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Multi-pronged intervention to increase secondary student participation in school lunch: Design and rationale

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ABSTRACT

Background: In the United States, the National School Lunch Program (NSLP) is the healthiest lunch option for students, yet participation is suboptimal and fruit and vegetable waste remains high. Improving school meal convenience, engaging teachers in the school-lunch program, and enhancing the cafeteria environment are promising strategies to improve participation and dietary intake, yet little evidence is available on their impact.

Methods/design: The Multi-Pronged Intervention to Increase Secondary Student Participation in School Lunch (MPI) is a 3-year quasi-experimental study in a large urban school district in California. A total of 24 middle and high schools participated in the study: half received the intervention and half served as controls. The intervention consisted of additional school lunch points of sale (vending machines and mobile carts), a school meal outreach program for teachers, and cafeteria redesigns. School meal participation, student-reported fruit and vegetable consumption, and school lunch plate waste were assessed at baseline and in years 1 and 2 of the intervention. Change in meal participation and fruit and vegetable consumption were compared between intervention and control arms to determine the impact of the intervention on school meal participation and dietary intake.

Discussion: This study is positioned to provide evidence on the feasibility and efficacy of a multi-level intervention to increase school meal participation and consumption of fruits and vegetables.

1. Background

Obesity, one of the most pressing health issues of our time, has been linked to secular changes in dietary intake [1]. Improving dietary intake among youth is critical to reducing childhood obesity, as only 1% of children in the United States meet the Dietary Guidelines [2]. Fruits and vegetables, in particular, play a vital role as intake is associated with reduced risk of obesity [3–6] and chronic disease [3,6,7]. However, approximately one third of adolescents consume less than one serving of fruit or vegetables per day [8], and low-income youth consume less than their higher income peers [9].

Schools are arguably the most important system in which to intervene to improve youth dietary intake [10]; school-aged children consume up to half of their daily calories at school [11]. While participation in the National School Lunch Program (NSLP) has been associated with significantly higher lunchtime fruit and vegetable intake [13] and higher diet quality overall [14], only 57% of students with program access participate on a given day [15]. Furthermore, though fruit and vegetable consumption has increased slightly since the 2010 Healthy Hunger-Free Kids Act went into effect, plate waste remains high; up to 59% of selected vegetables are wasted [16,17]. Efforts to improve what students eat at school are especially important for adolescents as they have greater autonomy [18], lower school-lunch participation rates [19], and consume less fruits and vegetables than their younger counterparts [9,20].

Convenience and social influences contribute to school meal participation and consumption [21–23]. Distributed points of sale, such as vending machines and mobile carts, are promising methods to increase convenience [23–25]. While vending machines have been shown to influence consumption of unhealthful foods in schools [26–28], to our knowledge no studies have assessed their impact, when used to deliver school meals (as opposed to snacks or beverages), on school-meal participation rates or fruit and vegetable consumption. Teacher promotion of school meals also has potential for improving youth dietary

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intake. While the influence of parents on youth dietary behaviors have been established [21–23], little is known about the impact of other adults on youth dietary behaviors in school settings and whether teachers in particular can influence school meal participation and consumption. The physical dining environment also affects satisfaction with school meals [29] and perceptions of food quality [30]. The same meal is perceived as of lower quality when served in a cafeteria compared to when served in a restaurant [30]. While perceptions of food quality influence school-meal participation rates [31,32], the direct effect of the physical dining environment on student behavior remains unknown.

Therefore, a multi-level intervention that incorporates the sale of school lunch through vending machines and mobile carts, teacher education about the school food program, and school dining redesigns was developed to improve school-lunch participation rates and fruit and vegetable consumption among middle and high school students at schools with 50% or more of the student body qualifying for free or reduced-price meals (FRPM). This manuscript describes the design and rationale for the Multi-Pronged Intervention to Increase Secondary Student Participation in School Lunch (MPI) study, as well as participant baseline characteristics.

2. Methods

2.1. Study design

The MPI study was a 3-year quasi-experimental study funded by the United States Department of Agriculture National Institute of Food and Agriculture with baseline data collected in the 2015–2016 school year from 12 middle schools and 12 high schools in a public school district in California: half received the intervention and half served as controls. The study received approval by the Committee for the Protection of Human Subjects at the University of California Berkeley and the participating school district. Students were provided written and verbal information about the study and were informed they could refuse to participate at any time.

2.2. Participants

All middle and high schools that require daily campus attendance were eligible to participate in the study, yielding 12 middle and 12 high schools eligible among the school district's 30 secondary schools. Data on school-meal participation represent all students in participating schools. On plate-waste data collection days, all students eating the school lunch were eligible to participate. All students in grades 7–10 were eligible to participate in the student survey in spring 2016 and 2017, and all students in grades 8–10 were eligible to participate in spring 2018. All teachers (approximately 1340 in total) were eligible to participate in the teacher survey each year.

2.3. Theory

Concepts from behavioral economics were the foundation of the school dining redesign and distributed points of sale intervention. Behavioral economics challenges the assumptions that individuals are rational, have stable preferences, and will act in their own long-term best interest. Instead, behavioral economics argues that cognitive biases impede the ability to make rational choices and that behaviors are susceptible to environmental cues such as marketing, convenience, and social norms [33]. As individuals are present-biased, food access and convenience influences selection and consumption behaviors [23,24,34]. Furthermore, behavioral economics posits that explicitly mandating what individuals can and cannot do is a less effective behavior change strategy than employing subtle environmental cues, or "nudges"; individuals are more likely to change behavior if they feel as though they have agency in decision-making [35]. We hypothesize that providing healthy food through mobile carts and vending machines will increase school lunch convenience, increase student choice, and provide an environmental cue to participate in the school lunch program. Furthermore, we hypothesize that redesigning cafeterias to be more visually and socially appealing to students will improve perceptions of school meals and offer an additional nudge to participate in the program. As a result, we expect increased school meal participation and decreased plate waste.

The teacher outreach component of the intervention was grounded in Social Learning Theory (SLT). SLT, developed by Bandura, posits that social environments influence both cognition and behavior [36]. Observers view new behavior, and in turn mimic, the new behavior. The new behavior is reinforced by changes in social norms around the behavior. We hypothesize that an intervention targeting teacher promotion and consumption of school meals will impact student school lunch participation and consumption through the mechanisms outlined in SLT.

2.4. Intervention description

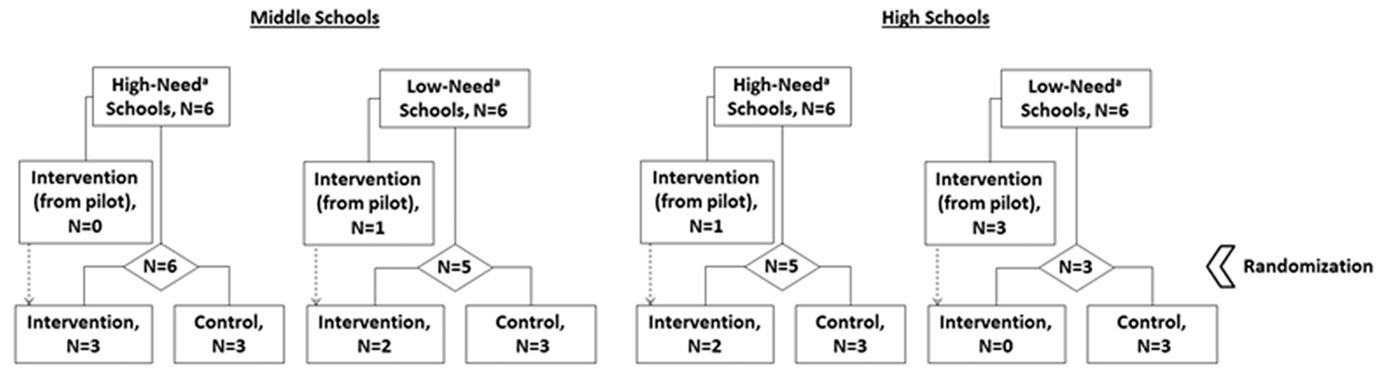
Intervention schools received three intervention components: 1) one mobile cart (serving hot meals) and one vending machine (serving cold meals), 2) teacher outreach, and 3) school dining redesign. Carts and vending machines were introduced in addition to the traditional school cafeteria lines. The majority of vending machines were located in the cafeterias, and the mobile carts were located in high-traffic hallways and courtyards. The teacher outreach component included staff meeting presentations about the school lunch program, video screenings that showcased school meals and redesigned cafeterias, school menu item taste tests, monthly themed newsletters, and a teacher resource website with information about the school lunch program and classroom activities, aligned with a variety of school academic subjects to promote learning about school meals. The cafeteria redesign consisted of décor and seating changes to make the space more inviting and conducive to socialization. Students were involved in the redesigns, and their input informed the unique design of each space. The redesigned cafeterias had colorful artwork and paint and a variety of new seating options, including couches, circular tables, and movable tables and chairs.

2.5. School assignment

In school year (SY) 2014–15, prior to creation of the study protocol, 1 middle and 4 high schools had received vending machines and/or were undergoing cafeteria redesign. (Schools were selected for cafeteria redesign based on availability of school funding.) These 5 schools were assigned to the intervention arm. The remaining 19 schools were randomly assigned to the intervention or control condition (Fig. 1) using random number generation. Randomization was stratified by school type (middle versus high) and high- versus low-need (determined based on eligibility for FRPM, percentage of non-White students, and the Academic Performance Index, a measure used in California schools to assess achievement on standardized tests) [37]. Thus, 5 high-need and 3 low-need high schools and 6 high-need and 5 low-need middle schools were subject to randomization.

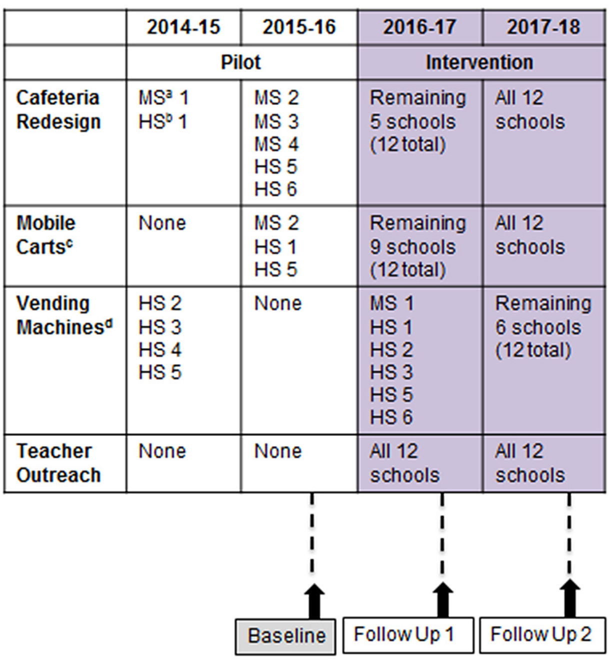
2.6. Timeline

The original study protocol called for all intervention components to begin in SY 2015–16. However, due to unexpected complications related to installing and running the vending machines and mobile carts, broad implementation of the intervention did not occur until SY 2016–17, and full implementation of vending machines did not occur until SY 2017–18. SY 2014–15 and SY 2015–16 were thus considered pilot years, and analyses (described below) were planned to account for delayed implementation of the vending machines. Fig. 2 depicts the



[a] Determined based on eligibility for the free or reduced-price meals (FRPM), percentage of non-White students, and the Academic Performance Index.

Fig. 1. Stratified randomization.



	2014-15	2015-16	2016-17	2017-18
	Pilot		Intervention	
Cafeteria Redesign	MS[a] 1 HS[b] 1	MS 2 MS 3 MS 4 HS 5 HS 6	Remaining 5 schools (12 total)	All 12 schools
Mobile Carts[c]	None	MS 2 HS 1 HS 5	Remaining 9 schools (12 total)	All 12 schools
Vending Machines[d]	HS 2 HS 3 HS 4 HS 5	None	MS 1 HS 1 HS 2 HS 3 HS 5 HS 6	Remaining 6 schools (12 total)
Teacher Outreach	None	None	All 12 schools	All 12 schools

[a] Middle school
[b] High school
[c] During SY 2015-16, mobile carts served an average of 395 meals per school (range 38-800), accounting for 0.8% of meals served at those schools.
[d] During SY 2014-15, vending machines served an average of 484 meals per school (range 19-1513), accounting for 0.7% of meals served at those schools.

Fig. 2. MPI study timeline.

roll-out of intervention components across all study schools. Seven intervention schools received cafeteria redesigns during the pilot period. Vending machines were piloted in 4 high schools during spring 2015, running an average of 54 days (range 10–121) per school. Pilot schools served an average of 484 meals (range 29–1513) through vending machines at each school, accounting for 0.7% of all meals sold at these schools during SY 2014–15. Mobile carts were piloted in 1 middle and 2 high schools during spring 2016, serving an average of 395 meals (range 38–800) per school over an average of 11 days (range 3–19). Meals served through mobile carts accounted for 0.8% of meals sold at pilot schools during SY 2015–16.

Cafeteria redesign and mobile carts were fully rolled out during SY 2016–17. Vending machines were fully functioning in all 12 intervention schools in fall of SY 2017–18. Six vending machines were implemented in fall 2016 but were removed after two months due to electrical and software issues.

The teacher outreach components were introduced in fall of SY 2016–17 to all 12 intervention schools. Control schools received none of the intervention components; these schools only served meals through their existing cafeteria serving lines.

2.7. Measures

Average daily school lunch participation is the primary outcome of the study. Secondary outcomes include plate waste, student and teacher perceptions of school lunch, staff perceptions of the intervention, and student body mass index (BMI).

2.7.1. School meal participation

District nutrition services administrators provided daily school meal participation data, through electronic point of sale records, for breakfast and lunch by points of sale venue (vending machine, mobile cart, and cafeteria line) at control and intervention schools for SY 2015–16 through SY 2017–18. Although the focus of the intervention was on the school lunch, school breakfast participation was also tracked in order to document any spillover effects. Mobile carts were not in operation daily at every school lunch due primarily to insufficient staffing and vending machines were not in operation on some days due to software problems. District nutrition services administrators provided reports of days when the vending machines and mobile carts were available to students.

2.7.2. Plate waste

Researchers conducted plate waste assessments to quantify (by weight) the aggregate amounts of entrees, milk, fruits, and vegetables selected but uneaten by students during one lunch period at each school in spring of SY 2015–16 and SY 2017–18. Aggregate plate waste measures offer comparable results to the gold-standard individual weighing method [38]. Menus were reviewed prior to selection of plate waste assessment dates in order to match, to the extent possible, items served at each school at baseline and follow-up and between control and intervention schools. The school district uses a combination of menu items from a contract food service vendor as well as in-house production. Menu items prepared by the vendor were chosen based on popularity, which influences what is likely to remain on the menu throughout the duration of the study, to minimize confounding. Items prepared in-house that were served on the same day as the chosen meals prepared by the vendor were also incorporated into the plate waste analysis. Before the lunch period began, researchers weighed 3 random samples of each pre-portioned menu item at each school, and calculated the average weight to the nearest gram. All students participating in the school lunch program were invited to take part in the plate waste assessment. Those who chose to join the study received a numbered food tray (a maximum of 220 trays were distributed per school) before entering a point of meal distribution. As students exited the point of distribution, researchers recorded the tray number and all chosen menu items. Students were instructed to return the tray with leftover food and trash to the research team. At the end of the lunch period, researchers placed food from each tray in separate buckets for each menu item and then weighed each bucket. During each plate waste assessment, students were eligible for a drawing for a $10 gift card.

2.7.3. Student survey

School staff administered surveys to all students in the homeroom classes in grades 7–10 during spring of SY 2015–16 and SY 2016–17 and in grades 8–10 in spring of SY 2017–18 to assess self-reported number of days, amount, and variety of fruits and vegetables consumed over a typical week (adapted from the Block Kids 2–17 Screener [39]), attitudes towards school lunch (taste, satiety, wait time, meal quality), lunch selection behavior, peer lunch perceptions and participation, school staff encouragement of school meals, and sociodemographic characteristics (race/ethnicity, gender, mother's highest level of education). Some of the survey questions assessing attitudes towards school lunch and lunch selection behavior were adapted from the Healthful Eating Active Communities Student Survey [40]. As the Block Screener is a semi-quantitative measure of dietary intake, fruit and vegetable intake assessed via the student survey are estimates and not absolute amounts. Every year, schools with the two highest survey response rates each received a $100 gift card.

2.7.4. Teacher survey

Researchers administered surveys to teachers in control and intervention schools in spring of 2016, 2017, and 2018 to assess teacher attitudes and perceptions of school lunch, school lunch participation, and modeling and encouragement of healthy eating behaviors. In 2018 questions were added to assess teacher receipt of information and resources to promote school meals. Questions related to teachers' participation in school meals and general health were adapted from a prior study [41]. Teachers were eligible for a single district-wide drawing of a $100 gift card each year.

2.7.5. School personnel interviews

Researchers conducted semi-structured interviews with foodservice staff at intervention schools during spring 2018 to assess satisfaction with and feasibility of the vending machines and mobile carts and changes in the school food environment that may have impacted school meal intake or participation. We employed purposive sampling of foodservice managers at intervention sites and staff who operated vending machines or mobile carts (n = 24). Similar questions were asked of district administrators, as well as questions about factors that affected implementation of the intervention and sustainability of the new points of sale. We used purposive sampling strategies to recruit school meal operations decision-makers and administrators with involvement in the intervention (n ≈ 13).

2.7.6. Student body mass index as an exploratory outcome

All California schools conduct fitness assessments with students in grades 7 and 9 annually, including measuring height and weight [42]. Schools provided BMI, age, sex, FRPM status, and race/ethnicity data for all students in grades 7 and 9 for SY 2015–16 through SY 2017–18.

2.8. Planned analyses

Mixed effects linear regression models with a group-by-time interaction term will be used to assess differences between intervention and control groups in: 1) average daily school-lunch participation (proportion of students purchasing school lunch, overall and by FRPM status (paid vs. free or reduced price)); 2) school lunch plate waste (percent of fruits and vegetables wasted); and 3) students' reported intake of fruits and vegetables. For lunch participation and plate waste, models will adjust for, as appropriate, school-level racial/ethnic composition, enrollment, FRPM eligibility, and Community Eligibility Program participation. Similar models will assess student-reported intake of fruits and vegetables and additionally adjusted for student gender, race/ethnicity, and mother's education (a proxy for socioeconomic status), as appropriate. A dose-response analysis will examine the impact of the length of intervention exposure (number of days the vending machines and mobile carts were available during lunch in intervention schools) on meal participation.

Foodservice staff district administrator interview transcripts will be analyzed through thematic analysis to assess: (1) operational feasibility of the intervention; (2) satisfaction with and sustainability of the intervention; and (3) how administrative, regulation, and policy factors influenced intervention implementation [43]. Open-coding will be employed to produce themes grounded in the data. After open-coding, selective coding will be conducted to match primary themes with supporting evidence and related themes. Data will be analyzed using Provalis Research QDA Miner software.

2.8.1. Power calculations

With a total of 24 schools in the study, we expect to have 80% power to detect a difference between groups in change in school-lunch participation of 11% (two-sided alpha of 0.05), based on a standard deviation for change of 9% between the 2011–12 and 2012–13 school years. While smaller effect sizes would still be clinically meaningfully, this is a conservative estimate, as we will use a repeated measures approach that includes average daily lunch participation in each month of the school year, at baseline and follow-up, for all schools. For fruit and vegetable consumption, we expect to have 80% power to detect a 0.5-serving difference between groups, with a standard deviation of 3.5, based on a prior study [44], assuming 250 students per school (the minimum we will survey in any given year).

2.8.2. Exploratory analysis

We will use a linear mixed-effects model (with random effect for school), controlling for the same school-level covariates used in the primary outcome models, to examine differences in changes in control and intervention students' BMI z-score students across all 3 study years. Although we are not powered to detect clinically meaningful changes in BMI, data trends can serve to generate hypotheses to be tested in future studies.

3. Results

Table 1 presents baseline school characteristics in the 2015–2016 school year. There were no significant differences in school-level median enrollment, mean proportion of students eligible for FRPM, or

Table 1
Baseline characteristics of intervention and control schools.

	Intervention schools N = 12	Control schools N = 12	P- value[a]
School enrollment, median (IQR)	890 (599, 1260)	824 (572, 1058)	0.525
Students eligible for FRPM, % ± SD	68% ± 3%	59% ± 5%	0.139
Race/ethnicity, % ± SD			
African American	10% ± 2%	8% ± 1%	0.298
Asian	46% ± 6%	42% ± 6%	0.647
Latino	31% ± 5%	29% ± 6%	0.829
White	9% ± 2%	12% ± 2%	0.397

IQR: Interquartile range.
[a] P-value based on Wilcoxan Rank Sum Test for school enrollment. All other p-values based on *t*-tests.

Table 2
Baseline characteristics of students participating in survey.

	Intervention N = 4731	Control N = 4426	P-value[a]
Gender, N (%)			**< 0.001**
Female	2088 (47%)	2141 (52%)	
Male	2281 (52%)	1884 (46%)	
Other	60 (1%)	79 (2%)	
Grade, N (%)			**< 0.001**
7	822 (19%)	1109 (27%)	
8	993 (23%)	1100 (27%)	
9	1332 (31%)	909 (22%)	
10	1237 (28%)	950 (23%)	
Mother's education, N (%)			**< 0.001**
No HS degree	582 (13%)	301 (7%)	
HS degree	510 (12%)	346 (9%)	
Some college	469 (11%)	421 (10%)	
College degree	1170 (27%)	1715 (42%)	
Race/ethnicity, N (%)			**< 0.001**
African American	203 (5%)	148 (4%)	
Asian	2230 (51%)	2039 (50)	
Latino	904 (21%)	551 (13%)	
White	264 (6%)	552 (13%)	
Reported dietary intake			
Fruit Intake, cups/day total,[b] mean ± SD	1.2 ± 1.1	1.3 ± 1.1	0.110
Vegetable Intake, cups/day total,[c] mean ± SD	0.89 ± 0.92	0.91 ± 0.91	0.668
Ate fruit at lunch yesterday total,[b] N (%)	4647 (98%)	4350 (98%)	0.906
Ate vegetable at lunch yesterday total,[c] N (%)	4642 (98%)	4362 (99%)	0.470
Behaviors and perceptions			
Ate school lunch yesterday, N (%)	1240 (27%)	881 (20%)	0.054
Ate school breakfast yesterday, N (%)	539 (12%)	340 (8%)	0.203
Usually get lunch from school, N (%)	1145 (24%)	862 (19%)	0.166
Lunch lines long[d], mean ± SD	3.7 ± 1.0	3.4 ± 1.1	0.092
Friends eat school lunch, mean ± SD	3.1 ± 1.1	3.0 ± 1.1	0.632
Adults encourage to eat school lunch, mean ± SD	2.6 ± 1.1	2.5 ± 1.1	0.195
Like school lunch fruit, mean ± SD	3.1 ± 1.1	3.0 ± 1.0	0.088
Like school lunch vegetable, mean ± SD	2.4 ± 0.99	2.4 ± 0.96	0.494
School lunch healthier than other options, mean ± SD	2.4 ± 1.0	2.3 ± 1.0	**0.014**
School lunch tastes good[d], mean ± SD	2.2 ± 0.97	2.1 ± 0.96	0.378

The bolded text refers to significant coefficients ($p < .05$).

[a] P-value for demographic characteristics based on Chi^2 tests. P-value for behaviors and attitudes/perceptions based on logistic regression for categorical variables and linear regression for continuous variables, accounting for clustering by school.

[b] Whole fruit and 100% fruit juice.

[c] Includes non-fried and fried potatoes.

[d] Question responses on a 5 point Likert scale from Strongly Disagree (1) to Strongly Agree (5).

mean proportion of students among the different racial/ethnic groups. There were, however, significant differences in the demographic composition of student survey respondents between control and intervention schools (Table 2). Significant differences for gender, grade, race/ethnicity, and mother's education (a proxy for socioeconomic status) were found between participating students in control and intervention schools ($p < .001$). The sample size for each category, however, is large enough to carry out planned analyses. Due to demographic differences, we plan to control for student-level gender, grade, and race/ethnicity in future analyses.

Table 2 presents baseline characteristics of student survey respondents from the 2015/16 school year. Students in intervention schools perceived the school lunch to be healthier than students in control schools, with a mean score of 2.4 for students in intervention schools compared to a mean score of 2.3 for students in control schools ($p = .014$, based on a 5 point Likert scaled from strongly disagree (1) to strongly agree (5). No other significant differences in behaviors, attitudes, or perceptions were found between control and intervention schools at baseline. Of the attitude and perceptions questions, students agreed the most with the statement that 'lunch lines were long' (mean of 3.7 for intervention and 3.4 for control schools, $p = .092$) and agreed the least with the statement that 'school lunch tastes good' (mean of 2.2 for intervention and 2.1 for control schools, $p = .378$).

Table 3 presents baseline results (SY 2015–16) from the teacher survey. No statistically significant differences in teacher behaviors or attitudes and perceptions were found between control and intervention schools, when accounting for clustering by school. Among control and intervention schools, a small proportion of teachers ate the school lunch 1 or more times during the school year (31% vs. 25%, $p = .219$). Of the attitude and perceptions measures, teachers agreed the least with the statement that "students think school meals taste good" (mean score of 1.9 for both control and intervention schools, $p = .892$).

4. Discussion

In light of the childhood obesity epidemic, schools are uniquely positioned to improve youth dietary patterns at the population level by increasing student consumption of school meals [12–14]. In order to address suboptimal participation [15] and fruit and vegetable consumption [16,17,45] in the National School Lunch Program, it may be essential to modify the physical and social environments around school food. As the physical environment impacts perceptions of meal quality [30], and perceptions of meal quality are directly tied to student participation in school lunch programs [31,32], improving the visual appeal of school cafeterias is a promising strategy to increase participation. Furthermore, improving the convenience of school meals may reduce wait times and therefore boost healthy school meal sales [34]. While the average lunch period is 30 minutes long for U.S. middle and high schools [46], students can spend a great deal of their lunch period waiting in line. With only an average of 10–11 minutes to eat once seated [47], students report that time is a key factor in meal selection [21]. As lunch period duration is negatively associated with fruit and

Table 3
Baseline characteristics of teachers participating in survey.

Behaviors,[a] N (%)	Intervention N = 284	Control N = 273	P-value[b]
1 or more times per year			
Ate school lunch	71 (25%)	84 (31%)	0.219
Purchased food items from school dining	43 (15%)	48 (18%)	0.608
Ate lunch with students in the cafeteria	33 (12%)	40 (15%)	0.377
1 or more times per week			
Discussed healthy eating with students	68 (24%)	62 (23%)	0.834
Encouraged students to make healthy food choices	95 (34%)	86 (33%)	0.771
Encouraged students to eat school lunch	56 (20%)	52 (20%)	0.990
Ate lunch in classroom with students	131 (48%)	90 (34%)	0.192
Ate fruits or vegetables in front of students	160 (58%)	149 (57%)	0.908
Attitudes and perceptions, Mean ± SD			
School meals are healthy[c]	2.7 ± 0.74	2.6 ± 0.75	0.305
School meals taste good	2.3 ± 0.81	2.3 ± 0.81	0.868
Students think school meals taste good[c]	1.9 ± 0.74	1.9 ± 0.78	0.892

[a] Proportion of respondents who have engaged in the behavior over the past school year.
[b] P-value based on logistic regression for categorical variables and linear regression for continuous variables, accounting for clustering by school.
[c] Question responses on a 4 point Likert scale from Strongly Disagree (1) to Strongly Agree (4).

vegetable waste [48,49], increased convenience of school lunch has the potential to both increase the time available to eat and decrease plate waste. There is a paucity of literature, however, on how the addition of convenient school food points of sale, such as vending machines and mobile carts, can be leveraged to improve school meal participation. Finally, while adults exhibit social influence over youth dietary behavior [21,22], teachers and school staff may have poorer diets than the general population [50] and negative perceptions of school meals [51]. To our knowledge, no studies have assessed whether changing teacher perceptions of and participation in school meals can increase student participation and consumption. This study will be the first to assess whether a distributed points of sale, teacher outreach, and cafeteria redesign intervention improves school meal participation and dietary fruit and vegetable intake and reduces obesity among low-income middle and high school youth.

The MPI study has additional limitations. While a cluster randomized controlled trial would allow for stronger conclusions, only partial randomization was possible due to the nature of the pilot school selection process conducted by the school district. As readiness for change is an important indicator of successful implementation in community-based research [52], the district chose schools that demonstrated initial commitment to the project. Furthermore, the timing of the pilot and intervention phases were spread out over time and between schools. The school dining redesign in particular was not something that could be accomplished at all 12 intervention schools at once. Over half of the intervention schools received their cafeteria redesigns, and mobile carts and vending machines were piloted in many intervention schools, before baseline measures were collected for all but meal participation. This will make it more difficult to detect a change in plate waste and student-reported measures. Further, the multi-component nature of the study also renders it difficult to ascertain which intervention components had the greatest impact on outcomes. This is a good direction for future research.

5. Conclusions

As a result of the MPI study, we anticipate finding significant improvements in school lunch participation, school lunch waste, and consumption of fruits and vegetables by middle and high school students in intervention schools and significant increases in teacher perceptions and promotion of school meals. We expect findings to have implications for innovative school meal delivery with the potential to influence school meal practices in school districts across the United States.

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References

[1] D.M. Cutler, E.L. Glaeser, J.M. Shapiro, Why have Americans become more obese? J. Econ. Perspect. 17 (3) (2003) 93–118, https://doi.org/10.1257/089533003769204371.
[2] S.M. Krebs-Smith, P.M. Guenther, A.F. Subar, S.I. Kirkpatrick, K.W. Dodd, Americans do not meet federal dietary recommendations, J. Nutr. 140 (10) (2010) 1832–1838, https://doi.org/10.3945/jn.110.124826.
[3] H. Boeing, A. Bechthold, A. Bub, et al., Critical review: vegetables and fruit in the prevention of chronic diseases, Eur. J. Nutr. 51 (6) (2012) 637–663, https://doi.org/10.1007/s00394-012-0380-y.
[4] K. Charlton, P. Kowal, M.M. Soriano, et al., Fruit and vegetable intake and body mass index in a large sample of middle-aged Australian men and women, Nutrients 6 (6) (2014) 2305–2319, https://doi.org/10.3390/nu6062305.
[5] M.L. Bertoia, K.J. Mukamal, L.E. Cahill, et al., Changes in intake of fruits and vegetables and weight change in United States men and women followed for up to 24 years: analysis from three prospective cohort studies, PLoS Med. 12 (9) (2015), https://doi.org/10.1371/journal.pmed.1001878.
[6] P. Jääskeläinen, C.G. Magnussen, K. Pahkala, et al., Childhood nutrition in predicting metabolic syndrome in adults: the cardiovascular risk in young Finns study, Diabetes Care 35 (9) (2012) 1937–1943, https://doi.org/10.2337/dc12-0019.
[7] V. Mikkilä, L. Räsänen, O.T. Raitakari, P. Pietinen, J. Viikari, Longitudinal changes in diet from childhood into adulthood with respect to risk of cardiovascular diseases: the cardiovascular risk in young Finns study, Eur. J. Clin. Nutr. 58 (7) (2004) 1038–1045, https://doi.org/10.1038/sj.ejcn.1601929.
[8] State Indicator Report on Fruits and Vegetables: 2013, https://www.cdc.gov/nutrition/downloads/state-indicator-report-fruits-vegetables-2013.pdf, (2013).
[9] M. Rasmussen, R. Krølner, K.-I. Klepp, et al., Determinants of fruit and vegetable consumption among children and adolescents: a review of the literature. Part I: quantitative studies, Int. J. Behav. Nutr. Phys. Act. 3 (2006) 22, https://doi.org/10.1186/1479-5868-3-22.
[10] Committee on Accelerating Progress in Obesity Prevention, Food and Nutrition Board, Institute of Medicine, D. Glickman, L. Parker, L.J. Sim, H. Del Valle Cook, E.A. Miller (Eds.), Accelerating Progress in Obesity Prevention: Solving the Weight of the Nation, National Academies Press (US), Washington (DC), 2012, http://www.ncbi.nlm.nih.gov/books/NBK201141/ , Accessed date: 23 May 2018.
[11] K.W. Cullen, T.-A. Chen, The contribution of the USDA school breakfast and lunch program meals to student daily dietary intake, Prev. Med. Rep. 5 (2017) 82–85, https://doi.org/10.1016/j.pmedr.2016.11.016.
[12] N. Cole, M.K. Fox, Diet Quality of American School-Age Children by School Lunch Participation Status: Data from the National Health and Nutrition Examination Survey, 1999-2004, US Department of Agriculture, Food and Nutrition Service, Office of Research, Nutrition and Analysis, 2008, https://fns-prod.azureedge.net/sites/default/files/NHANES-NSLP.pdf.
[13] I. Hur, T. Burgess-Champoux, M. Reicks, Higher quality intake from school lunch meals compared with bagged lunches, ICAN 3 (2) (2011) 70–75, https://doi.org/10.1177/1941406411399124.
[14] L.E. Au, N.J. Rosen, K. Fenton, K. Hecht, L.D. Ritchie, Eating school lunch is associated with higher diet quality among elementary school students, J. Acad. Nutr. Diet. 116 (11) (2016) 1817–1824, https://doi.org/10.1016/j.jand.2016.04.010.

[15] M.K. Fox, M.K. Crepinsek, P. Connor, M. Battaglia, School Nutrition Dietary Assessment Study-II, https://fns-prod.azureedge.net/sites/default/files/sndaII.pdf, (April 2001).
[16] M.B. Schwartz, K.E. Henderson, M. Read, N. Danna, J.R. Ickovics, New school meal regulations increase fruit consumption and do not increase total plate waste, Childh. Obes. 11 (3) (2015) 242–247, https://doi.org/10.1089/chi.2015.0019.
[17] J.F.W. Cohen, S. Richardson, E. Parker, P.J. Catalano, E.B. Rimm, Impact of the new U.S. Department of Agriculture school meal standards on food selection, consumption, and waste, Am. J. Prev. Med. 46 (4) (2014) 388–394, https://doi.org/10.1016/j.amepre.2013.11.013.
[18] E. Waters, A. de Silva-Sanigorski, B.J. Hall, et al., Interventions for preventing obesity in children, Cochrane Database Syst. Rev. 12 (2011) CD001871, , https://doi.org/10.1002/14651858.CD001871.pub3.
[19] School Nutrition Operations Report: The State of School Nutrition 2016, https://schoolnutrition.org/uploadedFiles/Resources_and_Research/Research/2016OperationsReportExecutiveSummary.pdf, (2016).
[20] A Closer Look Inside Healthy Eating Patterns - 2015-2020, Dietary Guidelines, https://health.gov/dietaryguidelines/2015/guidelines/chapter-1/a-closer-look-inside-healthy-eating-patterns/, (2015) , Accessed date: 18 October 2017.
[21] M.Y. Kubik, L. Lytle, J.A. Fulkerson, Fruits, vegetables, and football: findings from focus groups with alternative high school students regarding eating and physical activity, J. Adolesc. Health 36 (6) (2005) 494–500, https://doi.org/10.1016/j.jadohealth.2004.05.010.
[22] E.F. Molaison, C.L. Connell, J.E. Stuff, M.K. Yadrick, M. Bogle, Influences on fruit and vegetable consumption by low-income black American adolescents, J. Nutr. Educ. Behav. 37 (5) (2005) 246–251.
[23] R. Krolner, M. Rasmussen, J. Brug, K.-I. Klepp, M. Wind, P. Due, Determinants of Fruit and Vegetable Consumption Among Children and Adolescents: A Review of the Literature. Part II: Qualitative Studies, (2011).
[24] R. Bhatia, P. Jones, Z. Reicker, Competitive foods, discrimination, and participation in the National School Lunch Program, Am. J. Public Health 101 (8) (2011) 1380–1386, https://doi.org/10.2105/AJPH.2011.300134.
[25] J. Olsta, Bringing breakfast to our students: a program to increase school breakfast participation, J. Sch. Nurs. 29 (4) (2013) 263–270, https://doi.org/10.1177/1059840513476094.
[26] N. Cisse-Egbuonye, S. Liles, K.E. Schmitz, N. Kassem, V.L. Irvin, M.F. Hovell, Availability of vending machines and school stores in California schools, J. School Health 86 (1) (2016) 48–53, https://doi.org/10.1111/josh.12349.
[27] M.S. Nanney, R.F. MacLehose, M.Y. Kubik, et al., School obesity prevention policies and practices in Minnesota and student outcomes: a longitudinal cohort study, Am. J. Prev. Med. 51 (5) (2016) 656–663, https://doi.org/10.1016/j.amepre.2016.05.008.
[28] M.Y. Kubik, L.A. Lytle, P.J. Hannan, C.L. Perry, M. Story, The association of the school food environment with dietary behaviors of young adolescents, Am. J. Public Health 93 (7) (2003) 1168–1173.
[29] M.K. Meyer, Top predictors of middle/junior high school Students' satisfaction with school food service and nutrition programs, J. Acad. Nutr. Diet. 100 (1) (2000) 100–103, https://doi.org/10.1016/S0002-8223(00)00031-6.
[30] H.L. Meiselman, J.L. Johnson, W. Reeve, J.E. Crouch, Demonstrations of the influence of the eating environment on food acceptance, Appetite 35 (3) (2000) 231–237, https://doi.org/10.1006/appe.2000.0360.
[31] C.A. Marples, D.-M. Spillman, Factors affecting students' participation in the Cincinnati public schools lunch program, Adolescence 119 (1995) 745.
[32] S. Smith, L. Cunningham-Sabo, G. Auld, Satisfaction of middle school lunch program participants and non- participants with the school lunch experience, J. Child Nutr. Manag. 39 (2) (2015) 14.
[33] J. Thapaa, C. Lyford, Behavioral economics in the school lunchroom: can it affect food supplier decisions? A systematic review, Int. Food Agribusiness Manag. Rev. 17 (A) (2014) 187–208.
[34] A.S. Hanks, D.R. Just, L.E. Smith, B. Wansink, Healthy convenience: nudging students toward healthier choices in the lunchroom, J. Public Health 34 (3) (2012) 370.
[35] P.J. Liu, J. Wisdom, C.A. Roberto, L.J. Liu, P.A. Ubel, Using behavioral economics to design more effective food policies to address obesity, Appl. Econ. Perspect. Pol. 36 (1) (2014) 6–24, https://doi.org/10.1093/aepp/ppt027.
[36] D. Bahn, Social learning theory: its application in the context of nurse education, Nurse Educ. Today 21 (2) (2001) 110–117, https://doi.org/10.1054/nedt.2000.0522.
[37] Executive Summary Explaining the Academic Performance Index (API), https://www.cde.ca.gov/ta/ac/ap/documents/apiexecsummary.pdf, (2018).
[38] C. Jacko, J. DeLlava, K. Ensle, D. Hoffman, Use of the plate-waste method to measure food intake in children, J. Ext. 45 (6) (2007), https://joe.org/joe/2007december/rb7.php (Accessed May 23, 2018).
[39] M. Hunsberger, J. O'Malley, T. Block, J.C. Norris, Relative validation of Block kids food screener for dietary assessment in children and adolescents, Matern. Child Nutr. 11 (2) (2015) 260–270, https://doi.org/10.1111/j.1740-8709.2012.00446.x.
[40] W. Gosliner, K.A. Madsen, G. Woodward-Lopez, P.B. Crawford, Would students prefer to eat healthier foods at school? J. School Health 81 (3) (2011) 146–151, https://doi.org/10.1111/j.1746-1561.2010.00573.x.
[41] M.Y. Kubik, L.A. Lytle, P.J. Hannan, M. Story, C.L. Perry, Food-related beliefs, eating behavior, and classroom food practices of middle school teachers, J. School Health 72 (8) (2002) 339–345.
[42] CalEd Facts, Physical Fitness Testing - CalEdFacts, CA Dept of Education, June 15, 2018, https://www.cde.ca.gov/ta/tg/pf/cefpft.asp , Accessed date: 26 June 2018.
[43] L. Green, M. Kreuter, Health Program Planning: An Educational and Ecological Approach, 4th ed., McGraw-Hill Humanities/Social Sciences/Languages, 2004.
[44] A. Keihner, N. Rosen, P. Wakimoto, et al., Impact of California Children's power play! Campaign on fruit and vegetable intake and physical activity among fourth- and fifth-grade students, Am. J. Health Promot. 31 (3) (2017) 189–191, https://doi.org/10.4278/ajhp.141125-ARB-592.
[45] K.W. Cullen, T.-A. Chen, J.M. Dave, Changes in foods selected and consumed after implementation of the new National School Lunch Program meal patterns in Southeast Texas, Prev. Med. Rep. 2 (2015) 440–443, https://doi.org/10.1016/j.pmedr.2015.05.007.
[46] SNA National Survey Reveals Increased Efforts to Promote Student Consumption of Healthy Choices, School Nutrition Association, September 6, 2016, https://schoolnutrition.org/NewsPublications/PressReleases/SNANationalSurveyRevealsIncreasedEffortsToPromoteStudentConsumptionOfHealthyChoices/ , Accessed date: 7 April 2018.
[47] E.A. Bergman, N.S. Buergel, E. Joseph, A. Sanchez, Time spent by schoolchildren to eat lunch, J. Am. Diet. Assoc. 100 (6) (2000) 696–698, https://doi.org/10.1016/S0002-8223(00)00202-9.
[48] W. Gosliner, School-level factors associated with increased fruit and vegetable consumption among students in California middle and high schools, J. School Health 84 (9) (2014) 559–568, https://doi.org/10.1111/josh.12188.
[49] J.F.W. Cohen, J.L. Jahn, S. Richardson, S.A. Cluggish, E. Parker, E.B. Rimm, Amount of time to eat lunch is associated with children's selection and consumption of school meal Entrée, fruits, vegetables, and milk, J. Acad. Nutr. Diet. 116 (1) (2016) 123–128, https://doi.org/10.1016/j.jand.2015.07.019.
[50] H.L. Hartline-Grafton, D. Rose, C.C. Johnson, J.C. Rice, L.S. Webber, Research: are school employees role models of healthful eating? Dietary intake results from the action worksite wellness trial, J. Am. Diet. Assoc. 109 (2009) 1548–1556, https://doi.org/10.1016/j.jada.2009.06.366.
[51] B.W. Henry, N.J. White, T.J. Smith, Ly Thi LeDang, An exploratory look at teacher perceptions of school food environment and wellness policies, ICAN 2 (5) (2010) 304–311, https://doi.org/10.1177/1941406410382577.
[52] S.F. Castañeda, J. Holscher, M.K. Mumman, et al., Dimensions of community and organizational readiness for change, Prog. Community Health Partnersh. 6 (2) (2012) 219–226, https://doi.org/10.1353/cpr.2012.0016.