outdoor Facilities [0,6]	3.0 (1.5)	2.8 (1.5)	3.2 (1.5)
PA Opportunities [1,7]	3.3 (1.4)	3.5 (1.5)	2.7 (1.1)

Source: New Jersey Child Health Study data collected for school year 2015–2016 from public schools in Camden, Newark, New Brunswick, and Trenton, NJ.

2.2. Statistical analyses

We examined the association between each school environment index and students’ BMI z-scores after adjusting for covariates (student race, age, sex, school’s rate of free and reduced-price lunch participation, and number of students enrolled). First we modeled indices in each of the two domains separately; then we included all food and PA indices in one model. In order to assess if the combined set of indices within each domain predicted students’ BMI z-scores, we tested the joint significance, which indicates the collective predictive power of a set of variables net of the other variables in the model. The null hypothesis associated with the joint significance test is that all coefficients included in the test are equal to 0. This approach has been used in previous studies examining multiple factors within different domains and their association with child weight status (Ohri-Vachaspati et al., 2015). We used multilevel linear models to account for the nested structure of the data. Analyses were conducted in 2019–2020 using STATA 15. This study was approved by the Institutional Review Boards of the authors’ respective institutions.

3. Results

Table 1 provides descriptive statistics of student and school-level characteristics for the full sample, and then stratified by school level. Two-thirds (66%) of the students attended elementary schools. A vast

Table 2
Mixed Model Regression of BMI Z-scores on Indices of School Food and Physical Activity (PA) Environment.

Indices	Elementary Schools (n = 12,722)		Secondary Schools (n = 6,466)	
	Individual Domains	Full model	Individual Domains	Full model
Food Environment Domain	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)
NSLP – Healthy	–0.03 (–0.07, +0.00)	–0.03 (–0.06, 0.01)	–0.06 (–0.11, –0.00)*	–0.03 (–0.10, 0.04)
NSLP – Unhealthy	–0.01 (–0.00, 0.03)	–0.01 (–0.05, 0.03)	–0.01 (–0.09, 0.08)	0.01 (–0.05, 0.06)
Vending Machine – Healthy	–0.01 (–0.06, 0.03)	–0.01 (–0.05, 0.04)	0.02 (–0.08, 0.11)	–0.03 (–0.14, 0.07)
Vending Machine – Unhealthy	0.03 (–0.01, 0.08)	0.04 (–0.00, 0.08)[†]	0.03 (–0.07, 0.13)	0.12 (+0.00, 0.23)*
A La Carte – Healthy	0.01 (–0.00, 0.02)	0.01 (–0.01, 0.03)	0.01 (–0.02, 0.03)	–0.01 (–0.03, 0.02)
A La Carte – Unhealthy	–0.01 (–0.04, 0.03)	–0.01 (–0.04, 0.03)	0.01 (–0.03, 0.05)	0.02 (–0.02, 0.05)
Joint Significance (Wald F and p-value)	F = 9.7 p = 0.137	F = 18.4** p = 0.005	F = 43.1*** p = 0.000	F = 18.9** p = 0.004
PA Environment Domain				
Indoor Facilities	0.03 (–0.03, 0.10)	0.02 (–0.04, 0.08)	–0.09 (–0.14, –0.03)**	–0.09 (–0.19, 0.01) [†]
Outdoor Facilities	–0.03 (–0.05, –0.01)*	–0.03 (–0.06, –0.00)*	–0.02 (–0.06, 0.01)	–0.07 (–0.13, –0.00)*
PA Opportunities	–0.03 (–0.06, 0.01)	–0.03 (–0.07, 0.01)	–0.03 (–0.07, 0.02)	+0.00 (–0.04, 0.04)
Joint Significance (Wald F and p-value)	F = 20.5*** p = 0.000	F = 23.8*** p = 0.000	F = 11.33* p = 0.010	F = 9.8* p = 0.020

Source: New Jersey Child Health Study data collected for school year 2015–2016 from public schools in Camden, Newark, New Brunswick, and Trenton, NJ. Note: All models adjusted for student race, age, sex, free and reduced-price lunch participation, and number of students enrolled. Models labeled “Individual Domains” include all indices within the single domains. Models labeled “Full model” include all 9 indices simultaneously. [†]p < 0.10, *p < 0.05, **p < 0.01, ***p < 0.001

majority of the students were Hispanic (54%) or black (43%). Overall, over 72% of students were eligible for free or reduced-price meals. Schools, on average, offered 7 to 8 healthy and about 3 unhealthy NSLP items. A la carte and vending machine items were more common in secondary schools. Overall, more healthy items were included as a la carte options than unhealthy items, while vending machines had an approximately equal number of healthy and unhealthy items. On average, the schools in our sample offered two indoor and three outdoor PA facilities. The number of PA opportunities was slightly higher in elementary schools than in secondary schools (3.5 vs. 2.7).

Table 2 reports the results of the multivariate analyses. For elementary schools, the model including only the indices in the food environment domain showed no association between each individual index and BMI z-score, nor jointly for all indices in the domain combined. In the model confined to indices in the PA domain, the index capturing the counts of outdoor facilities was associated with a 0.03 unit decrease in BMI z-score (p < 0.05). Further, the indices in the PA domain were jointly associated with BMI z-scores (p < 0.001). In the full model, where indices from both domains were entered, the PA indices continued to be jointly significant for association with BMI z-score, with the index capturing the counts of outdoor facilities still inversely associated with BMI z-score. Unlike results from the domain-specific model, in the full model for elementary schools, the food environment indices were also jointly significant (p < 0.01), suggesting that the indices in this domain were collectively significant predictors of students' BMI, after adjusting for all other variables in the model.

For secondary schools, in domain-specific models, food environment indices were jointly significant (p < 0.001), as were the PA indices (p < 0.05). In particular, we found that for every additional healthy item in the National School Lunch Program (NSLP), BMI z-score

was 0.06 units lower (p < 0.05), while in the PA only model, for every additional indoor facility BMI z-score was 0.09 units lower (p < 0.01). In the full model including all domains, again, both food and PA environment indices were jointly significant in predicting BMI z-score (p < 0.01 and p < 0.05, respectively). In this model, each additional unhealthy item in vending machines was associated with a 0.12 unit increase in BMI z-score, while each additional outdoor PA facility was associated with 0.07 unit lower BMI z-score (p < 0.05). Indoor facilities were associated with a 0.09 unit lower BMI z-score (p < 0.10). No significant associations for student weight outcomes were observed with unhealthy NSLP, healthy vending, and healthy and unhealthy a la carte indices, nor with the index measuring other PA opportunities (besides facilities) in the PA domain. When we conducted sensitivity analyses with BMI percentiles as the outcome, our findings remained the same for both sets of models for elementary and secondary schools (data not shown).

4. Discussion

A comprehensive set of indices characterizing school food and PA environments were examined in a sample of 90 elementary and secondary schools in New Jersey to assess their association with students' BMI. Overall, in this large low-income, high minority sample, healthier attributes of the school food and PA environments were negatively associated with BMI z-score among both elementary and secondary school-age children. Notably, several of these relationships persisted in models including both the food and PA indices, emphasizing the unique contributions of elements from each domain.

Consistent with previous research, (Terry-McElrath et al., 2009; Fox et al., 2009) we found a significant, positive association between

unhealthy vending machine offerings and increased weight status among secondary school students. A similar (although only marginally significant) trend was also observed for elementary school students. Vending machines often provide energy dense foods and beverages (Pasch et al., 2011), which have been shown to replace healthier snacks (such as fruit) among students (Terry-McElrath et al., 2009), potentially contributing to energy imbalance. Healthier NSLP options were associated with lower BMI z-score in secondary school students in the food environment model. There is strong evidence that availability of healthier options in school meals is associated with healthier meals selected and consumed by students (Fox and Gearan, 2019). Our findings, along with previous research (Micha et al., 2018), support policies such as those implemented as part of the Healthy Hunger Free Kids Act (HHFKA), by providing evidence that healthy school food environments might contribute to healthier weight outcomes for students.

A novel finding in this study is the significant independent association between the school PA environment and children's weight status in both elementary and secondary schools. Our data show that an increased number of both indoor and outdoor facilities is associated with lower student BMI. An earlier study using a nationally representative sample, found that indoor and outdoor PA facilities were associated with increased moderate-to-vigorous physical activity among high school students; however, it did not find an association with weight status in their full sample (Hood et al., 2014). In moderation analysis, authors reported significant associations for weight status with indoor and outdoor facilities for 8th graders from lower SES families and for high school girls.

Our findings suggest that PA and food environments play a significant and unique role in improving weight outcomes in children. Though the actual contribution of each aspect of the food and PA environment in mitigating obesity may be relatively small given the multifaceted etiology of obesity, collectively these efforts can help address the burden of obesity. This prospect is supported by our finding that in the full models for both school levels, indices in the PA domain taken together as well as indices in the food domain assessed collectively, were jointly significant. Schools should be encouraged through implementation of federal policies such as the HHFKA, local wellness policies, and other initiatives, to improve students' access to healthy food and facilities for PA during the school day.

The main limitation of this study is its cross-sectional design, which does not allow us to determine causality; we cannot therefore conclude that the BMI outcomes were caused by specific aspects of the school

food and PA environment. Also, the school food and PA environment indices captured availability of food items and PA facilities, but did not measure students' food consumption and activity choices. Lastly, our sample was comprised of schools with very high minority populations. This is both a strength, because there are fewer studies looking at school environments in these vulnerable populations, but also a limitation, in that our findings may not be generalizable to schools with different demographic compositions. The strengths of the study include the comprehensive assessment of multiple aspects of the school food and PA environments and reliance for our outcome measure on nurse-measured heights and weights data for a large number of children.

5. Conclusion

Our findings indicate that healthier school food and PA environments, specifically healthier options in school meals and fewer unhealthy competitive food offerings, and a higher number of PA facilities, is associated with lower BMI among school-age children. Future studies should examine the impact of changes in school food and PA environments on students' weight status longitudinally to determine whether the association we observed is causal. Another promising avenue for research would be analyzing actual food consumption and PA behaviors.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix

Table A.1
List of Indices and Items Included.

Index name and score range	Items included
<i>Food Environment Indices</i>	
National School Lunch Program healthy (0–9)	At least half whole grains Whole grains Variety of vegetables Pizza – modified recipe Fat free/1% unflavored milk Fat-free flavored milk Fresh fruit Raw vegetables Salad bar
National School Lunch Program unhealthy (0–5)	Fries Pizza – traditional recipe Dessert Full fat/2% unflavored milk Full fat/1% flavored milk
Vending machine healthy (0–4)	Bottled water 100% juice Fat free/1% unflavored milk Fat-free flavored milk
Vending machine unhealthy (0–9)	Juice drink Diet soda Soda Energy or sports drinks Full fat/2% unflavored milk Full fat/2%/1% flavored milk Salty snacks Cookies, cakes Candy
A la carte healthy (0–9)	Bottled water 100% juice Fat free/1% unflavored milk Fat-free flavored milk Dairy foods, lower in fat Raw FV Salad bar Sandwiches
A la carte unhealthy (0–12)	Pizza - modified recipe Juice drinks Diet soda Soda Energy or sports drinks Full fat/2% unflavored milk Full fat/2%/1% flavored milk Salty snacks Fried potatoes Pizza – traditional recipe Cookies, cakes Frozen desserts Candy
<i>Physical Activity Environment Indices</i>	
Indoor facilities (0–4)	Gymnasium Indoor pool Weight room
Outdoor facilities (0–6)	Other (cafeteria, auditorium, etc) Playground equipment Track Sports courts Baseball/softball fields General use/multi-purpose field
PA opportunities (0–6)	Parking lot Intramural sports Extramural sports Noncompetitive, school-sponsored Nontraditional PE activities Recess (for third grade) Physical education (0 = 0–1 day; 1 = 2 + days)

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