USDA School Breakfast and Lunch Programs: National Prevalence of Sodium and Saturated Fat Exposure and the Impacts of School Kitchen Infrastructure on School Meal Selection and Consumption

HARVARD UNIVERSITY

Graduate School of Arts and Sciences

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The undersigned, appointed by the
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**"USDA School Breakfast and Lunch Programs:
National Prevalence of Sodium and Saturated Fat Exposure
and the Impacts of School Kitchen Infrastructure
on School Meal Selection and Consumption"**

presented by

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A dissertation presented by Scott A. Richardson to the Committee on Higher Degrees in Population Health Sciences in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the subject of Population Health Sciences.

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USDA School Breakfast and Lunch Programs: National Prevalence of Sodium and Saturated Fat Exposure and the Impacts of School Kitchen Infrastructure on School Meal Selection and Consumption

Abstract

Subsidized meals provided through the National School Breakfast and Lunch programs, which are administered by the U.S. Department of Agriculture (USDA), provide nearly 30 million Federally subsidized lunches and 15 million Federally subsidized breakfasts to children each school day. These programs can play a significant role in overall childhood dietary quality, as students who participate in both the SBP and NSLP may consume as much as fifty percent or more of their daily calories at school. Because childhood is a critical time to set food preferences school meals are also powerful intervention points to promote healthy dietary patterns that can help lower diet-related disease posed by excess saturated fat, and sodium consumption and limited fresh fruit and vegetable intake across the life course.

The passage of the Healthy Hunger Free Kids Act (HHFKA) in 2010 provided USDA with the for first opportunity in 30 years to make significant nutrition reforms to the SBP and NSLP. Since its implementation in 2012, the HHFKA's updated nutrition regulations have placed caps on the saturated fat content of school meals, detailed a phased decrease in sodium content, and mandated increased offerings of fruits and vegetables to students. These improved guidelines have not only been shown to increase consumption of fruits and vegetables, but also provide students with more nutritious meals than those typically brought from home.

Despite these documented improvements, many school districts nationally continue to struggle to fully realize the intended benefits of the nutrition regulations on student dietary quality, namely excess saturated fat and sodium intake coupled with vegetable consumption below recommended levels.

This dissertation employs three unique data sets collected by the author to investigate these issues. **Chapter 1** utilizes a nationally representative sample of publicly available school menus from the 2018/19 school year to examine the daily prevalence of meal combinations that exceed USDA saturated fat and sodium guidelines. **Chapter 2** utilizes direct observation plate waste data to examine differences in meal selection and consumption between students in schools serving pre-packaged meals and students who receive fresh meals prepared on-site in school kitchens. Lastly, **Chapter 3** utilizes pre/post intervention plate waste data to examine the impacts on selection and consumption of a school kitchen renovation where students transitioned from being offered pre-packaged meals to meals prepared on-site halfway through the school year. Collectively, these works can help inform evidence-based continuous improvements to how we regulate and administer USDA school meal programs to best support child dietary health.

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Acknowledgements

This dissertation is the culmination of not just five years of doctoral work, but of nearly 15 years of advocacy and effort to improve the quality of school meals across many different roles. Throughout that time, Dr. Eric Rimm and Dr. Juliana Cohen have been my collaborators, mentors, instructors, and cheerleaders. I will be forever grateful to them for encouraging me to enter the field of Public Health Nutrition and for the guidance they have provided to me as I embarked on a new phase of my career.

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A special thanks goes out to my team of research assistants who helped me collect the data necessary for two of these chapters. They tirelessly and cheerful joined me for more than forty hectic days in deafening elementary school cafeterias to collect and weigh two tons of student lunch waste by hand, one tray at a time.

Lastly, I would like to thank my wife, Holly, whose unwavering support over the past five years made my academic dream become a reality. I could not have done any of this without her.

Dedication

This work is dedicated to the tens of millions of children across the United States who depend on school meals to combat daily hunger and fuel their academic success.

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Chapter 1: Daily Saturated Fat and Sodium Content of Elementary School Meals in a large sample of 128 geographically diverse school systems in the United States

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Abstract

Background: Subsidized meals provided through the National School Breakfast and Lunch programs are an important source of daily nutrition for nearly 30 million school-aged students across the United States. Despite federal regulations limiting saturated fat and sodium levels on a weekly average basis, daily nutrient content of these meals is not regulated, leading to potential large fluctuations and intake well in excess of dietary recommendations.

Objective: To assess the daily prevalence of potential school meal combinations that exceed the USDA's weekly average reimbursable meal thresholds for saturated fat and sodium in U.S. elementary schools.

Methods: Four weeks of publicly available school breakfast and lunch menus with associated nutrition data were collected from a stratified random sample of 128 school districts to inform an imputed dataset of all possible daily reimbursable meal offerings. Daily distributions of total meal sodium and saturated fat content were then compared against weekly average USDA nutrient thresholds to assess the national prevalence of daily meals in excess of school meal guidelines.

Results: Most sample districts' menus (97.7% for breakfast, 100.0% for lunch) contained reimbursable meal combinations on a daily basis that exceed USDA weekly average dietary guideline thresholds for saturated fat and/or sodium.

Conclusions: Widespread availability of meals exceeding average sodium and saturated fat guidelines suggest that concern about child overnutrition through school meals is warranted. Daily entrée saturated fat and sodium caps should be considered to limit prevalence of meal combinations that well exceed current guidelines.

Background

The School Breakfast Program (SBP) and National School Lunch Program (NSLP), which are administered by the U.S. Department of Agriculture (USDA), provide nearly 30 million federally subsidized lunches and 15 million federally subsidized breakfasts to children each school day.[1]

For school meal program participants, school meals can provide more than half of a child's daily calories and therefore are instrumental in helping children meet their daily dietary recommendations.[2] Currently, school-aged children in the United States consume more saturated fat and sodium than recommended for long-term health.[3,4] Coupled with the fact that elementary school meals can play an important role in lowering childhood sodium and saturated fat intake, they also set the foundation for lifetime taste preferences which are established through diet at a young age.[5–8]

More than 40% of the sodium consumed each day by US children comes from 10 types of food, including breads and rolls, pizza, sandwiches, cold cuts and cured meats, soups, burritos and tacos, savory snacks, chicken, cheese, eggs and omelets, all of which feature prominently on school menus.[9]

Current SBP and NSLP nutritional guidelines, implemented in 2012 as part of the Healthy Hunger Free Kids Act (HHFKA), made notable improvements to nutrient standards by providing age-appropriate upper limits for sodium and saturated fat content in school meals where none existed prior.[10] Today, most district menu planners utilize menu planning software that helps them comply with current nutrient regulations. However, this software is typically designed to aid districts in meeting federal regulations which require offering meals that do not exceed *weekly average limits*. These weekly average guidelines were originally recommended by the Institute of Medicine Committee on Nutrition Standards for National School Lunch and Breakfast Programs, which was requested by USDA to consider student acceptability, program participation, and industry's ability to respond to the need for low-sodium products when making their recommendations for sodium levels in school meals.[11] Despite its positive influence on lowering overall sodium in school meals, this weekly average nutrient approach leaves a regulatory gap which enables schools to offer meal combinations which can substantially exceed USDA guidelines on a daily basis while remaining technically compliant across a given week as long as they are balanced with lower to moderate sodium and saturated fat meals across a given week.[12]

To our knowledge, no previous studies have investigated the full range of saturated fat and sodium from reimbursable breakfasts and lunches available to elementary school students through the SBP and NSLP on a daily basis. The current study aims to fill this gap in the literature by examining daily saturated fat and sodium exposure from K-5 breakfasts and lunches in US school districts to inform potential legislative remedies to lower childhood sodium and saturated fat intake.

Methods

Study Design and Sampling Frame

Inclusion criteria for the sampling frame of this cross-sectional ecological study consisted of all operational, non-charter, coeducational public school districts serving K-5 students and participating in the NSLP across all 50 states and Washington, DC based on the comprehensive list of districts maintained by the National Center for Education Statistics[13] (n=12,736).

A total of 128 districts were selected via stratified random sampling across 77 strata by USDA Food and Nutrition Service region (n=7)[14] and total district K-5 enrollment (n=11). Sample district demographic details are outlined in Table 1.1.

Table 1.1 Sample district mean (SD) K-5 student enrollment by region and size tier

Size Tier	Region							
	North East (n=14)	Mid Atlantic (n=20)	South East (n=22)	Mid West (n=16)	Mountain Plains (n=17)	South West (n=20)	West (n=19)	Overall (n=128)
Tier 1 (n=14)	164 (183)	220 (106)	284 (134)	328 (183)	288 (177)	171 (89)	311 (146)	252 (134)
Tier 2 (n=14)	1,225 (322)	1,360 (193)	1,322 (529)	1,168 (225)	1,072 (314)	1,092 (187)	1,700 (228)	1,277 (305)
Tier 3 (n=14)	2,370 (504)	2,533 (434)	2,122 (33)	2,232 (153)	2,982 (236)	2,880 (1,198)	4,005 (383)	2,732 (739)
Tier 4 (n=14)	5,194 (6)	5,288 (374)	4,576 (57)	5,257 (480)	5,976 (1,245)	5,853 (1,107)	4,983 (53)	5,304 (677)
Tier 5 (n=14)	7,574 (285)	8,194 (315)	8,462 (560)	8,382 (2,107)	7,810 (120)	8,633 (2,069)	8,559 (1,294)	8,230 (993)
Tier 6 (n=14)	12,894 (3,310)	14,302 (3,946)	15,696 (1,198)	11,468 (959)	14,011 (4,675)	17,076 (2,039)	11,648 (232)	13,871 (2,854)
Tier 7 (n=13)	24,439†ƚ	24,452 (1,178)	23,529 (3,692)	24,026 (2,848)	21,766 (2,830)	23,804 (2,848)	24,540 (2,614)	23,898 (2,263)
Tier 8 (n=8)	*	35,730 (6,812)	30,312 (2,587)	34,284†	33,661 (5,853)	32,370 (703)	32,496 (6,476)	33,038 (4,037)
Tier 9 (n=5)	*	56,942 (6,087)	46,464 (722)	*	43,328†	46,252 (5,067)	61,584†	50,528 (7,456)
Tier 10 (n=5)	*	75,799 (10,996)	71,402 (10,827)	*	*	75,221†	*	73,924 (8,056)
Tier 11 (n=7)	470,656†	*	140,734 (25,132)	169,384†	*	105,649†	228,826 (112,607)	212,115 (131,697)
Overall (n=128)	39,567 (124,259)	22,582 (25,612)	31,355 (41,920)	19,337 (41,250)	12,851 (13,591)	22,857 (27,856)	36,608 (74,388)	26,374 (56,284)

† *Only one district met the sample selection criteria.*
ƚ *This district operates two distinct food service models: a "scratch cooked" menu for certain schools and a "pre-packaged" menu for others. Both menus contributed to our analyses as "separate" districts.*
* *No district met the sample selection criteria.*

Sampled districts that did not publish current menus with associated calorie, saturated fat, and sodium content, or whose menus and nutritional information could not be located with a detailed online search, were replaced with additional randomly selected districts from within the same stratum until a maximum of two districts per stratum were selected or the available district list within each stratum was exhausted. There were only two exceptions to these criteria. The first was the inclusion of one larger midwestern district (the only district of its size in the region) which posted carbohydrate counts for menu items, allowing for accurate estimation of other nutrient values. The second exception was the inclusion of two distinct menus with full nutritional information – one for pre-packaged meals served in schools without kitchens and one for scratch-cooked meals served in schools with kitchens – posted by one larger northeastern district (again, the only district of its size in the region) which accounts for the discrepancy between district sample size (n=128) and menu sample size (n=129) in our dataset.

Eighty percent of sample districts (n=103) meeting the inclusion criteria were selected within the first five searches. Another ten percent (n=13) were identified within the first ten searches. Half of the remaining ten percent (n=6) required up to twenty searches prior to identification as meeting the inclusion criteria, while the remainder (n=6) of districts required more than twenty searches. The main limitation was that most districts posted monthly menus to their websites, many did not include nutritional information.

A total of 2,865 days of elementary breakfast and lunch menus from 128 sample districts were collected as available in October (n=121) , November (n=6) , and December (n=2) 2019 to provide representative menu day cycles (mean days per district=22.2, sd=2.0) which typically repeat across the school year.[15]

Data Cleaning and Coding

Menus were downloaded in PDF format and electronically converted to spreadsheet form or, where necessary (n=13), transcribed directly into Microsoft Excel (v. 2107) for cleaning and formatting prior to importation into R statistical analysis software (version 4.0.3, 2020-10-10).[16]

Each line of this initial data set consisted of a unique menu item coded by district, day, and USDA mandated meal component(s) including “Meat/Meat Alternate”, “Grain/Bread”, “Vegetable”, “Fruit”, and “Fluid Milk".[17] Desserts, while not required, but allowed under USDA guidelines, were also coded. All data were error-checked against their downloaded menu PDFs and nutrient data ranges were examined by district and meal component type for implausible calorie, saturated fat, and sodium values.

Missing calorie, saturated fat, and/or sodium values were identified for estimation in 3.6% of menu items. Where possible, missing values were populated by finding exact product matches within the data set or via internet search for a products USDA Child Nutrition label.[18] Remaining missing values were populated from similar items within a given district's menu, updated from menus posted by the district later in the 2019/20 school year, or, where suitable proxies were not available within a district, estimated by identifying like items from similarly sized and geographically proximal districts within the data set.

Following estimation of missing values, a random sample of five percent of unique menu items was selected from the comprehensive data set and compared again against downloaded menus. This last step confirmed a low data entry error rate of 2.5% with no discrepancies significantly altering the nutrient profiles of any menu item.

Imputation of Meal Combinations and Estimation of Overages

A comprehensive data set of all possible unique, creditable, and plausible meal combinations was then generated for each district day (breakfast n=959,448, lunch n= 2,304,349). "Creditable" meals are those that qualify for federal reimbursement under the Offer versus Serve (OVS) Provision of the SBP/NSLP by being comprised of no less than three of five meal components (meat/meat alternative, grain/bread, vegetable, fruit, and fluid milk) and at least one serving of fruit or vegetable as required by USDA.[19]

"Plausible meal combinations" refers to the addition of condiments and dressings to entrees and side vegetables which, when included on menus, were combined with appropriate entrée and vegetable side items to create new unique menu items (e.g. "hamburger + ketchup", "garden salad + ranch dressing", etc.) prior to meal combination imputation to avoid combinations unlikely to occur in a natural school setting (e.g. "peanut butter sandwich + ketchup", "pizza + ranch dressing", etc.).

These meal combinations were then coded for compliance/non-compliance with current weekly average USDA sodium (<=540mg/day for breakfast, <=1,230mg/day for lunch) and saturated fat (<=10% of total calories per day for breakfast or lunch) guidelines for K-5 menus.[20] National daily mean percentage of meal combinations exceeding these guidelines were calculated as the grand mean of daily district percent overages by nutrient.

Entrée Sub-Analyses

In sub-analyses, we restricted meal combinations only to those which included entrees as they have been shown to be selected by a majority of students as one or two (meat/meat alternate, grain) of the three required components and tend to contribute the majority of sodium and saturated in meals.[21–23]

Sub-analyses were conducted on breakfast and lunch entrees to estimate sodium and saturated fat contribution to meal combinations and nutrient levels by entrée class. Breakfast entrees were classified into two categories by inclusion/exclusion of a meat/meat alternate component, which is not required by USDA for the SBP. Lunch entrees were classified into fifteen mutually exclusive categories typically available in the NSLP including "Asian-inspired", "Breakfast for Lunch", "Breaded Chicken", "Breaded Fish", "Burger", "Cold Deli Sandwich", "Hot Sandwich", "Pasta", "Pizza, Calzones, and Stromboli", "Peanut Butter and Jelly", "Southwestern", "Other – with meat", "Other – vegetarian", and "Grain Only".

Statistical Analyses

Logistic regression models, adjusted for geographic region and district size, were used to estimate associations between entrée, saturated fat, and sodium and the likelihood of meal combinations to exceed USDA guidelines. The upper entrée nutrient thresholds in the logistic regression models (400mg sodium / 4.5g saturated fat for breakfast, 1,000mg sodium / 6g saturated fat for lunch) were selected to allow for the inclusion of the most commonly selected beverage – a 1% low-fat fluid milk, which contributes ~1.5g of saturated and ~130mg of sodium to meals – without exceeding USDA weekly average nutrient thresholds.

Results

Imputation of meal combinations generated 959,465 unique reimbursable breakfast combinations and 2.3 million unique reimbursable lunch combinations across 2,864 district menu days, with a wide range of daily saturated fat and sodium levels distributed around the SBP/NSLP guidelines for both breakfasts and lunches. Prevalence of daily meal combinations exceeding USDA nutrient thresholds are detailed in Table 1.2.

Table 1.2 Mean percent of meal combinations over USDA guidelines*

MENU	**MEAL TYPE**	**PERCENT (CI) (%) OF MEALS EXCEEDING USDA WEEKLY AVERAGE GUIDELINES**	
		SFA (BY % OF CALORIES)	**SODIUM**
SBP	All Combinations (n=2,864)	10.6 (10.0 – 11.1)	11.0 (10.3 – 11.6)
	Without Entrée (n=2,855)†	0.2 (0.1 – 0.3)	0.1 (0 – 0.1)
	With Entrée (n=2,864)	12.0 (11.3 – 12.6)	12.7 (12.0 – 13.5)
	With Entrée & Condiment (n=762)†	25.0 (22.5 – 27.5)	27.0 (24.6 – 29.5)
NSLP	All Combinations (n=2,864)	34.0 (33.1 – 34.9)	12.4 (11.8 – 13.0)
	Without Entrée (n=2,850)†	2.8 (2.5 – 3.1)	0.1 (0.0 – 0.1)
	With Entrée (n=2,864)	36.7 (35.7 – 37.7)	13.3 (12.7 – 14.0)
	With Entrée & Condiment (n=1,209)†	38.9 (36.9 – 41.0)	26.9 (25.2 – 28.7)

* *n= Total district menu days; Mean percentages estimated within district by day and then across all district menu days. Note: CI: 95% Confidence Interval, SBP: School Breakfast Program, NSLP: National School Lunch Program*

† *Smaller sample size is a function of not all districts offering this combination on all menu days.*

Overall, 10.6% (95% CI: 10.0 – 11.1) of possible daily breakfast combinations and 34.0% (95% CI: 33.1 – 34.9) of possible daily lunch combinations exceeded the USDA standard of <=10% of total calories from saturated fat, while 11.0% (95% CI: 10.3 – 11.6) of breakfast combinations and 12.4% (95% CI: 11.8 – 13.0) of lunch combinations exceeded sodium thresholds of <=540mg and <=1,230mg, respectively. Daily overages were markedly higher for meal combinations that included an entrée and/or a condiment. Among meals containing entrees, 12.0% (95% CI: 11.3 – 12.6) of possible daily breakfast combinations and 36.7% (95% CI: 35.7 – 37.7) of possible daily lunch combinations exceeded the USDA saturated fat guidelines, while 12.7% (95% CI: 12.0 – 13.5) of breakfast combinations and 13.3% (95% CI: 12.7 – 14.0) of lunch combinations exceeded sodium guidelines. Among meals containing entrees with condiments, 25.0% (95% CI: 22.5 – 27.5) of possible daily breakfast combinations and 38.9% (95% CI: 36.9 – 41.0) of possible daily lunch combinations exceeded the USDA saturated fat guidelines, while 27.0% (95% CI: 24.6 – 29.5) of breakfast combinations and 26.9% (95% CI: 25.2 – 28.7) of lunch combinations exceeded sodium guidelines. Overage percentages by specific breakfast and lunch component combination types can be found in Supplemental Tables 1.1 and 1.2.

Daily average percentages of imputed combinations exceeding USDA sodium guidelines ranged from 0 – 42.5% for breakfasts and 0 – 38.4% for lunches. Daily average percentages for meals exceeding 10% of calories from saturated fat ranged from 0-40.3% for breakfasts and 0-55.8% for lunches. Considerable variability in daily overage percentages was observed both by region and district size. Overall, the highest concentration of possible breakfast combinations exceeding USDA sodium guidelines occurred among the smallest and largest districts in our sample, particularly among smaller southeastern and larger southwestern districts. The smallest and largest eastern districts sampled, along with several mid-sized western districts contained the highest concentration of imputed breakfast combinations exceeding 10% of calories from saturated fat.   Smaller districts, joined by mid-sized districts in the southeast and southwest accounted for the highest concentration of imputed lunch combinations exceeding 1,230mg of sodium, while southwestern districts of all sizes had the highest concentration of lunch combinations exceeding 10% of calories from saturated fat. Specific results by strata can be found in the Supplemental Tables 1.3 – 1.6.

Entrée Sub-analysis

Level of sodium and saturated fat for both breakfast and lunch entrees were strongly associated with meal combinations exceeding USDA guidelines. Odds ratio calculations (see Table 1.3) indicate that breakfasts which included entrees with greater than 400mg of sodium were more than 1,200 times as likely to exceed USDA sodium guidelines (OR:1,260, CI 1,202 – 1,322) than when entrees had <350mg of sodium. Breakfasts containing entrees with greater than 4.5g of saturated were nearly 450 times as likely to exceed 10% of calories from saturated fat (OR:448, CI 443 - 463) than breakfasts with entrée <3.5g sat fat. Similarly, lunches with entrées containing more than 1,000mg of sodium (vs <700mg) or 6g saturated fat (vs <4g) were both strongly associated with exceeding USDA guidelines for both sodium (OR: 257, CI 253 – 261) and saturated fat (OR: 120, CI 119 – 121).

Table 1.3 Association between entrée nutrient and meal combination over USDA guideline

Variable	Category	Unadjusted		Adjusted*	
		Odds Ratio	95% CI	Odds Ratio	95% CI
SBP entrée sodium					
	<350mg (RC)	1.0		1.0	
	350 – 399mg	50	48 – 53	60	57 – 63
	>=400mg	1,143	1,092 – 1,196	1,260	1,202 – 1,322
NSLP entrée sodium					
	<700mg (RC)	1.0		1.0	
	700 – 999mg	19	19 – 19	19	18 – 19
	>=1,000mg	283	279 – 288	257	253 – 261
SBP entrée SFA					
	<3.5g (RC)	1.0		1.0	
	3.5g – 4.49g	34	33 – 35	28	27 – 29
	>=4.5g	356	346 – 367	448	443 – 463
NSLP entrée SFA					
	<4g (RC)	1.0		1.0	
	4g – 5.99g	14	13 – 14	13	13 – 13
	>=6g	121	119 – 122	120	119 – 121

Note: RC: Reference category, CI: Confidence interval, SBP: School Breakfast Program, NSLP: National School Lunch Program
** Adjusted for district size and geographic region*

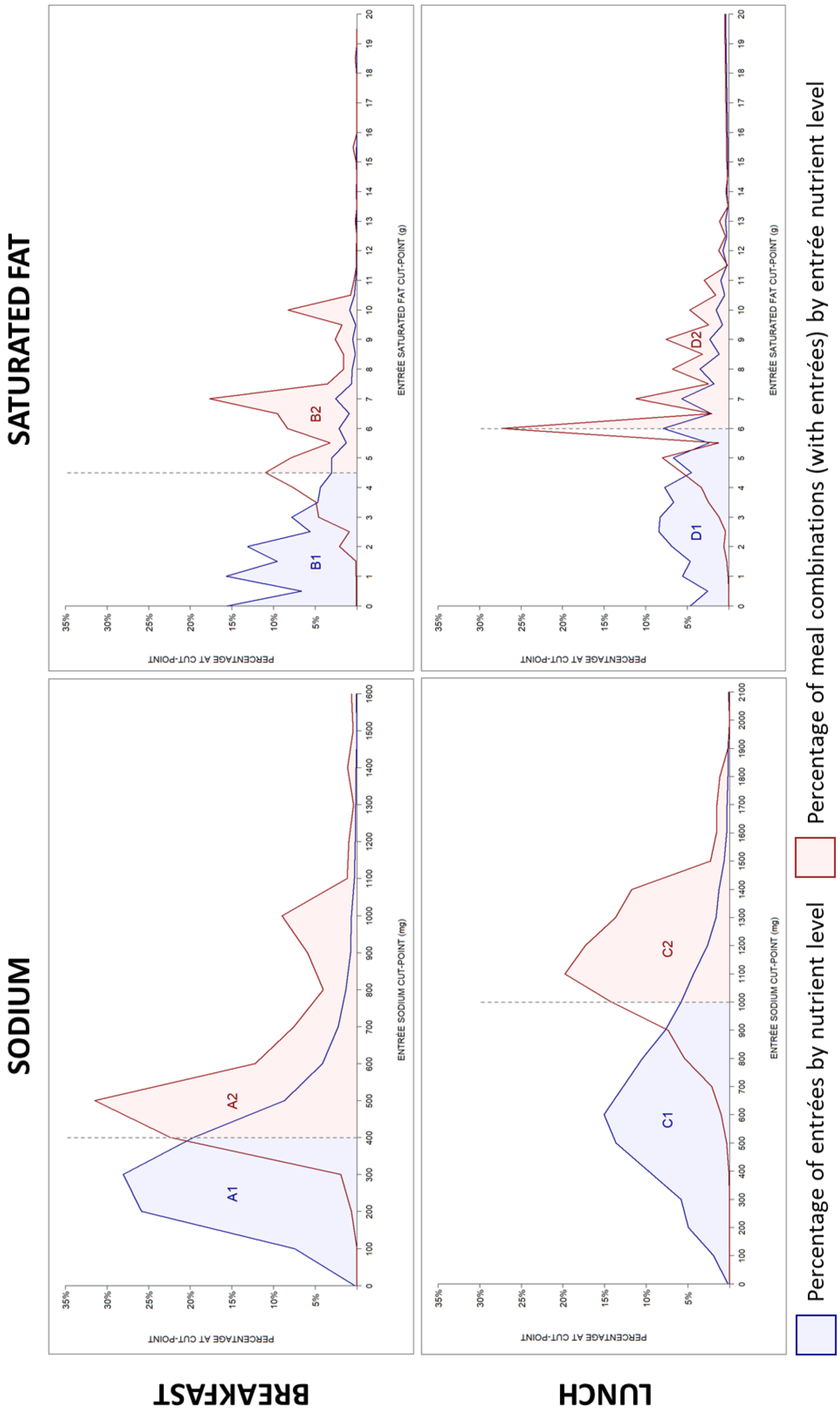
While a majority of breakfast and lunch entrées contained less than our highest threshold category for saturated fat and sodium in breakfast and lunch entrees, a majority of imputed meal combinations that exceeded USDA guidelines contained entrées that fell into these higher categories, suggesting that these could serve as daily entrée nutrient limits to reduce or eliminate meal combination overages. For example, Figure 1.1 illustrates the distribution of saturated fat and sodium in entrees, with a threshold level indicated by the vertical dotted line. **A1** indicates that 81.2% of unique breakfast entrées in our dataset fell at or below 400mg of sodium. If we only choose the imputed meals which contain the entrees above this threshold, the distribution of total meals above the USDA sodium meal limit is indicated by A2. Thus, 75.0% of imputed meal combinations containing an entrée and exceeding the USDA breakfast sodium guideline (<=540mg) contained an entrée with greater than 400mg of sodium. For lunches, 88.2% of unique entrées fell at or below 1,000mg of sodium (**C1**), while 69.4% of meal combinations containing an entrée and exceeding the lunch sodium guideline (<=1,230mg) contained an entrée with greater than 1,000mg of sodium (**C2**).

Results for entrée saturated fat at both breakfast and lunch followed a similar pattern. 86.1% of unique breakfast entrées contained <=4.5g of saturated fat (**B1**), whereas 68.6% of meals containing an entrée and exceeding the guideline (<=10% calories from saturated fat) contained an entrée with more than 4.5g of saturated fat (**B2**). 76.9% of unique lunch entrées contained <=6g of saturated fat (**D1**), while 49.3% of meal combinations containing an entrée and exceeding the guideline (<=10% calories from saturated fat) contained an entrée with more than 6g of saturated fat (**D2)**.

Entrée Types

Cold sandwiches typically containing processed deli meats and/or cheese showed the highest sodium levels (942mg, CI: 915 - 969), while vegetarian and grain-only (eg. rolls, plain pasta, seasoned rice) entrees contained the least (404mg, CI: 372 - 437). "Tex Mex" style entrees (eg. burritos, fajitas, tacos, etc.) contained the highest saturated fat content on average (6.0g, CI: 5.8 – 6.2), while Asian-inspired dishes (eg. General Tso's Chicken, Mandarin Chicken, etc.) had the lowest saturated fat content on average (1.8g, CI: 1.7 - 2.0). A comparative table and chart of typical lunch entrée nutrient content can be found in the Supplemental Table 1.7 and Supplemental Figure 1.1.

Figure 1.1 Distribution of entrées and possible meal combinations over USDA guidelines



Discussion

Prior to the implantation of the HHFKA, the major sources of saturated fat, and sodium in NSLP lunches offered were combination entrees, such as pizza, entree salads, sandwiches with meat or cheese, and Tex-mex style items.[24] Results from our national scan indicate that this remains the case today. Despite the fact that most school districts nationwide do now offer a variety of possible meal combinations in adherence with weekly USDA guidelines, students in most districts in our sample were still presented with entrees that contributed to meal combinations in excess of these thresholds on a daily basis, suggesting that a targeted intervention focused on the "center of the plate" could have a substantive impact on bringing a majority of daily K-5 meal nutrient levels in line with weekly guidelines.

Since its implementation in school year 2012–2013, The Healthy, Hunger-Free Kids Act of 2010 has resulted in a transformation that has resulted in students consuming more fruit, vegetables, and whole grains and fewer starchy vegetables through their school meals.[25,26] Over the same period, children in poverty, who are particularly vulnerable to obesity[27] and rely on school meals for a greater percent of their total calories, have seen their odds of prevalent obesity reduced by 9 percent annually.[28] These are facts that should be celebrated as a testament to the power of continual science-based improvements in public health nutrition policy. Despite these laudable achievements, HHFKA guidelines initially designed to reduce sodium content of meals gradually over a 10-year period through two intermediate reduction targets, have been stuck at Target 1 (1,230mg weekly average), largely through industry lobbying efforts that characterized further sodium reductions as impractical.[29,30]

Our results suggest otherwise. There was considerable variability in nutrient levels across the breadth of "traditional" school entrees such as pizza, sandwiches, and burritos in our sample, suggesting that specific entrée products selected by districts, rather than type of entrée, play an outsized role in determining the total nutrient content of meal combinations. Given the odds of exceeding USDA guidelines as entrée nutrient levels increase, we believe that setting reasonable *daily* limits specifically on entrée saturated fat and sodium levels would reduce potential exposure to daily overnutrition by K-5 students while allowing districts to retain a majority of current menu items, either through replacement or reformulation of higher sodium and saturated fat offerings.

For instance, replacement of breakfast entrees in excess of 4.5 grams of saturated fat and 400mg of sodium (with condiments) would address nearly 68% of saturated and sodium overages in our sample while impacting just 23.5% of entrees. Similarly, setting lunch entrée nutrient thresholds at no more that 6g of saturated fat and 1,000mg of sodium (with condiments) would address 62.4% of overages and entail replacing 29% of entrees. Each of these cut-points is set low enough to allow students to continue to select a milk (which typically contributes 130mg of sodium and ~1.5g of saturated fat per eight fluid ounces) and/or a side vegetable with a moderate amount of sodium from salad dressing, while keeping total meal nutrient content within existing guidelines. We believe this provides a targeted and practical approach to reducing daily sodium and saturated fat levels with minimal disruption to school district operations and supply chains.

Strengths and Limitations

This study has a number of limitations that should be considered. First, these data represent K-5 menus only, so our findings may not be generalizable to middle or high school menus. Furthermore, because this analysis also examined school breakfast and lunch data exclusively, it cannot be generalized to school snacks, dinners, or student lunches brought from home. These data also rely on the accuracy of the menu and nutritional information publicly available through the districts' websites, so daily district- or school-level operations (particularly product and production fidelity to posted menus) correlate with the information posted for the public.

Another limitation in our analysis is the inability to weight our results to account for the selection or consumption of more popular meal components. That said, plate waste results from a number of studies all show that selection and consumption of entrees are consistently higher than for other meal components, thus our analyses of meals containing entrees is likely a close approximation to actual intake.[31–33]

Furthermore, we believe our estimates of the true distribution of saturated fat and sodium in school meal combinations is likely conservative for a few reasons. Firstly, we believe that equally weighting all lunch components offered by districts, including traditionally less popular items that tend to contain less saturated fat and sodium (eg. sunflower butter sandwiches, vegetarian entrees, garden salads, etc.), likely understates the true sodium levels in school meals. Furthermore, condiments such as ketchup or ranch dressing were not always listed on school menus (and were therefore not assumed in all meal imputations), even though it is likely that these are typically offered to students when they are served hamburgers, chicken nuggets, and side vegetables. Lastly, our analyses did not consider additional nutrient intake from ala carte sales or food brought from home that may be shared among students.

In conclusion, we believe that this study's large nationally representative sample provides a realistic picture of the true distribution of saturated and sodium in school meals today. Our data highlight that, despite the success of the HHFKA in reducing the saturated fat and sodium content of school meals since its 2012 implementation, there is still room for policy improvements that would enhance the healthfulness of meals fed to over 30 million school children daily.[34] We propose that setting daily limits at 4.5g SFA and 400mg sodium for breakfast entrees and 6g SFA and 1,000mg sodium and saturated fat for lunch entrees could substantially reduce the daily over consumption of these nutrients by US school children.

Chapter 2: Examining differences in student selection and consumption of pre-packaged lunches versus those prepared on-site in a large New England school district

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Abstract

Background: Subsidized meals provided through the National School Breakfast and Lunch programs are an important source of daily nutrition for millions of U.S. students. Aging school infrastructure has led some school districts to rely on pre-packaged meals to feed students over the past few decades. It is unclear how student meal selection and consumption in these schools differs from students who attend schools where meals are prepared on-site.

Objective: The aim of this study was to assess differences in student selection and consumption of lunches between schools serving pre-packaged meals from those serving lunches prepared on-site in full-service kitchens.

Design: Weighed plate waste measurements of 2,045 lunch trays collected in Fall 2018 from 1,329 3rd-8th graders at seven K-5 and three K-8 schools (8 receiving pre-packaged meals, 2 receiving meals prepared on-site in full-service kitchens) in a large urban school district in New England.

Statistical analyses performed: Descriptive statistics and mixed-model linear regressions controlling for grade, sex, and repeated observations nested within individual were used to examine difference in meal component selection, portion size, consumption, and waste by meal service type.

Results: Selection of entrees was high (>98%) across meal service types. Portion sizes of entrées prepared on-site were larger [191g (95% CI 186g – 196g)] than pre-packaged entrées [174g (95% CI 170g – 177g)]. Entrées prepared on-site were consumed at a higher rate [66.3% (95% CI 64.1% – 68.5%)] than pre-packed entrées [53.6% (95% CI 51.4% – 55.8%)]. After controlling for grade, sex, and individual, entrée consumption was 26g (95% CI 4.6% – 11.7%) higher in schools serving meals prepared on-site than in schools serving pre-packaged entrees.

Fruits were similar in offering and portion size across meal service type, as was their selection (>80%). Students across meal service types consumed just under half of their fruit, with 41.9% (95% CI 38.5% – 45.3%) consumption in schools receiving meals prepared on-site versus 43.9% (95% CI 41.05% – 46.9%) consumption in schools with pre-packaged offerings. Comparison of milk selection and consumption across schools was complicated by the fact that two schools, one small K-5 school offering pre-packaged meals and one large K-8 school offering meals prepared on-site did not serve flavored milk. In schools with pre-packaged meals, flavored milk was selected by 62.1% (95% CI 58.7% – 65.5%) of students 37.9% (95% CI 29.9% – 45.9%) selection by students offered meals prepared on-site. Among flavored milk selectors, consumption was 11.5% (95% CI 0.9% – 22.1%) higher (~1/8 carton) in schools offering meals prepared on-site than in schools offering pre-packaged meals. Plain milk selection in schools offering pre-packaged meals was 22.5% (95% CI 19.6% – 25.3%) versus 39.9% (95% CI 35.6% – 44.1%) in schools offering meals prepared on-site. There was no difference in plain milk consumption among selectors after controlling for sex, grade, and individual. Vegetable selection was 27.2 (95% CI 21.9% – 32.5%) percentage points higher in on-site preparation schools, but consumption among selectors was similar compared with pre-packaged meal schools. Vegetable portions and waste were 62.3% (95% CI 59.3% – 65.4%) and 124.4% (50g) (95% CI 121.1% – 127.6%)) larger, respectively, in pre-packaged meal schools than on-site preparation schools.

Conclusions: Schools serving meals prepared on-site did a better job of regulating vegetable serving sizes, which led to similar student consumption with lower waste. Vegetable waste in pre-packaged meal schools can be lowered by offering pre-packaged vegetables in ¼ or ½ cup portion sizes which would allow students to select a ½ cup minimum to fulfill USDA requirements while having the option to select additional vegetable portions as they wish.

Background

The National School Lunch Program (NSLP) and School Breakfast Program (SBP), which are administered by the U.S. Department of Agriculture (USDA), provide nearly 30 million Federally subsidized lunches and 15 million Federally subsidized breakfasts to children each school day.[35] These programs can play a significant role in overall childhood dietary quality, as students who participate in both the SBP and NSLP may consume as much as fifty percent or more of their daily calories at school.[36]

School meals served during the academic year are subject to meal pattern and nutrition regulations detailed in the Healthy Hunger Free Kids Act (HHFKA), implemented in 2012. The HHFKA mandates that five meal components – 1) Meat/Meat Alternate and 2) Grain/Bread (typically served together as an entrée), 3) Vegetable, 4) Fruit, and 5) Fluid Milk – must be offered in minimum quantities to students at lunch.[37] In particular, fruit and vegetables must be *offered* in minimum amounts of 1 cup and ¾ cup, respectively. Despite these minimum offering requirements, the Offer versus Serve (OVS) Provision of the NSLP, implemented in the 1970s to minimize food waste and now utilized by more than 80% of public school districts nationally, allows students to choose just three of the five required meal components, as long as one component is a minimum ½ cup of fruit or vegetable.[38] This mandated offering and required selection of a fruit or vegetable has been shown to increase their selection and consumption by students.[39,40]

Despite the resulting uptick in vegetable selection at lunch, fresh vegetable selection and consumption in the NSLP remains low. The most recent USDA audit of the NSLP found that only 68.3% of elementary students selected a vegetable as part of their school lunch, just 23.6% selected raw vegetables (as opposed to French fries or other cooked vegetables), and mean vegetable waste was 31%.[41]

School kitchen infrastructure, particularly districts' ability to prepare food on-site, may play a role in food selection and waste. The district in this study is an exemplar of our national trend of aging infrastructure. As one of the oldest districts in the country, more than 60% of its buildings were constructed prior to the passage of the National School Lunch Act in 1946. Schools of this age were constructed during an era when many students, particularly those in elementary grades, walked home for lunch. As a result, these buildings were not designed with preparation kitchens from which to serve students meals prepared on-site. Over the last 40 years, many of these schools were outfitted with warming ovens used to quickly reheat pre-packaged meals purchased from an outsourced vendor prior to be offered to students on a service line often located in a gymnasium, hallway, or basement. A 2012 National Center for Education Statistics school infrastructure audit concluded that the national average age of public schools was 44 years, suggesting that this issue may be national in scope.[42] A survey conducted by the Pew Charitable Trusts the same year bolsters this concern – it found that 27.7% of schools planned to meet NSLP requirements through purchases of ready-to-eat foods that arrive ready to serve with only minimal preparation.[43]

The operational challenges associated with reliance on pre-packaged meals is that they may limit a district's ability to offer appealing options for students while customizing portion sizes to meet NSLP offered-versus-served requirements without forcing students to take more food than they want. The aim of this study was to assess this potential impact by examining differences in student meal component selection and consumption between schools offering pre-packaged meals to those offering meals prepared on-site. To our knowledge, this is the first study utilizing direct measure plate waste to examine differences in student meal selection and consumption between these two lunch operating models.

Methods

Research Design and Study Population

To examine differences in student selection and consumption, a cohort of ten schools offering pre-packaged meals (n=8) and meals prepared on-site (n=2) in a large urban New England school district were selected for plate waste analysis. This study included third through fifth graders participating in the NSLP across all ten schools and sixth through eighth graders in one pre-packaged meal school and both on-site preparation schools. All schools offered universal free meals under the USDA Community Eligibility Provision.[44] The study protocol was reviewed and approved by the Merrimack College IRB, Assurance # FWA00014062. Schools for this study were selected as part of another study investigating changes in student consumption resulting from a school kitchen renovation program funded by a local charitable foundation designed to enable on-site meal production. These data represent pre-intervention baseline differences between intervention and controls for that intervention study. Details on the impact of the conversion from pre-packaged meals to meals prepared on-site are detailed elsewhere.[45]

Data Collection Schedule and Timeline

Two days of weighed plate waste data were collected at each school from one school per day from early October through early December 2018. All data were collected on non-consecutive days within school to minimize potential autocorrelation of dietary intake by students. Attendance records provided by the district confirm that testing dates were representative of typical school attendance levels for grades 3-8 on all study days. Attendance by school is detailed in Supplemental Table 2.1 and examples of the district's outsourced and traditional on-site preparation lunch menus are provided in Supplemental Figures 2.1 – 2.2.

Data Collection

A representative sample ($n \approx 25$) of each food item offered was weighed prior to lunch service on each study day to provide stable base weight estimates from which to assess student consumption. Flavored milk was unavailable in one pre-packaged meal school and one on-site preparation school. Lunch trays was labeled with a unique number in permanent marker at the center of the tray and along all four sides to ensure visibility in the presence of food. Prior to lunch service, all trash cans were removed from the cafeteria.

During lunch service, the contents of each tray were recorded with a timestamp by a research assistant as students exited the lunch line. Once students were seated and eating their lunches, researchers quickly circulated among tables to record the name, sex, grade, homeroom, and tray number of each student on paper forms. As students completed their meals, RAs collected their trays and placed them aside for weighing after the end of the lunch period. Students who did not select a school meal (roughly 1/3 of students present on data collection days) were excluded from data collection. The remnants of meals brought from home were collected and discarded.

Following the end of lunch service, research assistants worked in teams of two to weigh and record each meal component remaining on the tray in grams using a commercially available food scale (MODEL: Nourish Kitchen Scale #0480, Greater Goods, LLC). Each item present on a tray was weighed and recorded, including empty packaging (eg. empty milk carton) and food remnants. Fully consumed items (eg. orange peel, apple core, empty cardboard sandwich boat or plastic vegetable container) were additionally noted to enable the calculation of the starting weight of the edible portion of food offered to students. Plate waste data were entered into a spreadsheet (Microsoft® Excel® 2016 MSO 16.0.14228.20216 32-bit) formatted with drop-downs and data validation to minimize data entry errors.

Statistical Analyses

Descriptive statistics and linear mixed models adjusted for sex, grade, and repeated observations of individual students were used to estimate the differences in meal component selection, portion sizes, consumption, and waste between meal service types. Regressions were conducted in R using the *'nlme: Linear and Nonlinear Mixed Effects Models' package* (Jose Pinheiro, Douglas Bates, Saikat DebRoy, Deepayan Sarkar and the R Development Core Team (2013), R package version 3.1-108).

Results

Plate waste from a total of 2,299 lunch trays were collected for this study. Point of sale tray contents, student information, and plate waste data were synced by school, date, and tray number to provide a subset of trays (n=2,045) from unique students who had a minimum of one day of plate waste data (n=1,329 total students). Table 2.1 describes the study sample distribution by grade, sex, and race/ethnicity. Details of the study sample stratified by students with one (n=613) or two (n=716) days of observations can be found in Supplemental Table 2.2.

Table 2.1. Sample size by grade, sex, race or ethnicity, and meal service type

	PRE-PACKAGED (n=8)	PREPARED ON-SITE (n=2)
Total Trays (#)	1,223	822
Grade 3	379	96
Grade 4	377	138
Grade 5	371	137
Grade 6	32[a]	181
Grade 7	37[a]	126
Grade 8	27[a]	144
Total Subjects (#)	815	514
Grade 3	259	62
Grade 4	249	80
Grade 5	239	85
Grade 6	24[a]	118
Grade 7	26[a]	85
Grade 8	18[a]	84
Female sex (%)	48.1	52.7
Race or Ethnicity (%)[b]		
Hispanic	54.7	66.5
African American	35.4	17.8
White, non-Hispanic	6.5	12.3
Other racial or ethnic groups[c]	3.4	3.4

[a] Only one school offering pre-packaged meals enrolled 6^{th} – 8^{th} grade students.
[b] Percentages are among NSLP Fall 2018 participants in grades 3-8 as reported by the school district.
[c] Includes Asian, Native American, Native Hawaiian or Pacific Islander, and multiracial racial and ethnic groups.

Differences in selection, portion size, consumption, and waste were observed by meal component across meal service type, the largest of which were entrée portion sizes and consumption, flavored milk selection and consumption, and vegetable portion sizes and waste. Unadjusted comparisons of selection percentage, portion sizes, consumption and waste by meal service type can be found in Table 2.2. Table 2.3 provides point estimates of these differences, adjusted for grade level, sex, and repeated observations within individual student. Specific findings by meal component are detailed below. Full regression outputs for estimated differences in selection, portion size, consumption and waste between meal service types can be found in Supplemental Tables 2.3 – 2.6.

Table 2.2. Mean (95% CI) component selection, portion size, consumption, and waste by meal service type

	PRE-PACKAGED	PREPARED ON-SITE
SELECTION (%)[a]		
Entrée	98.5 (97.7 – 99.4)	99.6 (99.1 – 100.0)
Vegetable	55.8 (52.4 – 59.2)	82.1 (78.8 – 85.4)
Fruit	80.1 (77.4 – 82.9)	88.1 (85.3 – 90.9)
Plain Milk	22.5 (19.6 – 25.3)	39.9 (35.6 – 44.1)
Flavored Milk[b]	62.1 (58.7 – 65.5)	37.9 (29.9 – 45.9)
PORTION SIZE (g)[c]		
Entrée[d]	174 (170 – 177)	191 (186 – 196)
Vegetable[e]	112 (109 – 116)	69 (67 – 72)
Fruit	105 (103 – 107)	115 (113 – 116)
Milk[f]	245 (245 – 246)	243 (242 – 243)
CONSUMPTION (g)[g]		
Entrée	91 (87 – 95)	125 (120 – 130)
Vegetable	20 (17 – 23)	28 (26 – 31)
Fruit	44 (41 – 47)	45 (42 – 49)
Plain Milk	113 (99 – 126)	132 (120 – 144)
Flavored Milk	155 (147 – 163)	190 (169 – 210)
CONSUMPTION (%)		
Entrée	53.6 (51.4 – 55.8)	66.3 (64.1 – 68.5)
Vegetable	21.3 (18.6 – 24.1)	39.4 (36.7 – 42.0)
Fruit	43.9 (41.0 – 46.9)	41.9 (38.5 – 45.3)
Plain Milk	46.1 (40.6 – 51.6)	54.6 (49.5 – 59.6)
Flavored Milk	63.2 (60.0 – 66.5)	77.1 (68.8 – 85.5)
WASTE (g)[h]		
Entrée	83 (78 – 87)	66 (61 – 71)
Vegetable	92 (88 – 97)	41 (39 – 43)
Fruit	62 (58 – 65)	69 (65 – 74)
Plain Milk	132 (118 – 145)	110 (98 – 123)
Flavored Milk	90 (82 – 98)	56 (36 – 77)
WASTE (%)		
Entrée	46.4 (44.2 – 48.6)	33.7 (31.5 – 35.9)
Vegetable	78.7 (75.9 – 81.4)	60.6 (58.0 – 63.3)
Fruit	56.1 (53.1 – 59.0)	58.1 (54.7 – 61.6)
Plain Milk	53.9 (48.4 – 59.4)	45.4 (40.4 – 50.5)
Flavored Milk	36.8 (33.5 – 40.0)	22.9 (14.5 – 31.2)

[a] Students were classified as "selectors" if they chose meal component on at least one day of observations.
[b] Calculated across a subset of schools (pre-packaged meals n=7, on-site preparattion n=1) where flavored milk was offered
[c] Refers to edible portion chosen by students without packaging, milk cartons, rinds, pits, or seeds.
[d] Includes meat/meat alternates, grains, and condiments.
[e] Does not include vegetables offered as part of entrées.
[f] Includes non-fat chocolate milk, 1% plain milk, plain skim milk, and lactose free milk.
[g] Among selectors, calculated by subtracted remaining edible portion weight on tray from edible portion size estimates.
[h] Among selectors; refers to remaining edible portion only.

Table 2.3. Adjusted[a] differences (95% CI)[b] in selection percentage, portion size, consumption, and waste of meal components prepared on-site versus pre-packaged

	ENTRÉE	VEGETABLE	FRUIT	PLAIN MILK	FLAVORED MILK[c]
SELECTED (%)	1.6 (0.4 – 2.8)[e]	27.2 (21.9 – 32.5)[f]	3.9 (-0.8 – 8.6)	10.9 (5.8 – 16.0)[f]	-26.6 (-34.9 – -18.2)[f]
PORTION (g)	18 (12 – 24)[f]	-46 (-50 – -41)[f]	10 (7 – 13)[f]	-1 (-2 – -0.4)[e]	0.5 (-3 – 4)
CONSUMED (g)	26 (20 – 33)[f]	4 (0.2 – 8)[d]	-1 (-6 – 4)	-14 (-35 – 8)	29 (2 – 55)[d]
CONSUMED (%)	8.1 (4.6 – 11.7)[f]	14.3 (10.2 – 18.3)[f]	-4.8 (-10.0 – 0.4)	-5.4 (-14.1 – 3.4)	11.5 (0.9 – 22.1)[d]
WASTED (g)	-8 (-16 – -1)[d]	-50 (-55 – -44)[f]	11 (5 – 17)[f]	13 (-9 – 34)	-28 (-54 – -2)[d]
WASTED (%)	-8.1 (-11.7 – -4.6)[f]	-14.3 (-18.3 – -10.2)[f]	4.8 (-0.4 – 10.0)	5.4 (-3.4 – 14.1)	11.5 (-22.1 – -0.9)[d]

[a] Adjusted for grade level, sex, and repeated observations within individual student. Reference is pre-packaged meal schools.
[b] 95% Confidence interval
[c] Calculated across a subset of schools (satellite n=7, on-site prepation n=1) where flavored milk was offered
[d] $p < 0.05$
[e] $p < 0.01$
[f] $p < 0.001$

Entrees

Student selection of entrées was uniformly high (>98%) across school meal service type with students in on-site preparation schools selecting them 1.6% (95% CI 0.4% – 2.8%) more often than students in pre-packaged meal schools. On-site preparation schools served slightly larger entrees [18g (95% CI 12g – 24g)] to their students who consumed 8.1% (95% CI 4.6% – 11.7%) more than pre-packaged meal school students. Corresponding adjusted entrée waste was only 8g (95% CI 1g – 16g) lower in on-site preparation schools than in pre-packaged meal schools.

Fruit

Fruit offerings were similar across meal service type (typically an apple, banana, grapes, orange or pear), with the only substantive difference being that students in schools with pre-packaged meals often received their fruit wrapped in cellophane. Fruit selection was similarly high between meal service types with 80.1% (95% CI 77.4% – 82.9%) of pre-packaged meal school students selecting a fruit versus 88.1% (95% CI 85.3% – 90.9%) of students in on-site preparation schools. Fruit portion size and consumption was also similar across schools with pre-packaged meal school students consuming an average of 43.9% (95% CI 41.0% – 46.9%) of their 105g (95% CI 103g – 107g) offerings compared with their on-site preparation school peers who consumed 41.9% (95% CI 38.5% – 45.3%) of their 115g (95% CI 113g – 116g) portions.

Milk

Comparisons of overall milk selection across meal service models was complicated by the fact that two schools (one small K-5 school offering pre-packaged meals and one large K-8 school with on-site meal preparation) did not offer flavored milk. Across all schools, plain milk was selected by 22.5% (95% CI 19.6% – 25.3%) of pre-packaged meal school students versus 39.9% (95% CI 35.6% – 44.1%) of their peers in on-site preparation schools. Sub-analysis of the eight schools offering flavored milk indicated that it was selected by 62.1% (95% CI 58.7% – 65.5%) of students in pre-packaged meal schools, but by only 37.9% (95% CI 29.9% – 45.9%) of students in the one school with on-site meal preparation where it was offered.

Milk serving sizes – standard 8 ounce cartons – were essentially identical across schools. While consumption and waste of plain milk was similar across meal service type after adjusting for grade, sex, and student, adjusted flavored milk consumption was 29g (95% CI 2g – 55g) higher (~1/8 carton) among students receiving meals prepared on-site.

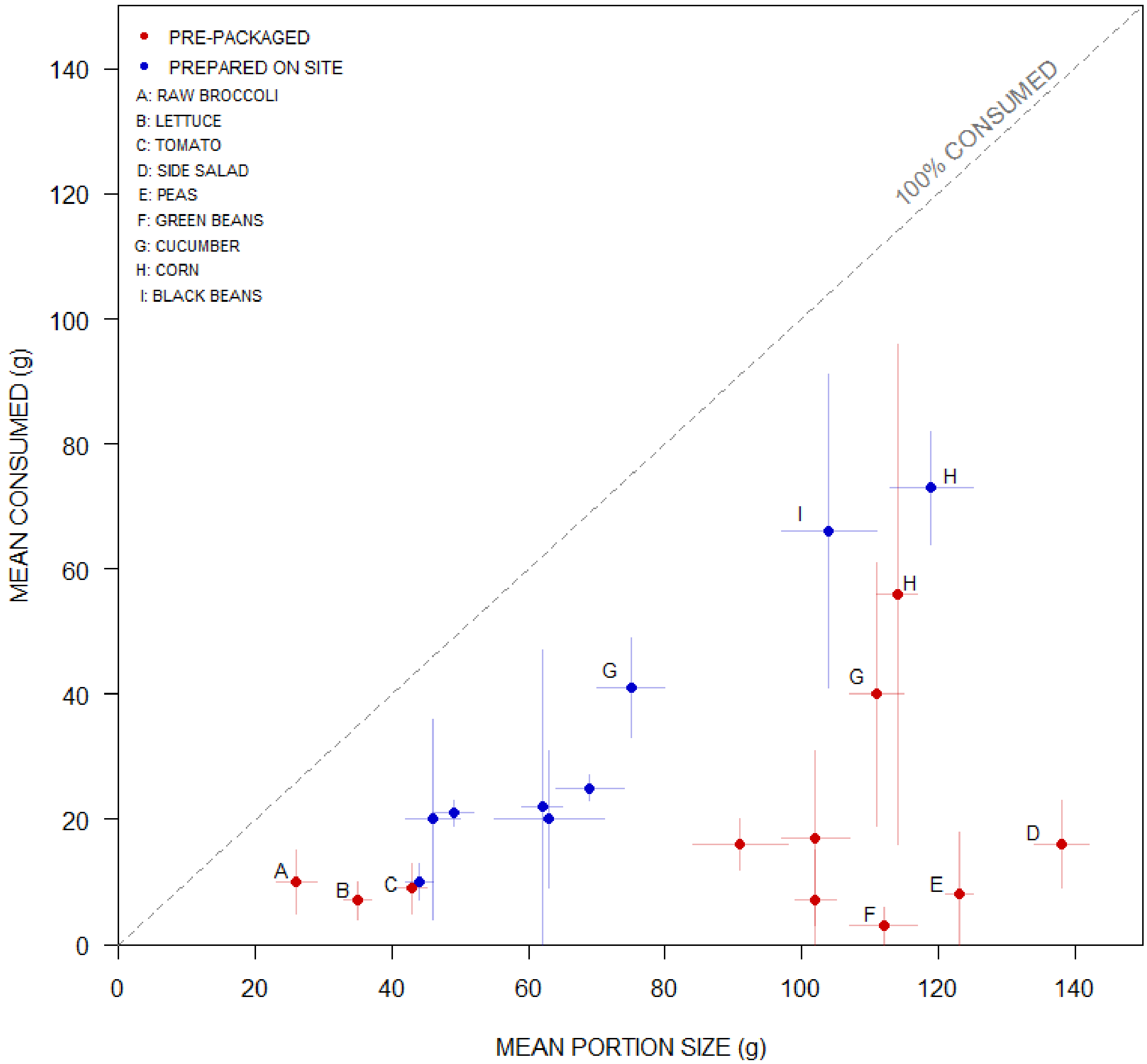
Vegetables

Significant differences in selection, portion sizes, and waste between meal service type were observed among vegetables. Vegetables were selected by 55.8% (95% CI 52.5% – 59.7%) of pre-packaged meal school students compared with 82.1% (95% CI 78.8% – 85.4%) of students in on-site preparation schools. Absolute vegetable consumption among vegetable selectors was similar across meal service type, however, with students in on-site preparation schools consuming just 4g (95% CI 0.2g – 8g) more (equivalent to ~1/2 a baby carrot) than their peers receiving pre-packaged meals.

The starkest differences between vegetables by meal service type were in portion sizes and waste in schools offering pre-packaged meals. Mean vegetable portions in schools offering pre-packaged meals were 46g (95% CI 41g – 50g) larger (~ ¼ cup) than portions offered in schools with on-site preparation. Given the similar consumption levels of vegetables across meal service type, mean vegetable waste was 50g (95 CI 44g – 55g) higher in pre-packaged meal schools as well, suggesting that both portion size and school-level factors may play a role in driving vegetable waste.

Figure 2.1 details the mean portion size and consumption in grams of specific vegetables offered across schools on days data collection days with specific vegetables indicated by the letters "A" through "I". With the exception of small portions of raw broccoli (label "A") lettuce ("B") and tomato ("C") that were offered in smaller packaging to be served in combination with other vegetables, the majority of vegetables served in pre-packaged meal schools (depicted in red) were offered and discarded in higher volumes than vegetables offered in on-site preparation schools. Pre-packaged items such as side salads, peas, and green beans ("D", "E", and "F", respectively) were associated with the largest amounts of waste due to their portion sizes, despite having similar consumption rates as other pre-packaged vegetables. Comparisons of cucumbers ("G") and corn ("H"), which were served in both pre-package meal schools and on-site preparation schools, indicate similar consumption levels, but higher waste among the larger pre-packaged offerings. Despite being offered in larger portions, black beans ("I") offered in on-site preparation schools had high consumption. A comparison of vegetable portions and waste by vegetable and meal service type is detailed in Supplemental Table 2.7.

Figure 2.1. Mean (95% CI) vegetable portion size (g) and consumption (g) by vegetable and meal service type.



Discussion

Our results show that while food waste was relatively high across all grades regardless of meal component, grade, and meal service type, there are considerable differences between pre-packaged meals served in pre-packaged meal schools and meals prepared on-site in full-service school kitchens. Most notable among our results was the significantly lower selection percentage, coupled with higher portion sizes and waste of vegetables among pre-packaged meal school students, despite similar consumption levels by students selecting vegetables across meal service type. Our results align with the vegetable selection findings of the USDA School Nutrition and Meal Cost Study which found that 68.3% of elementary students selected a vegetable as part of their school lunch.[46] Our observed vegetable waste percentages were significantly larger than the 31% they observed, however.

Vegetable selection in school lunches has been shown to be driven by a number of factors including the attractiveness of the offering of the day, whether staff pre-plate items, and even students' place in the lunch line and their subsequent amount of time to eat.[47] When the updated rules associated with the Healthy Hunger Free Kids Act were proposed in 2010 they garnered significant public comments regarding the potential for increased plate waste. In particular, many commenters noted that requiring students to take additional food, coupled with larger mandated vegetable portion sizes, might lead to increased waste by students have enough time to eat a larger quantity of food.[48] While vegetable waste can be driven by any combination of these factors and subsequent studies have found these fears to be somewhat overstated,[49,50] our findings suggest that portion size may play a role in vegetable food waste among students who select vegetables as part of their reimbursable meal.

The operational challenge facing districts that offer pre-packaged vegetables purchased from vendors who only offer one size option resides in the tension between meeting the OVS requirements of *offering* a minimum ¾ cup versus *serving* a minimum ½ cup to students who opt to select them. While more research is clearly warranted to understand more definitively both the effects of pre-packaging and serving sizes on vegetable selection and consumption, our results suggest that interim steps should be considered to limit vegetable waste in the short term, along with its associated economic and environmental costs. We propose that, particularly for schools that must serve pre-packaged vegetables currently, manufacturers offer vegetables in both ¼ or ½ cup servings, instead of only the maximum ¾ cup required to be offered under NSLP guidelines. We believe that doing so would allow students to embody the old adage, "take all you want, but eat all you take", maximizing consumption while minimizing waste in the short term, until additional data are available to inform further policy recommendations.

This study has several limitations to note prior to drawing conclusions to inform national school meal policy. Its primary limitation is the lack of random selection of schools due to logistical constraints within the district, which allows for potential confounding. While demographically similar schools were successfully enrolled, the possibility of confounding by unmeasured variables remains. Another potential limitation is the limited number of schools with full-service kitchens, as well as the number of days of observations, which increases the likelihood that preference for specific menu items could have skewed our results. Additionally, only students in one low income, urban school district were included. However, the menu items offered across both pre-packaged meal schools and on-site preparation schools were similar to large urban school districts across the United States, thus these results are likely generalizable to other low-income students of similar ages, who may benefit the most from school-based nutrition interventions.[51] Despite these limitations, this study's primary strength is its substantial sample size across multiple schools coupled with several days of precise pre- and post-intervention longitudinal plate waste measurements.

Chapter 3: Examining student plate waste following a conversion from pre-packaged lunches to meals prepared on-site: a longitudinal cohort study

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Abstract

Background: Subsidized meals provided through the National School Breakfast and Lunch programs are an important source of daily nutrition for millions of students across the United States. Aging school infrastructure has led some districts to rely on pre-packaged meals to feed students over the past few decades. It is unclear how investments in infrastructure upgrades that would enable districts to prepare food on-site in school kitchens might influence student selection and consumption of school meals.

Objective: The aim of this study was to assess changes in student selection and consumption of school lunches following a conversion from pre-packaged meals to lunches prepared on-site, the introduction of salad bars on the lunch line, and removal of flavored milk offerings.

Design: Quasi-experimental difference-in-difference analysis of pre/post direct observation weighed plate waste measurements collected in Fall 2018 and Spring 2019 from 595 3rd-5th graders at eight elementary schools (four intervention, four controls) in a large urban school district in New England.

Statistical analyses performed: Descriptive statistics and mixed-model linear regressions controlling for grade, sex, intervention, and observations nested within individual were used to examine changes in meal component selection and consumption.

Results: Student selection and consumption of vegetables increased by 31 grams (95%CI 18g – 43g) (equivalent to ~3.25 carrot sticks or grape tomatoes) in intervention schools relative to controls, while student selection and consumption of milk decreased by 46g (95%CI 18g – 43g) (~1/5 of an 8 ounce milk carton). Entrée and fruit selection and consumption did not change significantly.

Conclusions: Removal of flavored milk may lead to an initial decline in milk selection and consumption. Increased offerings of fresh unpackaged vegetables can increase student acceptance and consumption.

Background

The National School Lunch Program (NSLP) and School Breakfast Program (SBP), which are administered by the U.S. Department of Agriculture (USDA), provide nearly 30 million Federally subsidized lunches and 15 million Federally subsidized breakfasts to children each school day.[52] These programs can play a significant role in overall childhood dietary quality, as students who participate in both the SBP and NSLP may consume as much as fifty percent or more of their daily calories at school.[53]

School meals served during the academic year are subject to meal pattern and nutrition regulations detailed in the Healthy Hunger Free Kids Act (HHFKA), implemented in 2012. The HHFKA mandates that five meal components – 1) Meat/Meat Alternate and 2) Grain/Bread, typically served together as an entrée, 3) Vegetable, 4) Fruit, and 5) Fluid Milk – must be offered to students at lunch.[54] Under the Offer versus Serve (OVS) Provision NSLP, which is utilized by more 80% of public school districts nationally, students must choose a minimum of three meal components, one of which must be a fruit or vegetable, in order for their lunch to qualify for federal reimbursement.[55] This mandated offering and required selection of fruits and vegetables have been shown to increase student consumption of fruits and vegetables.[56,57] Despite this uptick, vegetable selection and consumption in school lunches remains low. The most recent USDA audit of the NSLP found that only 68.3% of elementary students selected a vegetable as part of their school lunch and just 23.6% selected raw vegetables (as opposed to French fries and other cooked vegetables).[58]

School kitchen infrastructure may play a key role in districts' ability to provide appealing meals for students. A 2012 National Center for Education Statistics school infrastructure audit concluded that the national average age of public schools was 44 years.[59] A survey conducted by the Pew Charitable Trusts the same year found that 24% of schools cited a need to remodel or upgrade kitchens in order to meet the improved nutritional guidelines of the HHFKA.[60] While 54% of districts surveyed expected to increase scratch cooking to meet the new requirements, 27.7% planned to meet the requirements through increased purchases of ready-to-eat foods that arrive ready to serve with only minimal preparation.[61]

While it is unclear what impact increasing offering of ready-to-eat food may have had on student meal component selection and consumption in those districts, a recent initiative in a large school district in New England switching many of its schools from pre-packaged “heat and serve” meals to lunches prepared on-site provides an opportunity to test the inverse.

The district undergoing the initiative is one of the oldest operating school districts in the United States, with more than 60% of its buildings constructed prior to the passage of the National School Lunch Act in 1946. Prior to that era, students typically walked home for lunch, thus many of these aging schools lack adequate preparation kitchens from which to serve students. These schools are typically outfitted with warming ovens used to quickly reheat pre-packaged meals purchased from an outsourced vendor prior to be offered to students on a service line often located in a gymnasium, hallway, or basement.

Beginning in summer 2017, the district partnered with a private foundation to launch an initiative which entailed a rolling schedule of retrofitting the district's schools lacking kitchens with the sinks, ovens, cooled/heated serving lines, and other equipment necessary to enable on-site scratch cooking of meals from fresher ingredients. Students in these renovated schools are encouraged to customize their meals by allowing them to request specific "deconstructed" entrée components to their liking (as opposed to being forced to take an entire entrée) as they proceed along the lunch line. Students are also provided with an array of daily fresh vegetables placed just before the point of sale on each lunch line which allows them to customize a salad. While fresh fruit offerings across these schools are typically similar to unrenovated schools, flavored milk is also removed as an offering following each renovation. Examples of the district's outsourced and post-intervention elementary school menus are provided in Supplemental Figures 3.1 and 3.2.

During the 2018/19 academic year, pre- and post-intervention plate waste data were collected from a cohort of intervention and control schools to assess changes in student meal component selection and consumption. To our knowledge, this is the first study utilizing direct measure plate waste to examine the impact on student meal consumption following an intervention that removed flavored milk and replaced pre-packaged meals with meals prepared on-site.

Methods

Research Design and Study Population

To test the impact of the intervention on student selection and consumption, a cohort of elementary schools (n=4) slated to receive renovations midway through the 2018/19 school year was selected by the district for plate waste analysis. Due to the district's established construction timeline, random assignment to the intervention (n=4) was not possible, so a cohort (n=4) of demographically similar schools scheduled to receive the intervention in subsequent years was selected to serve as a control, enabling a quasi-experimental difference-in-differences approach to assess student consumption attributable to the intervention. The study included third, fourth, and fifth graders participating in the NSLP across all eight schools. All schools offered universal free meals under the USDA Community Eligibility Provision.[62] The study protocol was reviewed and approved by the Merrimack College IRB, Assurance # FWA00014062.

Data Collection Schedule and Timeline

A total of four days (two days pre-intervention, two days post-intervention) of weighed plate waste data were collected at each school. Baseline data were collected at one school per day from early October through early December 2018. Follow-up data were collected at one school per day in Spring 2019. Post-intervention data collection at intervention schools was scheduled to allow for a suitable exposure period at each intervention school to minimize potential novelty effects (mean= 65 days, SD= 8.6). All data were collected on non-consecutive days within school to minimize potential autocorrelation of dietary intake by students. Attendance records provided by the district confirm that testing dates were representative of typical school attendance levels for grades 3-5 on all study days. Attendance by school is detailed in Supplemental Table 3.1.

Data Collection Methods

Pre-lunch preparation

A representative sample ($n \approx 25$) of each food item offered was weighed prior to lunch service on each study day to provide stable base weight estimates from which to assess student consumption. Lunch trays was labeled with a unique number in permanent marker at the center of the tray and along all four sides to ensure visibility in the presence of food. Prior to lunch service, all trash cans were removed from the cafeteria.

During lunch service

The contents of each tray were recorded with a timestamp by a research assistant as students exited the lunch line. A digital photo was also taken of each tray as students exited the line to provide a backup to the paper records.

Once students were seated and eating their lunches, researchers quickly circulated among tables to record the name, sex, grade, homeroom, and tray number of each student on paper forms. As students completed their meals, RAs collected their trays and placed them aside for weighing after the end of the lunch period. Students who did not select a school meal were excluded from data collection. The remnants of meals brought from home were collected and discarded.

Post-lunch service

Research assistants worked in teams of two to weigh and record each meal component remaining on the tray in grams using a commercially available food scale (MODEL: Nourish Kitchen Scale #0480, Greater Goods, LLC). Each item present on a tray was weighed and recorded, including empty packaging (eg. empty milk carton) and food remnants. Fully consumed items (eg. orange peel, apple core, empty cardboard sandwich boat or plastic vegetable container) were additionally noted to enable the calculation of the starting weight of the edible portion of food offered to students. Plate waste data were entered into a spreadsheet **(**Microsoft® Excel® 2016 MSO 16.0.14228.20216 32-bit) formatted with drop-downs and data validation to minimize data entry errors.

Statistical Analyses

Descriptive statistics and mixed-model linear regressions, adjusted to account for sex, grade, and individual observations nested within student and school were used to estimate changes in student selection and consumption. Regressions were conducted in R using the *'nlme: Linear and Nonlinear Mixed Effects Models' package* (Jose Pinheiro, Douglas Bates, Saikat DebRoy, Deepayan Sarkar and the R Development Core Team (2013), R package version 3.1-108).

Results

Plate waste from a total of 2,710 lunch trays were collected for this study. Point of sale tray contents, student information, and plate waste data were matched by school, date, and tray number to provide a longitudinal subset of trays (n=1,907) from unique students who had a minimum of one day of plate waste data pre-and post-intervention (n=595). Table 3.1 details the sample, which was well balanced between study arms by both grade and sex. Slight differences were observed between fourth and fifth grade participation in intervention versus control schools due to class field trips which occurred in both arms on a few study days.

Table 3.1 Intervention and control groups by grade, sex, and race or ethnicity

CHARACTERISTIC	INTERVENTION SCHOOLS (n=4)	CONTROL SCHOOLS (n=4)
Total Trays (#)	855	1,052
Grade 3	295	381
Grade 4	337	286
Grade 5	223	385
Total Subjects (#)	264	331
Grade 3	89	124
Grade 4	105	91
Grade 5	70	116
Female sex (%)	54.5	44.4
Race or Ethnicity (%)†		
Hispanic	52.7	50.4
African American	41.8	32.1
White, non-Hispanic	2.5	12.9
Other racial or ethnic groups*	3.0	4.6

† Percentages refer to all SBP/NSLP participants within each school as reported by the school district.
* Includes Asian, Native American, Native Hawaiian or Pacific Islander, and multiracial racial and ethnic groups.

Notable changes to meal component selection and consumption were observed in the intervention schools, specifically increased overall vegetable selection and consumption and decreased overall milk selection and consumption. Table 3.2 details the unadjusted mean pre- and post-intervention selection and consumption by study arm.

Table 3.2 Unadjusted mean (95% CI) student meal component selection (%) and consumption (g)

INTERVENTION	PRE-INTERVENTION TRAYS (n=422)		POST-INTERVENTION TRAYS (n=433)	
SCHOOLS (n=4)	**SELECTION (%)[a]**	**CONSUMPTION (g)[b]**	**SELECTION (%)[a]**	**CONSUMPTION (g)[b]**
Entrée	98.1 (96.4 – 99.8)	85 (79 – 91)	98.9 (97.6 – 100.0)	96 (90 – 102)
Vegetable	59.1 (53.2 – 65.0)	9 (7 – 11)	90.9 (87.4 – 94.4)	38 (34 – 42)
Fruit	89.4 (85.7 – 93.1)	34 (29 – 39)	94.7 (92.0 – 97.4)	55 (50 – 60)
Milk	79.9 (75.1 – 84.7)	100 (88 – 112)	51.1 (45.1 – 57.1)	51 (41 – 61)
Total Lunch	100.0	227 (213 – 241)	100.0	240 (226 – 254)
CONTROL	**PRE-INTERVENTION TRAYS (n=494)**		**POST-INTERVENTION TRAYS (n=558)**	
SCHOOLS (n=4)	**SELECTION (%)[a]**	**CONSUMPTION (g)[b]**	**SELECTION (%)[a]**	**CONSUMPTION (g)[b]**
Entrée	98.5 (97.2 – 99.8)	87 (81 – 93)	98.8 (97.6 – 100.0)	103 (98 – 108)
Vegetable	52.6 (47.2 – 58.0)	8 (6 – 10)	58.9 (53.6 – 64.2)	9 (7 – 11)
Fruit	73.1 (68.3 – 77.9)	31 (27 – 35)	84.6 (80.7 – 88.5)	42 (39 – 45)
Milk	78.5 (74.1 – 82.9)	111 (100 – 122)	77.3 (72.8 – 81.8)	107 (96 – 118)
Total Lunch	100.0	236 (222 – 250)	100.0	260 (247 – 273)

[a] Percentage of students who selected a meal component >0 times within intervention period

[b] Unadjusted overall consumption in grams across students regardless of selection

Meal Component Selection

While no significant change was observed in the percentage of students selecting entrees across either intervention or control schools, significant changes to vegetable and milk selection were observed in intervention schools following the intervention, where mean vegetable selection increased from 59.1% (95% CI 53.2 – 65.0) to 90.9% (95% CI 87.4 –94.4) and mean milk selection decreased from 79.9% (95% CI 75.1 – 84.7) to 51.1% (95% CI 45.1 – 57.1). The only significant change in control schools was in fruit selection, which increased modestly from 73.1% (95% CI 68.3 – 77.9) to 84.6% (95% CI 80.7 – 88.5). Unadjusted changes in student meal component selection are illustrated in Figure 3.1 and regression results for selection are detailed in Table 3.3.

Figure 3.1 Unadjusted change in mean student meal component selection (%)

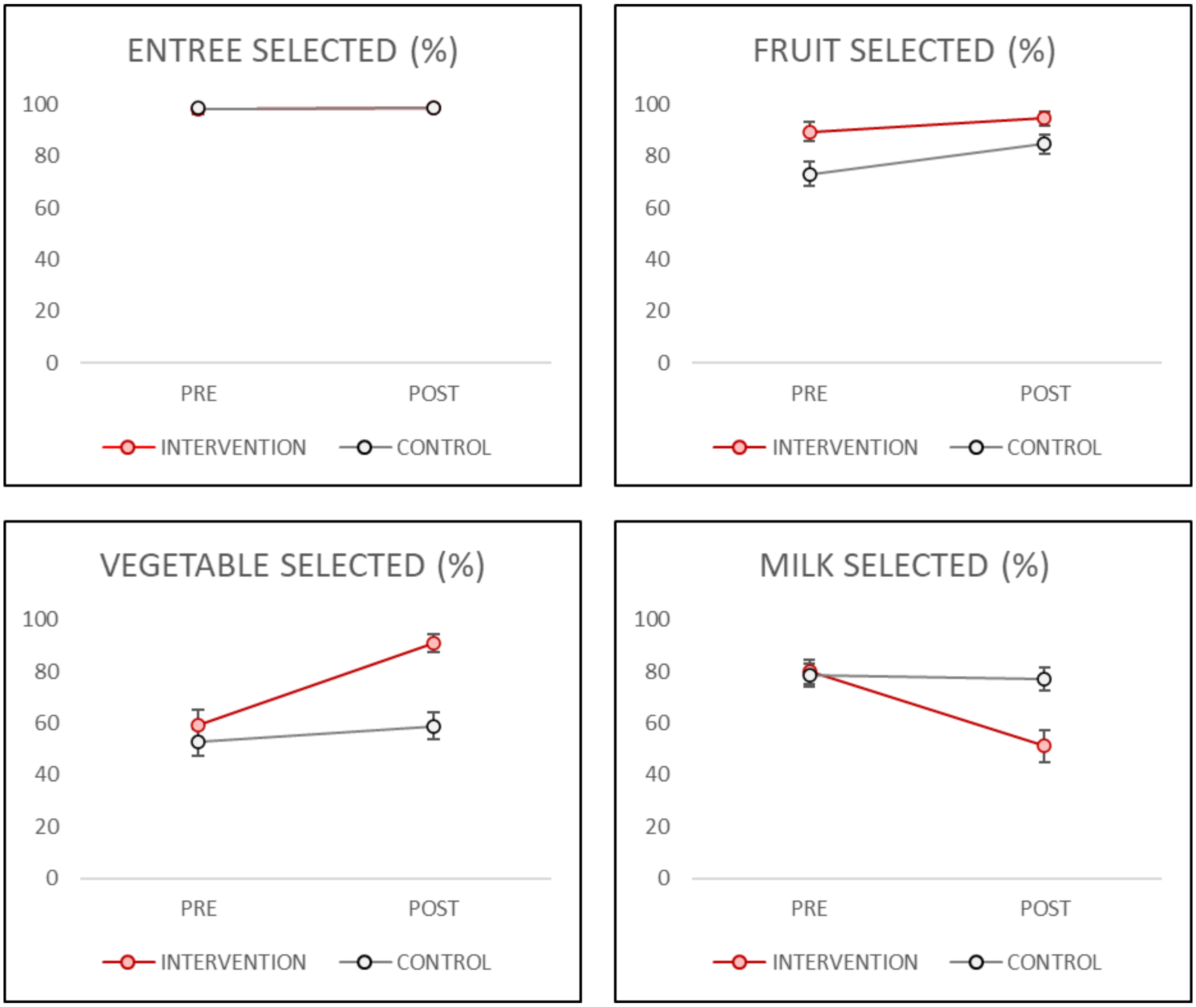

Table 3.3 Meal component selection percentage (%) difference-in-difference regression estimates

	ENTRÉE	VEGETABLE	FRUIT	MILK
INTERCEPT	0.98 (0.95 – 1.0)[a]	0.52 (0.25 – 0.79)[a]	0.73 (0.58 – 0.89)[c]	0.67 (0.41 – 0.93)[c]
INT SCHOOLS[d]	0.01 (-0.04 – 0.05)	-0.01 (-0.48 – 0.48)	0.10 (-0.17 – 0.37)	0.13 (-0.32 – 0.58)
TIME TREND[e]	0.00 (-0.01 – 0.02)	0.06 (-0.02 – 0.11)[a]	0.02 (-0.03 – 0.07)	-0.03 (-0.07 – 0.01)
DID[f]	-0.02 (-0.05 – 0.01)	0.33 (0.26 – 0.40)[c]	0.07 (0.00 – 0.14)[a]	-0.25 (-0.32 – -0.19)[c]
FEMALE (REF)	–	–	–	–
MALE	0.01 (-0.01 – 0.02)	-0.01 (-0.04 – 0.03)	-0.04 (-0.07 – 0.00)[a]	0.04 (-0.01 – 0.09)
GRADE 3 (REF)	–	–	–	–
GRADE 4	-0.002 (-0.02 – 0.02)	-0.04 (-0.09 – 0.002)	-0.01 (-0.05 – 0.03)	-0.10 (-0.16 – -0.04)[b]
GRADE 5	-0.02 (-0.04 – 0.001)	-0.03 (-0.08 – 0.02)	-0.06 (-0.10 – -0.02)[b]	-0.01 (-0.07 – 0.05)
R^2c	0.11	0.41	0.16	0.54

[a] $p < 0.05$
[b] $p < 0.01$
[c] $p < 0.001$
[d] Intervention Group specific effect (to account for average permanent difference from control)
[e] Time trend common to intervention and control groups
[f] Difference-in-difference estimator (true effect of treatment)

Meal Component Consumption

Significant changes in crude overall mean consumption were observed for vegetables, fruit, and milk in intervention schools. Mean overall vegetable consumption increased from 9g (95% CI 7 – 11) to 38g (95% CI 34 – 42) and mean overall fruit consumption rose from 34g (95% CI 29 – 39) to 55g (95% CI 50-60), while mean overall milk consumption decreased from 100g (95% CI 88 – 112) to 51g (95% CI 41 – 61). In control schools, crude mean overall entrée consumption increased from 87g (95% CI 81 – 93) to 103g (95% CI 98 – 108) and mean overall fruit consumption increased from 31g (95% CI 27 – 35) to 42g (95% CI 39 – 45). Table 3.2 and Figure 3.2 detail the changes in unadjusted mean student consumption by meal component and study arm.

Regression models controlling for grade, sex, and repeated observations within individual nested within school attenuated the significance of the change in overall fruit consumption associated with the intervention, but indicated a significant increase in overall vegetable consumption of 31g (95% CI 18 – 43) (equivalent to ~3.25 carrot sticks or grape tomatoes) and a significant decrease in overall milk consumption of -46g (95% CI -63 – -29) (~1/5 of an 8 ounce carton of milk). No significant change in overall entrée or lunch consumption was observed in either study arm. Regression results for meal component consumption are detailed in Table 3.4.

Figure 3.2 Unadjusted change in mean student meal component consumption (g)

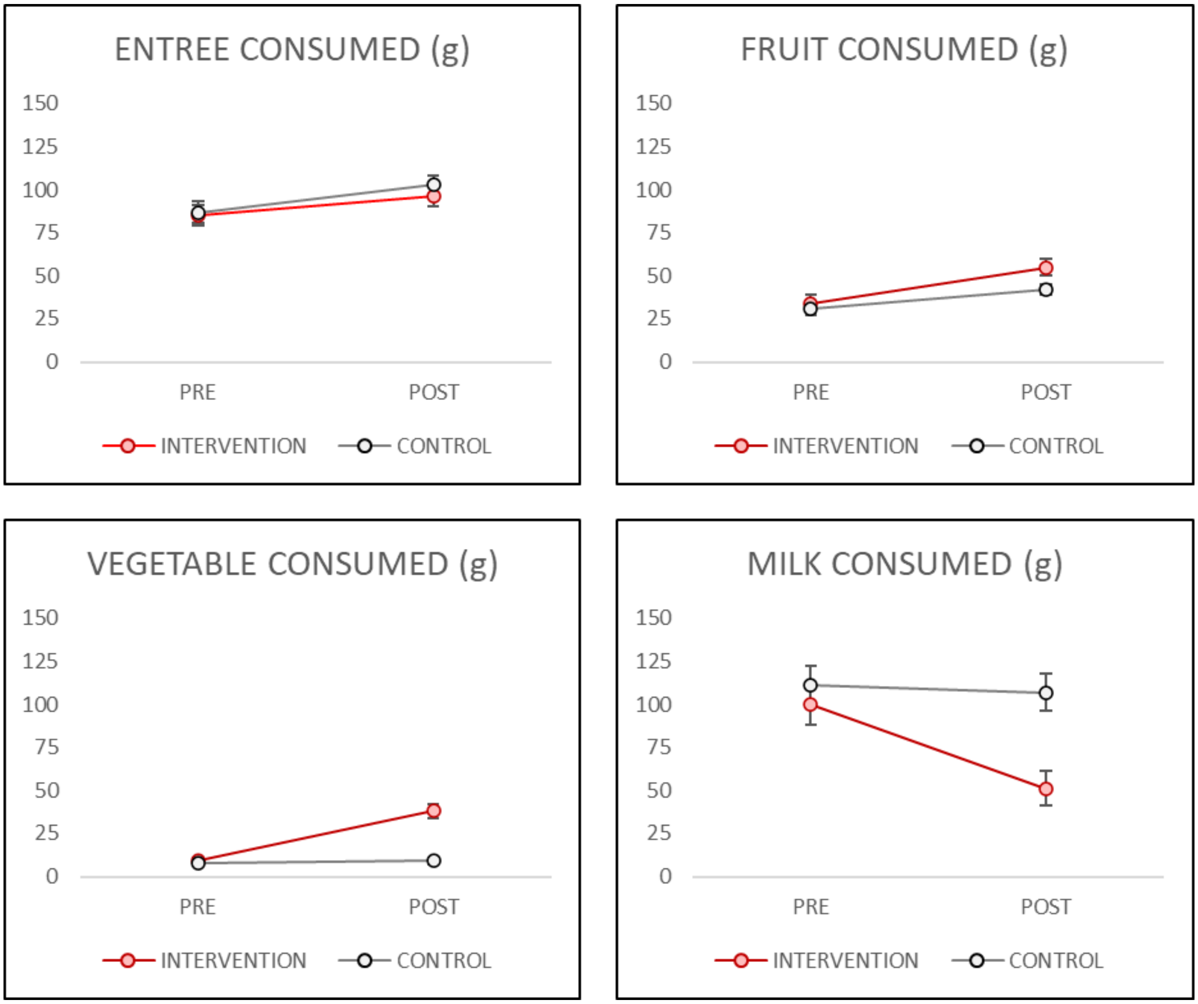

Table 3.4 Meal component consumption (g) difference-in-difference regression estimates

	ENTRÉE	VEGETABLE	FRUIT	MILK
INTERCEPT	78 (63 – 94)[c]	7 (2 – 12)[b]	36 (20 – 53)[c]	97 (63 – 130)[c]
INT SCHOOLS[d]	1 (-24 – 26)	-0.4 (-8 – 8)	-2 (-24 – 20)	9 (-36 – 54)
TIME TREND[e]	17 (4 – 31)[a]	0.5 (-8 – 9)	8 (-6 – 22)	-2 (-14 – 10)
DID[f]	-7 (-26 – 12)	**31 (18 – 43)[c]**	12 (-8 – 31)	**-46 (-63 – 29)[c]**
FEMALE (REF)	–	–	–	–
MALE	6 (-0.3 – 12)	0.7 (-2 – 3)	-5 (-9 – 0)[a]	18 (6 – 30)[b]
GRADE 3 (REF)	–	–	–	–
GRADE 4	-0.5 (-8 – 7)	2 (-1 – 5)	3 (-2 – 8)	-28 (-43 – 13)[c]
GRADE 5	19 (11 – 26)[c]	3 (0.4 – 6)	1 (-4 – 6)	-4 (20 – 11)
R^2c	0.33	0.44	0.20	0.57

[a] $p < 0.05$
[b] $p < 0.01$
[c] $p < 0.001$
[d] Intervention group specific effect (to account for average permanent difference from control)
[e] Time trend common to intervention and control groups
[f] Difference-in-difference estimator (true effect of treatment)

Sub-analyses by baseline selection behavior

While the analyses above highlight mean overall post-intervention changes by meal component, they do not elucidate potential heterogeneous changes in selection and consumption patterns by students who were either baseline selectors or baseline non-selectors of specific meal components, or of baseline lunch non-participants who opted to select a lunch post-intervention. To assess changes in these sub-populations, we conducted sub-analyses of selection and consumption in each group.

Sub-analysis of baseline selectors

Sub-analysis of baseline selectors, defined as students who selected a given meal component at least once pre-intervention, indicated higher post-intervention fruit and vegetable selection and lower milk selection among students in intervention schools versus control schools. Regression models controlling for sex, grade, and repeated observations within student nested within school indicated that mean fruit and vegetable consumption among prior selectors was higher in post- intervention schools [18g (95% CI 6 –30) and 34g (95% CI 17 – 51), respectively], while mean milk consumption was 42g (95% CI -76 – -9) lower. Supplemental Table 3.2 details these results.

Sub-analysis of baseline non-selectors

Sub-analyses of students who did not select milk or vegetables at baseline indicated higher post-intervention vegetable selection and lower milk selection in intervention schools versus control schools. Regression models controlling for sex, grade, and repeated observations within student nested within school indicated that mean vegetable consumption attributable to the interventions among prior non-selectors was 33g (95% CI 24 – 43) higher in post-intervention schools. Supplemental Table 3.3 details these results.

Sub-analysis of baseline non-participants

Sub-analysis of baseline non-participants, defined as students who we had no baseline longitudinal measures on, also indicated higher post-intervention vegetable selection and lower milk selection in intervention schools versus control schools. Regression models controlling for sex, grade, and repeated observations within student nested within school indicated that the only significant consumption difference was 31g (95% CI 15 – 47) higher vegetable consumption in post- intervention schools. Supplemental Table 3.4 details these results.

Discussion

In our study of a large diverse urban area school systems where intervention schools shifted from a healthy pre-packaged meal to an on-site scratch cooked meal with enhanced access to fresh vegetables and the elimination of flavored milk, we found that children were more likely to increase vegetable selection and consumption, but decrease milk selection and consumption. We did not find substantial changes in either entrée or fruit selection or consumption.

A wide array of cafeteria-based interventions designed to increase student acceptance and consumption of school meals have been documented in the decade since implementation of the Healthy Hunger Free Kids Act. The most rigorously evaluated of these documenting increased student fruit and vegetable intake have tended to focus on the presentation and palatability of meal components, increased variety of fruit and vegetable offerings, encouraging students to try fruits and vegetables, and giving students greater autonomy in portion size selection.[63–69] Our findings align with and build upon this prior research.

To our knowledge, this is the first plate waste study to assess the impact of removing flavored milk and switching from pre-packaged meals to meals prepared on-site. It is important to note that there is great variability in the marketplace of "pre-packaged" school meals, a catchall term that applies equally to shelf-stable, frozen, or fresh meals, each of which may have different nutritional, palatability, and cost profiles. In the case of this study, the pre-packaged meals under study were prepared fresh by at a central kitchen facility in nutritional compliance with USDA regulations, and subsequently delivered to schools daily.

Similarly, the term "meals prepared on-site" connotes the preparation of a meal from nothing but raw ingredients. In reality, most cooking in school kitchens is more aptly described as "light cooking and assembly", as most schools, including those in our study, do not bake their own bread, grind their own chuck steak for fresh hamburgers, or broil raw chicken and chop fresh tomatoes into salsa for inclusion in burritos. As such, the main differences we tested between school lunch operating models was the influence that entrée packaging, increased fresh vegetable variety, and the removal of flavored milk had on student selection and consumption. That said, our findings are worth the attention of school nutrition policy makers and food service directors who may be contemplating cafeteria infrastructure and staff training funding and investments.

Given the substantial costs and disruption of retrofitting kitchens into outdated school infrastructure, policy makers and school districts should consider which cafeteria interventions might provide the highest return on investment before making a wholesale shift in their operations. Most notably, our findings that the intervention did not impact entrée selection or consumption suggest that schools should consider whether a shift to preparing entrees on-site would result in healthier center-of-plate options with lower sodium and saturated fat for their students.

Similarly, while our findings showed that milk selection and consumption did decrease in the short term after flavored milk was removed mid-year, policy makers and districts should note that the literature on this subject is inconclusive and, thus, not reject the possibility of removing flavored milk out of hand. Two studies conducted before enactment of the HHFKA found that removal of flavored milk resulted in 11% and 26.0% lower milk selection, respectively, more recent research has found that students with access to only white milk resume consuming similar quantities of milk once they have had time to adjust to the change.[70–73] As a result, schools may still consider removing flavored milk as a strategy for decreasing student sugar intake, which is not currently regulated in school meals.

The clearest takeaway from our findings is the potential impact that increasing student exposure to a greater variety of daily fresh vegetable options, which was associated with significantly higher student vegetable selection and consumption. As a result, both schools with kitchens and those utilizing pre-packaged meal services due to lack of cooking infrastructure should all consider how they might increase their variety of fresh vegetable offerings to students daily on the lunch line.

This study has several limitations. Its primary limitation is the pre-study specification of the intervention schools by the school district, which necessitated a quasi-experimental approach to control for potential confounding. While demographically similar control schools were successfully enrolled, the possibility of confounding by unmeasured variables remains. Future studies using randomized intervention and controls should be conducted to isolate a potential causal effect to better inform policies regarding how vegetables should be offered in the NSLP.

Another limitation is the lack of ability to control for student breakfast intake (either at home or at school), which may have played a role in student hunger levels and subsequent lunch consumption. Additionally, only elementary students in a low income, urban school district were enrolled in our study. However, our results are likely generalizable to other low-income elementary students, who may benefit the most from school-based nutrition interventions. Future studies should examine the effect of similar interventions at the middle and high school levels and across other demographic and socio-economic strata. The primary strength of this study is its substantial sample size across multiple schools coupled with several days of precise pre- and post-intervention longitudinal plate waste measurements.

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Supplemental Tables

Supplemental Table 1.1 Percentage (95% CI) of reimbursable breakfast combinations exceeding USDA guidelines*

MEAL COMBINATION	SATURATED FAT (GRAMS)	SATURATED FAT (BY %)	SODIUM
EFFM (n=2,860)	8.3 (7.7 – 9.0)	10.7 (10.1 – 11.4)	14.1 (13.3 – 15.0)
EFF (n=2,850)	6.6 (6.0 – 7.2)	12.1 (11.4 – 12.9)	6.6 (6.0 – 7.2)
EFM (n=2,860)	8.6 (8.0 – 9.2)	13.7 (13.0 – 14.5)	14.4 (13.6 – 15.2)
FFM (2,855)	0.0	0.2 (0.1 – 0.3)	0.1 (0.0 – 0.1)

**n= district menu days; E=Entrée, V=Vegetable, F=Fruit (students can select two fruits at breakfast), M=Milk, D=Dessert, C=Condiment*

Supplemental Table 1.2 Percentage (95% CI) of reimbursable lunch combinations exceeding USDA guidelines*

MEAL COMBINATION	SATURATED FAT (GRAMS)	SATURATED FAT (BY %)	SODIUM
EF (n=2,765)	13.7 (12.8 – 14.6)	44.6 (43.3 – 45.9)	3.1 (2.7 – 3.6)
EFC (n=1,020)	15.4 (13.5 – 17.3)	41.7 (39.1 – 44.4)	6.1 (4.8 – 7.3)
EFD (n=171)	30.9 (25.6 – 36.1)	48.2 (42.6 – 53.9)	6.0 (3.5 – 8.6)
EFDC (n=64)	29.5 (20.0 – 38.9)	44.2 (33.7 – 54.6)	7.9 (2.5 – 13.4)
EFM (n=2,830)	18.4 (17.6 – 19.3)	32.9 (31.9 – 34.0)	4.6 (4.1 – 5.0)
EFMC (n=1,062)	20.1 (18.2 – 22.0)	34.7 (32.4 – 37.0)	14.2 (12.5 – 15.9)
EFMD (n=176)	30.9 (26.3 – 35.6)	35.2 (30.7 – 39.6)	10.4 (7.4 – 13.4)
EFMDC (n=67)	33.3 (24.1 – 42.5)	38.7 (29.6 – 47.8)	22.0 (13.9 – 30.0)
EV (n=2,809)	17.6 (16.7 – 18.5)	52.1 (50.9 – 53.3)	7.2 (6.6 – 7.8)
EVC (n=1,619)	22.5 (21.1 – 23.9)	52.6 (50.8 – 54.4)	16.3 (15.1 – 17.5)
EVD (n=178)	34.6 (29.3 – 40.0)	56.2 (50.8 – 61.6)	12.8 (9.6 – 16.0)
EVDC (n=109)	45.7 (37.9 – 53.5)	63.2 (56.0 – 70.4)	25.6 (19.7 – 31.5)
EVF (n=2,848)	15.3 (14.5 – 16.1)	37.4 (36.3 – 38.5)	6.3 (5.8 – 6.8)
EVFC (n=1,678)	21.3 (20.0 – 22.7)	41.0 (39.3 – 42.6)	15.7 (14.6 – 16.9)
EVFD (n=181)	30.0 (25.0 – 35.0)	41.6 (36.3 – 46.8)	11.9 (9.1 – 14.7)
EVFDC (n=112)	41.9 (34.6 – 49.2)	49.7 (42.5 – 56.9)	22.5 (17.4 – 27.6)
EVFM (n=2,848)	22.1 (21.2 – 23.0)	30.6 (29.6 – 31.6)	11.6 (11.0 – 12.3)
EVFMC (n=1,678)	27.1 (25.7 – 28.5)	33.2 (31.7 – 34.6)	25.3 (23.9 – 26.6)
EVFMD (n=181)	35.6 (30.8 – 40.4)	33.7 (29.0 – 38.3)	21.2 (17.4 – 24.9)
EVFMDC (n=112)	47.0 (40.0 – 54.0)	40.0 (33.2 – 46.8)	39.1 (33.6 – 44.6)
EVM (n=2,847)	22.2 (21.3 – 23.1)	40.5 (39.5 – 41.5)	11.6 (10.9 – 12.3)
EVMC (n=1,678)	27.2 (25.8 – 28.6)	43.1 (41.6 – 44.6)	25.3 (23.9 – 26.7)
EVMD (n=181)	35.5 (30.7 – 40.3)	42.4 (37.7 – 47.2)	21.1 (17.3 – 24.8)
EVMDC (n=112)	46.7 (39.6 – 53.7)	50.2 (43.4 – 56.9)	38.8 (33.3 – 44.4)
VFM (n=2,812)	0.03 (0.0 – 0.1)	1.8 (1.5 – 2.0)	0.04 (0.0 – 0.1)
VFMC (n=1,365)	0.0	5.1 (4.4 – 5.8)	0.1 (0.0 – 0.2)
VFMD (n=175)	2.3 (0.6 – 3.9)	12.4 (8.5 – 16.2)	0.0
VFMDC (n=89)	3.8 (0.8 – 6.8)	17.6 (11.0 – 24.2)	0.0

**n= district menu days; E=Entrée, V=Vegetable, F=Fruit (students can select two fruits at breakfast), M=Milk, D=Dessert, C=Condiment*

Supplemental Table 1.3 Percent (CI) (%) of breakfast combinations exceeding USDA sodium guideline (>540mg) by region/size

Size Tier	Region			
	North East (n=322)	**Mid Atlantic (n=461)**	**South East (n=488)**	**Mid West (n=363)**
Tier 1 (n=309)	16.5 (13.2 – 19.8)	42.5 (39.8 – 45.2)	25.2 (19.1 – 31.3)	20.3 (13.7 – 26.9)
Tier 2 (n=303)	33.5 (30.6 – 36.5)	4.1 (1.9 – 6.3)	17.1 (11.8 – 22.3)	2.3 (1.6 – 3.0)
Tier 3 (n=318)	13.4 (11.4 – 15.4)	1.1 (0.1 – 2.0)	18.9 (12.6 – 25.2)	3.6 (0.6 – 6.6)
Tier 4 (n=317)	8.9 (3.2 – 14.5)	8.1 (4.0 – 12.2)	6.3 (2.4 – 10.2)	8.3 (2.5 – 14.1)
Tier 5 (n=304)	2.4 (1.5 – 3.2)	6.4 (1.4 – 11.4)	13.8 (11.1 – 16.4)	5.5 (3.0 – 8.0)
Tier 6 (n=319)	0.4 (0.0 – 1.0)	9.4 (5.7 – 13.0)	41.1 (35.6 – 46.6)	3.4 (0.6 – 6.3)
Tier 7 (n=298)	7.5 (0.9 – 14.0)	2.7 (1.4 – 4.1)	11.8 (7.5 – 16.2)	1.9 (0.3 – 3.5)
Tier 8 (n=236)	*	7.9 (3.7 – 12.0)	13.4 (10.2 – 16.7)	17.8 (6.2 – 29.3)
Tier 9 (n=185)	*	2.1 (0.0 – 5.3)	6.5 (4.8 – 8.1)	*
Tier 10 (n=114)	*	6.1 (2.7 – 9.5)	13.7 (7.6 – 19.9)	*
Tier 11 (n=161)	7.0 (5.8 – 8.1)	*	15.5 (11.4 – 19.5)	7.0 (0.9 – 13.0)
Overall (n=2,864)	11.5 (9.8 – 13.2)	9.2 (7.7 – 10.7)	16.6 (15.0 – 18.2)	7.3 (5.7 – 9.0)

Note: n= district menu days, CI: 95% Confidence interval
** No district met the sample selection criteria.*

Supplemental Table 1.3 (Continued)

Size Tier	Region: Mountain Plains (n=356)	South West (n=437)	West (n=437)	Overall (n=2,864)
Tier 1 (n=309)	11.8 (9.0 – 14.7)	10.2 (5.6 – 14.8)	8.3 (3.5 – 13.1)	19.6 (17.5 – 21.8)
Tier 2 (n=303)	13.1 (10.6 – 15.5)	4.2 (2.2 – 6.2)	2.1 (0.0 – 4.2)	10.6 (9.1 – 12.2)
Tier 3 (n=318)	22.3 (19.0 – 25.6)	12.2 (6.4 – 18.1)	26.1 (19.0 – 33.1)	13.9 (12.0 – 15.9)
Tier 4 (n=317)	3.0 (1.3 – 4.7)	22.1 (13.7 – 30.4)	11.6 (6.7 – 16.5)	9.7 (7.7 – 11.8)
Tier 5 (n=304)	7.6 (4.1 – 11.2)	9.9 (6.9 – 12.8)	3.2 (2.2 – 4.2)	7.0 (5.8 – 8.2)
Tier 6 (n=319)	3.0 (0.0 – 6.6)	11.9 (5.8 – 18.0)	0.0 (0.0 – 0.0)	9.9 (7.8 – 11.9)
Tier 7 (n=298)	8.9 (5.0 – 12.9)	5.2 (3.1 – 7.2)	5.2 (1.6 – 8.9)	6.1 (4.7 – 7.6)
Tier 8 (n=236)	3.7 (0.9 – 6.4)	10.6 (7.6 – 13.6)	10.5 (4.9 – 16.1)	10.1 (8.1 – 12.0)
Tier 9 (n=185)	13.0 (8.2 – 17.8)	8.3 (4.7 – 12.0)	0.0 (0.0 – 0.0)	5.8 (4.3 – 7.3)
Tier 10 (n=114)	*	28.3 (16.0 – 40.5)	*	13.7 (9.7 – 17.8)
Tier 11 (n=161)	*	34.3 (22.0 – 46.6)	14.0 (8.2 – 19.8)	15.5 (12.4 – 18.7)
Overall (n=2,864)	9.6 (8.3 – 10.8)	12.8 (11.0 – 14.6)	8.5 (6.9 – 10.0)	11.0 (10.3 – 11.6)

Note: n= district menu days, CI: 95% Confidence interval
* *No district met the sample selection criteria.*

Supplemental Table 1.4 Percent (CI) (%) of breakfast combinations exceeding USDA SFA guideline (>10% kcals) by region/size

Size Tier	Region			
	North East (n=322)	**Mid Atlantic (n=461)**	**South East (n=488)**	**Mid West (n=363)**
Tier 1 (n=309)	19.8 (14.5 – 25.1)	31.8 (29.9 – 34.6)	22.0 (15.6 – 28.3)	13.6 (8.3 – 19.0)
Tier 2 (n=303)	40.3 (38.7 – 41.9)	0.9 (0.1 – 1.6)	17.1 (11.6 – 22.6)	4.9 (4.0 – 5.7)
Tier 3 (n=318)	9.3 (4.8 – 13.8)	1.8 (0.1 – 3.6)	11.7 (6.1 – 17.2)	8.9 (5.8 – 12.0)
Tier 4 (n=317)	13.9 (9.0 – 18.7)	1.7 (0.0 – 3.7)	7.6 (2.8 – 12.5)	3.5 (0.0 – 7.7)
Tier 5 (n=304)	8.8 (5.3 – 12.3)	3.3 (0.0 – 6.5)	7.5 (5.3 – 9.6)	11.7 (7.5 – 16.0)
Tier 6 (n=319)	1.8 (0.0 – 3.8)	4.2 (0.9 – 7.4)	34.8 (28.6 – 41.0)	5.8 (4.0 – 7.5)
Tier 7 (n=298)	4.2 (2.2 – 6.2)	2.7 (1.0 – 4.4)	5.2 (2.3 – 8.1)	6.4 (3.9 – 8.9)
Tier 8 (n=236)	*	14.2 (9.9 – 18.4)	10.4 (7.3 – 13.5)	11.0 (3.5 – 18.5)
Tier 9 (n=185)	*	3.0 (1.0 – 5.1)	9.2 (6.8 – 11.5)	*
Tier 10 (n=114)	*	9.2 (4.9 – 13.5)	10.3 (5.6 – 15.0)	*
Tier 11 (n=161)	21.5 (19.8 – 23.2)	*	18.5 (13.7 – 23.2)	13.7 (5.9 – 21.5)
Overall (n=2,864)	14.5 (12.7 – 16.3)	7.4 (6.2 – 8.7)	13.9 (12.3 – 15.4)	8.3 (6.9 – 9.7)

Note: n= district menu days, CI: 95% Confidence interval
** No district met the sample selection criteria.*

Supplemental Table 1.4 (Continued)

Size Tier	Region: Mountain Plains (n=356)	South West (n=437)	West (n=437)	Overall (n=2,864)
Tier 1 (n=309)	8.9 (5.8 – 12.1)	10.2 (5.9 – 14.5)	5.3 (0.4 – 10.1)	16.1 (14.1 – 18.2)
Tier 2 (n=303)	9.4 (6.3 – 12.6)	5.7 (3.6 – 7.7)	3.4 (0.5 – 6.3)	11.4 (9.6 – 13.2)
Tier 3 (n=318)	5.9 (3.2 – 8.6)	14.6 (9.0 – 20.2)	42.0 (37.1 – 46.9)	13.4 (11.3 – 15.5)
Tier 4 (n=317)	21.7 (17.7 – 25.7)	5.1 (1.9 – 8.3)	17.5 (11.1 – 23.9)	10.0 (8.2 – 11.9)
Tier 5 (n=304)	2.2 (0.6 – 3.8)	11.5 (8.5 – 14.5)	5.5 (3.8 – 7.2)	7.2 (6.0 – 8.3)
Tier 6 (n=319)	4.8 (1.5 – 8.1)	9.9 (4.1 – 15.7)	7.1 (3.4 – 10.8)	9.7 (7.8 – 11.6)
Tier 7 (n=298)	5.6 (1.1 – 10.1)	4.4 (2.3 – 6.5)	2.7 (0.5 – 4.9)	4.4 (3.5 – 5.4)
Tier 8 (n=236)	16.5 (13.8 – 19.2)	14.7 (10.7 – 18.6)	10.5 (5.5 – 15.5)	13.0 (11.3 – 14.7)
Tier 9 (n=185)	12.4 (7.3 – 17.6)	6.0 (3.1 – 8.8)	7.8 (4.8 – 10.8)	7.1 (5.8 – 8.5)
Tier 10 (n=114)	*	16.3 (8.1 – 24.6)	*	11.1 (8.0 – 14.1)
Tier 11 (n=161)	*	15.7 (6.6 – 24.9)	3.2 (1.2 – 5.2)	13.3 (10.7 – 15.8)
Overall (n=2,864)	9.5 (8.3 – 10.8)	9.9 (8.5 – 11.2)	10.6 (9.0 – 12.3)	10.6 (10.0 – 11.1)

Note: n= district menu days, CI: 95% Confidence interval
* *No district met the sample selection criteria.*

Supplemental Table 1.5 Percent (CI) (%) of lunch combinations exceeding USDA sodium guideline (>1,230mg) by region/size

Size Tier	Region			
	North East (n=324)	**Mid Atlantic (n=461)**	**South East (n=488)**	**Mid West (n=362)**
Tier 1 (n=309)	35.4 (30.9 – 39.8)	26.8 (19.4 – 34.1)	12.7 (6.2 – 19.2)	10.5 (6.1 – 14.8)
Tier 2 (n=301)	7.7 (4.6 – 10.7)	18.7 (14.1 – 23.2)	11.6 (6.6 – 16.7)	20.9 (17.2 – 24.7)
Tier 3 (n=318)	27.3 (20.4 – 34.2)	6.0 (1.9 – 10.0)	8.3 (5.7 – 10.8)	5.1 (2.6 – 7.7)
Tier 4 (n=314)	26.8 (23.3 – 30.3)	8.1 (5.6 – 10.5)	25.4 (20.1 – 30.8)	14.9 (9.7 – 20.1)
Tier 5 (n=304)	15.1 (11.4 – 18.8)	16.0 (10.2 – 21.9)	21.1 (16.9 – 25.3)	11.6 (6.7 – 16.4)
Tier 6 (n=319)	3.7 (1.1 – 6.3)	10.6 (6.9 – 14.3)	35.7 (30.4 – 40.9)	9.6 (4.8 – 14.5)
Tier 7 (n=303)	3.4 (0.9 – 5.9)	2.8 (1.3 – 4.3)	14.2 (8.8 – 19.6)	14.6 (10.8 – 18.3)
Tier 8 (n=236)	*	4.3 (2.2 – 6.5)	20.5 (16.5 – 24.5)	11.8 (3.0 – 20.5)
Tier 9 (n=185)	*	5.3 (3.2 – 7.3)	9.4 (6.0 – 12.8)	*
Tier 10 (n=114)	*	3.5 (1.6 – 5.3)	5.0 (2.4 – 7.7)	*
Tier 11 (n=161)	8.0 (4.3 – 11.7)	*	5.9 (2.7 – 9.1)	4.5 (1.1 – 7.9)
Overall (n=2,864)	16.4 (14.5 – 18.4)	10.2 (8.8 – 11.7)	15.5 (13.9 – 17.0)	12.0 (10.4 – 13.6)

Note: n= district menu days, CI: 95% Confidence interval
* *No district met the sample selection criteria.*

Supplemental Table 1.5 (Continued)

Size Tier	Region			
	Mountain Plains (n=354)	**South West (n=438)**	**West (n=437)**	**Overall (n=2,864)**
Tier 1 (n=309)	9.2 (5.7 – 12.8)	15.6 (10.6 – 20.5)	1.3 (0.5 – 2.1)	16.1 (13.8 – 18.3)
Tier 2 (n=301)	14.6 (9.6 – 19.5)	38.4 (30.4 – 46.5)	6.1 (0.5 – 11.7)	16.6 (14.3 – 18.8)
Tier 3 (n=318)	12.0 (8.5 – 15.5)	13.4 (9.7 – 17.1)	11.5 (6.7 – 16.3)	11.9 (10.1 – 13.7)
Tier 4 (n=314)	2.4 (0.6 – 4.3)	23.7 (16.4 – 31.1)	3.2 (1.2 – 5.2)	14.5 (12.6 – 16.5)
Tier 5 (n=304)	10.1 (6.6 – 13.6)	18.8 (16.5 – 21.1)	5.6 (3.2 – 8.1)	14.1 (12.5 – 15.6)
Tier 6 (n=319)	11.5 (6.9 – 16.1)	11.7 (7.5 – 15.8)	8.1 (3.9 – 12.3)	12.9 (11.0 – 14.8)
Tier 7 (n=303)	6.0 (3.5 – 8.5)	7.1 (3.5 – 10.7)	5.8 (0.7 – 11.0)	7.8 (6.3 – 9.3)
Tier 8 (n=236)	18.7 (10.3 – 27.1)	18.7 (13.7 – 23.8)	9.1 (4.3 – 13.9)	13.9 (11.6 – 16.2)
Tier 9 (n=185)	10.8 (5.6 – 16.1)	9.8 (7.3 – 12.3)	12.0 (7.3 – 16.7)	9.0 (7.5 – 10.5)
Tier 10 (n=114)	*	14.4 (4.3 – 24.5)	*	6.3 (3.8 – 8.8)
Tier 11 (n=161)	*	0.0 (0.0 – 0.0)	6.0 (2.6 – 9.4)	5.1 (3.6 – 6.6)
Overall (n=2,864)	10.6 (9.0 – 12.2)	16.0 (14.3 – 17.7)	6.5 (5.3 – 7.8)	12.4 (11.8 – 13.0)

Note: n= district menu days, CI: 95% Confidence interval
* *No district met the sample selection criteria.*

Supplemental Table 1.6 Percent (CI) (%) of lunch combinations exceeding USDA SFA guideline (>10% kcals) by region/size

Size Tier	Region			
	North East (n=324)	**Mid Atlantic (n=461)**	**South East (n=488)**	**Mid West (n=362)**
Tier 1 (n=309)	32.8 (24.8 – 40.7)	39.5 (33.0 – 46.0)	36.4 (28.5 – 44.3)	34.1 (26.3 – 41.8)
Tier 2 (n=301)	43.6 (37.8 – 49.5)	26.4 (20.2 – 32.6)	30.0 (23.2 – 36.7)	28.5 (25.3 – 31.7)
Tier 3 (n=318)	22.2 (19.2 – 25.2)	26.2 (19.5 – 32.9)	34.8 (28.5 – 41.1)	31.4 (23.0 – 39.8)
Tier 4 (n=314)	55.4 (50.4 – 60.5)	31.7 (24.6 – 38.9)	21.0 (15.6 – 26.3)	16.5 (11.8 – 21.2)
Tier 5 (n=304)	45.8 (39.9 – 51.6)	31.5 (22.6 – 40.3)	51.3 (44.9 – 57.8)	44.9 (34.8 – 55.0)
Tier 6 (n=319)	15.1 (11.3 – 18.9)	30.8 (24.6 – 37.0)	55.8 (49.3 – 62.4)	25.7 (19.5 – 31.9)
Tier 7 (n=303)	27.4 (21.2 – 33.6)	19.5 (16.7 – 22.4)	26.0 (21.5 – 30.6)	41.6 (35.7 – 47.4)
Tier 8 (n=236)	*	36.0 (30.8 – 41.1)	34.3 (29.1 – 39.6)	26.5 (14.2 – 38.7)
Tier 9 (n=185)	*	30.5 (25.7 – 35.3)	29.3 (23.2 – 35.3)	*
Tier 10 (n=114)	*	45.6 (38.9 – 52.3)	25.6 (20.9 – 30.3)	*
Tier 11 (n=161)	2.4 (0.8 – 3.9)	*	27.6 (21.9 – 33.2)	39.6 (28.6 – 50.6)
Overall (n=2,864)	31.9 (29.3 – 34.4)	31.9 (29.8 – 34.0)	33.8 (31.8 – 35.8)	31.6 (29.0 – 34.2)

Note: n= district menu days, CI: 95% Confidence interval
** No district met the sample selection criteria.*

Supplemental Table 1.6 (Continued)

Size Tier	Region			
	Mountain Plains (n=354)	**South West (n=438)**	**West (n=437)**	**Overall (n=2,864)**
Tier 1 (n=309)	36.5 (27.9 – 45.1)	44.4 (36.7 – 52.1)	25.3 (17.6 – 33.0)	35.4 (32.4 – 38.3)
Tier 2 (n=301)	39.0 (30.8 – 47.3)	54.5 (46.3 – 62.7)	40.6 (30.5 – 50.7)	37.2 (34.3 – 40.1)
Tier 3 (n=318)	33.8 (26.3 – 41.4)	43.6 (37.6 – 49.6)	37.9 (28.8 – 47.0)	32.7 (30.0 – 35.4)
Tier 4 (n=314)	31.5 (24.4 – 38.5)	36.1 (27.8 – 44.4)	26.3 (18.8 – 33.9)	30.6 (27.8 – 33.3)
Tier 5 (n=304)	24.8 (18.9 – 30.8)	45.0 (40.2 – 49.7)	26.9 (22.5 – 31.4)	38.5 (35.7 – 41.2)
Tier 6 (n=319)	44.6 (37.2 –52.0)	20.8 (15.2 – 26.5)	47.1 (39.3 – 54.9)	34.2 (31.4 – 37.0)
Tier 7 (n=303)	31.4 (24.4 – 38.5)	37.8 (31.5 – 44.0)	29.9 (21.3 – 38.5)	30.7 (28.2 – 33.1)
Tier 8 (n=236)	36.1 (26.5 – 45.6)	32.2 (26.2 – 38.2)	30.7 (21.4 – 40.1)	33.3 (30.3 – 36.4)
Tier 9 (n=185)	38.3 (31.6 – 45.0)	41.5 (35.2 – 47.7)	28.4 (21.7 – 35.0)	33.6 (30.8 – 36.4)
Tier 10 (n=114)	*	43.7 (31.0 – 56.3)	*	37.0 (32.5 – 41.4)
Tier 11 (n=161)	*	51.6 (34.6 – 68.6)	34.3 (29.8 – 38.8)	31.6 (27.4 – 35.8)
Overall (n=2,864)	35.0 (32.4 – 37.6)	40.3 (37.9 – 42.7)	32.9 (30.4 – 35.5)	34.0 (33.1 – 34.9)

Note: n= district menu days, CI: 95% Confidence interval
** No district met the sample selection criteria.*

Supplemental Table 1.7 Mean nutrient content by lunch entrée type

Entrée Type	n	Mean SFA (g) (95% CI)	Mean Sodium (mg) (95% CI)
DELI	486	4.6 (4.4 – 4.8)	942 (915 – 969)
HOT SANDWICH	358	5.1 (4.8 – 5.4)	766 (737 – 794)
ENTRÉE SALAD	639	5.3 (5.1 – 5.6)	744 (717 – 771)
TEX MEX	1,398	6.0 (5.8 – 6.2)	707 (689 – 725)
HOT DOG	429	4.3 (4.1 – 4.5)	694 (672 – 717)
BREADED CHIX	1,065	2.8 (2.7 – 2.9)	644 (632 – 657)
BURGER	451	5.5 (5.3 – 5.6)	637 (616 – 658)
PASTA	504	5.3 (5.0 – 5.6)	632 (605 – 658)
PIZZA	600	5.7 (5.5 – 5.9)	622 (605 – 638)
ASIAN INSPIRED	324	1.8 (1.7 – 2.0)	606 (560 – 652)
OTHER	563	4.0 (3.8 – 4.2)	595 (572 – 619)
BREADED FISH	137	2.3 (2.1 – 2.5)	555 (516 – 594)
PBJ	104	4.8 (4.3 – 5.2)	497 (461 – 532)
VEGETARIAN	350	3.4 (3.1 – 3.7)	404 (372 – 437)
GRAIN ONLY	366	0.8 (0.7 – 0.9)	191 (178 – 203)
OVERALL	8,269	4.4 (4.3 – 4.4)	633 (626 – 640)

Supplemental Table 2.1. District-reported student attendance by school, grade, and study date

PRE-PACKAGED	GRADE	3rd		4th		5th		6th		7th		8th	
	DATE	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**
School 1	T11/13, T11/20	72	75	73	73	79	81	–	–	–	–	–	–
School 2	T10/23, R10/25	55	57	57	55	36	38	–	–	–	–	–	–
School 3	M11/19, M11/26	22	22	23	23	23	23	–	–	–	–	–	–
School 4	T10/30, T11/06	50	54	52	51	43	47	–	–	–	–	–	–
School 5	W10/17, W10/24	47	45	56	57	50	53	–	–	–	–	–	–
School 6	M11/26, T12/04	21	21	23	25	19	19	–	–	–	–	–	–
School 7	R11/1, R11/8	38	38	44	43	37	38	–	–	–	–	–	–
School 8	W10/10, R10/18	47	51	61	60	40	40	47	47	34	34	26	26
PREPARED ON-SITE	**GRADE**	**3rd**		**4th**		**5th**		**6th**		**7th**		**8th**	
	DATE	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**
School 9	R10/11, M10/22	43	42	44	42	38	36	35	36	15	15	22	22
School 10	W11/14, W12/05	82	79	103	99	100	98	120	125	88	83	75	80

Supplemental Table 2.2 Sample size by days of observations, grade, sex, meal service type

	PRE-PACKAGED		PREPARED ON-SITE	
DAYS OF OBSERVATIONS	**ONE**	**TWO**	**ONE**	**TWO**
Total Subjects (#)	407	408	206	308
Grade 3	139	120	28	34
Grade 4	121	128	22	58
Grade 5	107	132	33	52
Grade 6[a]	16	8	55	63
Grade 7[a]	15	11	44	41
Grade 8[a]	9	9	24	60
Female sex (%)	47.4	48.8	53.4	52.3

[a] Only one pre-packaged meal school enrolled 6th – 8th grade students.

Supplemental Table 2.3. Adjusted component selection difference (%, 95% CI)[a] of meals prepared on-site versus pre-packaged meals

COVARIATE	ENTRÉE	VEGETABLE	FRUIT	PLAIN MILK	FLAVORED MILK
INTERCEPT	98.4 (97.2 – 99.6)[e]	51.8 (46.6 – 57.0)[e]	75.2 (70.5 – 79.8)[e]	13.6 (8.6 – 18.6)[e]	59.6 (53.5 – 65.8)[e]
PREPARED ON-SITE[b]	1.6 (0.4 – 2.8)[d]	27.2 (21.9 – 32.5)[e]	3.9 (-0.8 – 8.6)	10.9 (5.8 – 16.0)[e]	-26.6 (-34.9–-18.2)[e]
FEMALE (REF)	–	–	–	–	–
MALE	-0.4 (-1.4 – 0.6)	-5.8 (-10.2 – -1.4)[c]	-4.0 (-8.0 – -0.1)[c]	0.5 (-3.8 – 4.8)	11.3 (5.6 – 17.0)[e]
GRADE 3 (REF)	–	–	–	–	–
GRADE 4	0.4 (-1.1 – 1.8)	-2.0 (-8.3 – 4.4)	4.6 (-1.1 – 10.2)	7.6 (1.5 – 13.7)[c]	-20.1 (-27.6 – -12.7)[e]
GRADE 5	-0.8 (-2.3 – 0.6)	-4.6 (-10.9 – 1.8)	-2.1 (-7.7 – 3.6)	6.1 (-0.01 – 12.2)	-6.3 (-13.4 – 1.2)
GRADE 6	0.4 (-1.7 – 2.4)	-0.7 (-10.0 –8.2)	2.4 (-5.6 – 10.3)	4.7 (-3.9 – 13.2)	-22.5 (-35.9 – -9.1)[d]
GRADE 7	-0.1 (-2.3 – 2.1)	-15.2 (-24.7– -5.7)[d]	0.0 (-8.5 – 8.4)	20.7 (11.6 – 29.8)[e]	-5.8 (-20.1 – 9.4)
GRADE 8	-2.0 (-4.1 – 0.2)	-4.5 (-14.1 – 5.1)	-2.0 (-10.5– 6.5)	15.7 (6.4 – 25.0)[d]	-5.9 (-21.1 – 9.4)
R^2c	0.008	0.25	0.17	0.57	0.52

[a] Models adjust for grade, sex, and repeated observation by students. CI:95% Confidence interval
[b] Reference group is pre-packaged meal schools.
[c] $p < 0.05$
[d] $p < 0.01$
[e] $p < 0.001$

Supplemental Table 2.4. Adjusted component portion size difference (g, 95% CI)[a] of meals prepared on-site versus pre-packaged meals

COVARIATE	ENTRÉE	VEGETABLE	FRUIT	PLAIN MILK	FLAVORED MILK
INTERCEPT	180 (174 – 187)[e]	112 (107 – 118)[e]	103 (100 – 106)[e]	245 (244 – 245)[e]	247 (245 – 248)[e]
PREPARED ON-SITE[b]	18 (12 – 24)[e]	-46 (-50 – -41)[e]	10 (7 – 13)[e]	-1 (-2 – -0.4)[d]	0.5 (-3 – 4)
FEMALE (REF)	–	–	–	–	–
MALE	-6 (-11 – -1)[c]	1 (-4 – 5)	-1 (-4 – 1)	-0.1 (-1 – 0.4)	0.3 (-2 – 2)
GRADE 3 (REF)	–	–	–	–	–
GRADE 4	-12 (-19 – -4)[d]	1 (-5 – 7)	0.1 (-3 – 4)	-0.1 (-1 – 1)[c]	-0.3 (-3 – 2)
GRADE 5	-7 (-15 – 0.3)	-2 (-9 – 4)	5 (2 – 9)[d]	-1 (-1 – 0.4)	-2 (-4 – 1)
GRADE 6	-5 (-15 – 6)	1 (-7 – 9)	1 (-4 – 6)	-2 (-3 – -1)[e]	-2 (-8 – 4)
GRADE 7	-9 (-20 – 3)	15 (5 – 24)[d]	7 (2 – 13)[c]	-2 (-3 – -1)[e]	-3 (-8 – 2)
GRADE 8	-1 (-12 – 11)	9 (0.3 – 18)[c]	3 (-3– 9)	-2 (-3 – -1)[e]	-2 (-8 – 3)
R^2C	0.03	0.25	0.05	0.15	0.01

[a] Models adjust for grade, sex, and repeated observation by students. CI:95% Confidence interval
[b] Reference group is pre-packaged meal schools.
[c] $p < 0.05$
[d] $p < 0.01$
[e] $p < 0.001$

Supplemental Table 2.5. Adjusted component consumption difference (g, 95% CI)[a] of meals prepared on-site versus pre-packaged meals

COVARIATE	ENTRÉE	VEGETABLE	FRUIT	PLAIN MILK	FLAVORED MILK
INTERCEPT	80 (73 – 87)[e]	17 (13 – 21)[e]	40 (34 – 45)[e]	103 (79 – 127)[e]	155 (139 – 170)[e]
PREPARED ON-SITE[b]	26 (20 – 33)[e]	4 (0.2 – 8)[c]	-1 (-6 – 4)	-14 (-35 – 8)	29 (2 – 55)[c]
FEMALE (REF)	–	–	–	–	–
MALE	11 (6 – 17)[e]	0.2 (-3 – 4)[c]	2 (-3 – 6)[c]	29 (12 – 46)[e]	18 (3 – 33)[c]
GRADE 3 (REF)	–	–	–	–	–
GRADE 4	-3 (-11 – 5)	2 (-3 – 8)	7 (1 – 13)[c]	-20 (-48 – 7)	-24 (-44 – -5)[c]
GRADE 5	12 (4 – 20)[d]	4 (-2 – 9)	3 (-3 – 9)	2 (-26 – 30)	-12 (-30 – 6)
GRADE 6	21 (9 – 32)[e]	8 (1 – 15)[c]	-4 (-13 – 5)	25 (-10 – 60)	-10 (-54 – 34)
GRADE 7	22 (10 – 34)[e]	15 (7 – 23)[e]	10 (0.5 – 20)[c]	57 (22 – 91)[d]	40 (2 – 78)[c]
GRADE 8	19 (7 – 31)[d]	17 (9 – 24)[e]	10 (1 – 20)[c]	53 (18 – 88)[d]	6 (-36 – 48)
R^2c	0.08	0.05	0.01	0.46	0.50

[a] Models adjust for grade, sex, and repeated observation by students. CI:95% Confidence interval
[b] Reference group is pre-packaged meal schools.
[c] $p < 0.05$
[d] $p < 0.01$
[e] $p < 0.001$

Supplemental Table 2.6. Adjusted component waste difference (grams, 95% CI)[a] of meals prepared on-site versus pre-packaged meals

COVARIATE	ENTRÉE	VEGETABLE	FRUIT	PLAIN MILK	FLAVORED MILK
INTERCEPT	101 (93 – 108)[e]	95 (90 – 101)[e]	64 (58 – 70)[e]	142 (118 – 166)[e]	92 (77 – 107)[e]
PREPARED ON-SITE[b]	-8 (-16 – -1)[c]	-50 (-55 – -44)[e]	11 (5 – 17)[e]	13 (-9 – 34)	-28 (-54 – -2)[c]
FEMALE (REF)	–	–	–	–	–
MALE	-17 (-24 – -11)[e]	-0.4 (-4 – 5)	-3 (-8 – 2)	-29 (-47 – -12)[e]	-17 (-32 – -2)[c]
GRADE 3 (REF)	–	–	–	–	–
GRADE 4	-9 (-18 – -0.2)[c]	-1 (-8 – 6)	-7 (-14 – 0.4)	20 (-8 – 48)	24 (4 – 43)[c]
GRADE 5	-20 (-28 – -11)[e]	-6 (-13 – 1)	2 (-5 – 10)	-2 (-30 – 26)	11 (-8 – 29)
GRADE 6	-25 (-38 – -13)[e]	-7 (-15 – 2)	5 (-5 – 15)	-27 (-63 – 8)	9 (-35 – 52)
GRADE 7	-31 (-44 – -18)[e]	-0.5 (-11 – 10)	-3 (-14 – 8)	-59 (-94 – -25)[e]	-43 (-80 – -5)[c]
GRADE 8	-20 (-33 – -7)[d]	-7 (-17 – 2)	-7 (-18 – 4)	-55 (-91 – -20)[d]	-9 (-50 – 33)
R^2c	0.16	0.30	0.02	0.46	0.52

[a] Models adjust for grade, sex, and repeated observation by students. CI:95% Confidence interval
[b] Reference group is pre-packaged meal schools.
[c] $p < 0.05$
[d] $p < 0.01$
[e] $p < 0.001$

Supplemental Table 2.7. Mean vegetable portion size and waste (95% CI) by vegetable and meal service type

	SERVING SIZE (g)		WASTE (g)	
	PRE-PACKAGED	PREPARED ON-SITE	PRE-PACKAGED	PREPARED ON-SITE
Carrot, Raw	91 (84 – 98)	63 (54 – 71)	90 (83 – 97)	55 (42 – 67)
Corn	114 (110 – 117)	119 (113 – 126)	57 (5 – 108)	46 (36 – 55)
Cucumber	111 (106 – 115)	75 (70 – 80)	70 (48 – 92)	31 (21 – 41)
Green Beans, Hot	112 (107 – 117)	98 (89 – 107)	102 (98 – 106)	51[a]
Side Salad	138 (134 – 143)	62 (58 – 65)	121 (114 – 129)	40 (4 – 76)
Broccoli, Raw	26 (23 – 29)	–	16 (10 – 22)	–
Edamame	102 (96 – 108)	–	86 (72 – 101)	–
Garbanzo Beans	102 (100 – 105)	–	91 (82 – 100)	–
Lettuce	35 (33 – 38)	–	30 (26 – 34)	–
Peas, Hot	123 (120 – 125)	–	115 (104 – 126)	–
Tomato, Raw	43 (41 – 45)	–	37 (32 – 41)	–
Three Bean Salad	136 (133 – 140)	–	122[a]	–
Black Beans, Cold	–	104 (96 – 112)	–	38 (9 – 67)
Broccoli, Steamed	–	69 (65 – 74)	–	43 (41 – 45)
Celery	–	46 (42 – 51)	–	26 (4 – 48)
Sweet Potato Fries	–	49 (46 – 52)	–	29 (27 – 32)
Taco Topping	–	44 (42 – 46)	–	34 (31 – 37)

[a] Only one student selected this item.

Supplemental Table 3.1 District-reported student attendance by school, grade, and study day

SCHOOL	FALL DATES	SPRING DATES	3RD Grade				4th Grade				5th Grade			
INTERVENTION SCHOOLS			**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
SCHOOL A	W10/10, R10/18	R5/30, R6/6	46	49	49	47	59	59	55	54	39	39	38	37
SCHOOL B	T10/23, R10/25	T6/04, T6/11	52	54	56	49	55	53	49	44	35	37	31	34
SCHOOL C	R11/1, R11/8	W5/22, W5/29	38	38	39	41	44	43	41	40	37	38	38	35
SCHOOL D	M11/19, M11/26	T5/21, R5/23	22	22	24	24	23	23	23	24	23	23	24	23
CONTROL SCHOOLS														
SCHOOL E*	W10/17, W10/24	M6/03, M6/10, W6/12	47	45	46	44	55	56	58	55	50	53	51	52
SCHOOL F	T10/30, T11/06	M4/22, W4/24	50	54	49	48	5	50	51	50	43	47	43	43
SCHOOL G	T11/13, T11/20	W4/03, R4/11	71	74	74	79	72	72	76	74	77	79	83	89
SCHOOL H	M11/26, T12/04	R3/28, F4/26	21	21	23	18	23	25	22	24	19	19	20	18

* A class trip on the third day of data collection at this school necessitated a fifth day of data collection to ensure complete panel data. Attendance rates on this day were: 3rd grade: 41, 4th grade: 53, 5th grade: 48

Supplemental Table 3.2 Post-intervention selection and consumption changes among baseline selectors [a]

CONTROL SCHOOLS	ENTRÉE	VEGETABLE	FRUIT	MILK
Students (n)	326	174	242	260
Selection (%)	98.8 (98.0 – 100.0)	76.4 (70.0 – 82.8)	86.0 (81.5 – 90.4)	86.9 (82.8 – 91.0)
INTERVENTION SCHOOLS	**ENTRÉE**	**VEGETABLE**	**FRUIT**	**MILK**
Students (n)	259	156	236	211
Selection (%)	99.2 (98.2 – 100.0)	91.0 (86.5 – 95.6)	95.3 (92.6 – 98.0)	59.2 (52.6 – 65.9)
Consumption (g)[b]	-7 (-26 – 13)	**34 (17 – 51)**[c]	**18 (6 – 30)**[d]	**-42 (-76 – -9)**[e]

[a] Defined as students who selected meal component >0 times pre-intervention.
[b] Post-intervention consumption change in intervention schools versus controls, adjusted for sex, grade, and repeated observations within individuals nested within schools
[c] p <0.001
[d] p <0.01
[e] p <0.05

Supplemental Table 3.3 Post-intervention selection and consumption patterns of baseline non-selectors[a]

CONTROL SCHOOLS	**ENTRÉE**	**VEGETABLE**	**FRUIT**	**MILK**
Students (n)	5	157	89	71
Selection (%)	100.0	39.5 (31.8 – 47.2)	80.9 (72.6 – 89.2)	42.3 (30.5 – 54.0)
INTERVENTION SCHOOLS	**ENTRÉE**	**VEGETABLE**	**FRUIT**	**MILK**
Students (n)	5	108	28	53
Selection (%)	80.0 (24.5 – 100.0)	90.7 (85.2 – 96.3)	89.3 (77.1 – 100.0)	18.9 (8.0 – 29.8)
Consumption (g)[b]	-42 (-119 – 34)	**33 (24 – 43)**[c]	15 (-10 – 41)	-26 (-58 – 5)

[a] Defined as students who did not select meal component pre-intervention.
[b] Post-intervention consumption change in intervention schools versus controls, adjusted for sex, grade, and repeated observations within individuals nested within schools
[c] $p < 0.001$

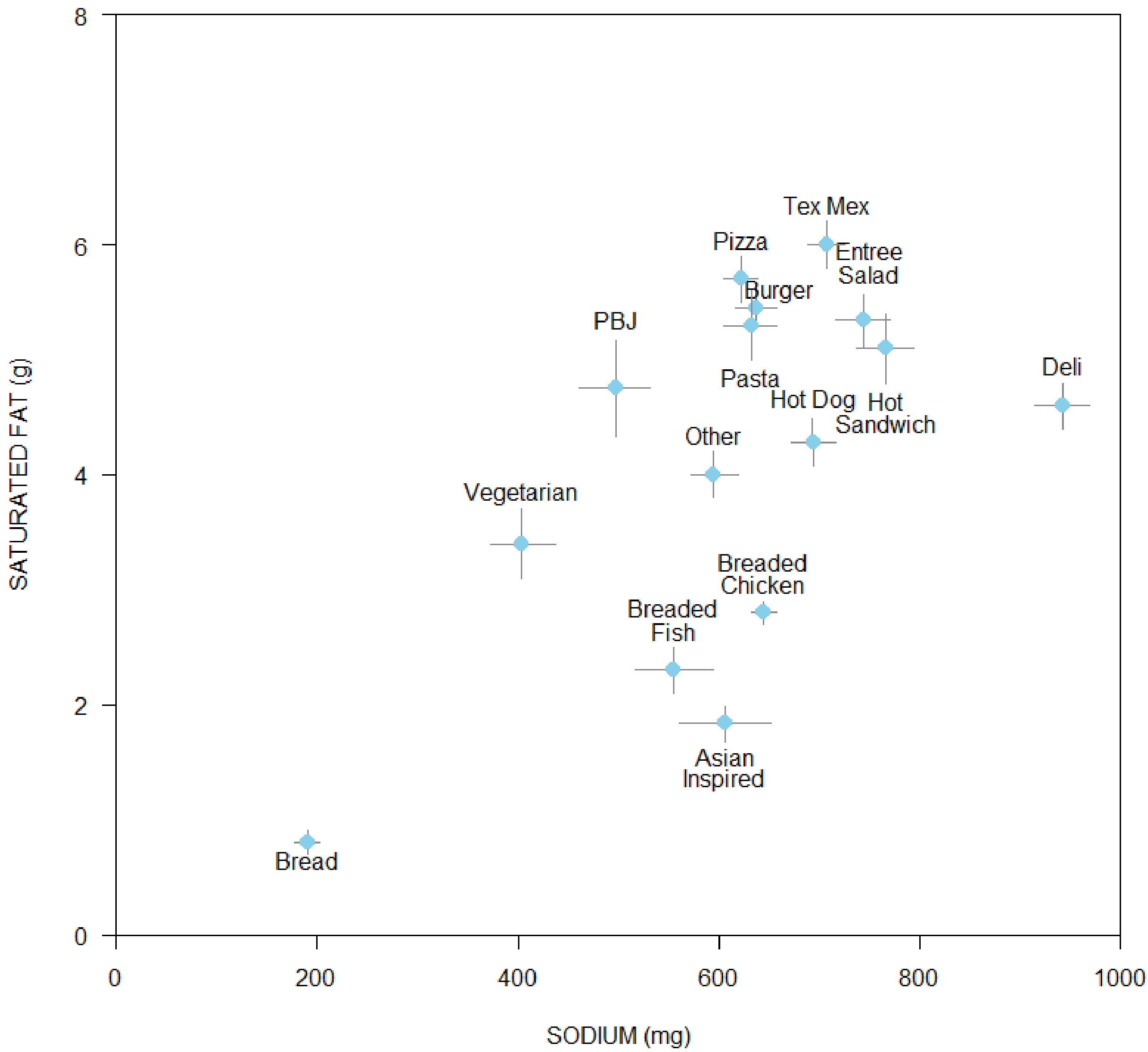
Supplemental Table 3.4 Post-intervention selection and consumption patterns of baseline non-participants[a]

CONTROL SCHOOLS	**ENTRÉE**	**VEGETABLE**	**FRUIT**	**MILK**
Students (n)	451	261	371	353
Selection (%)	98.4 (96.2 – 100.0)	52.4 (43.5 – 61.2)	72.2 (64.3 – 80.2)	77.0 (69.5 – 84.4)
INTERVENTION SCHOOLS	**ENTRÉE**	**VEGETABLE**	**FRUIT**	**MILK**
Students (n)	392	357	373	187
Selection (%)	97.8 (95.2 – 100.0)	87.3 (81.6 – 93.0)	91.8 (87.1 – 96.5)	38.8 (30.4 – 47.2)
Consumption (g)[b]	-13 (-32 – 5)	**31 (15 – 47)**[c]	11 (-10 – 32)	-42 (-84 – 0.4)

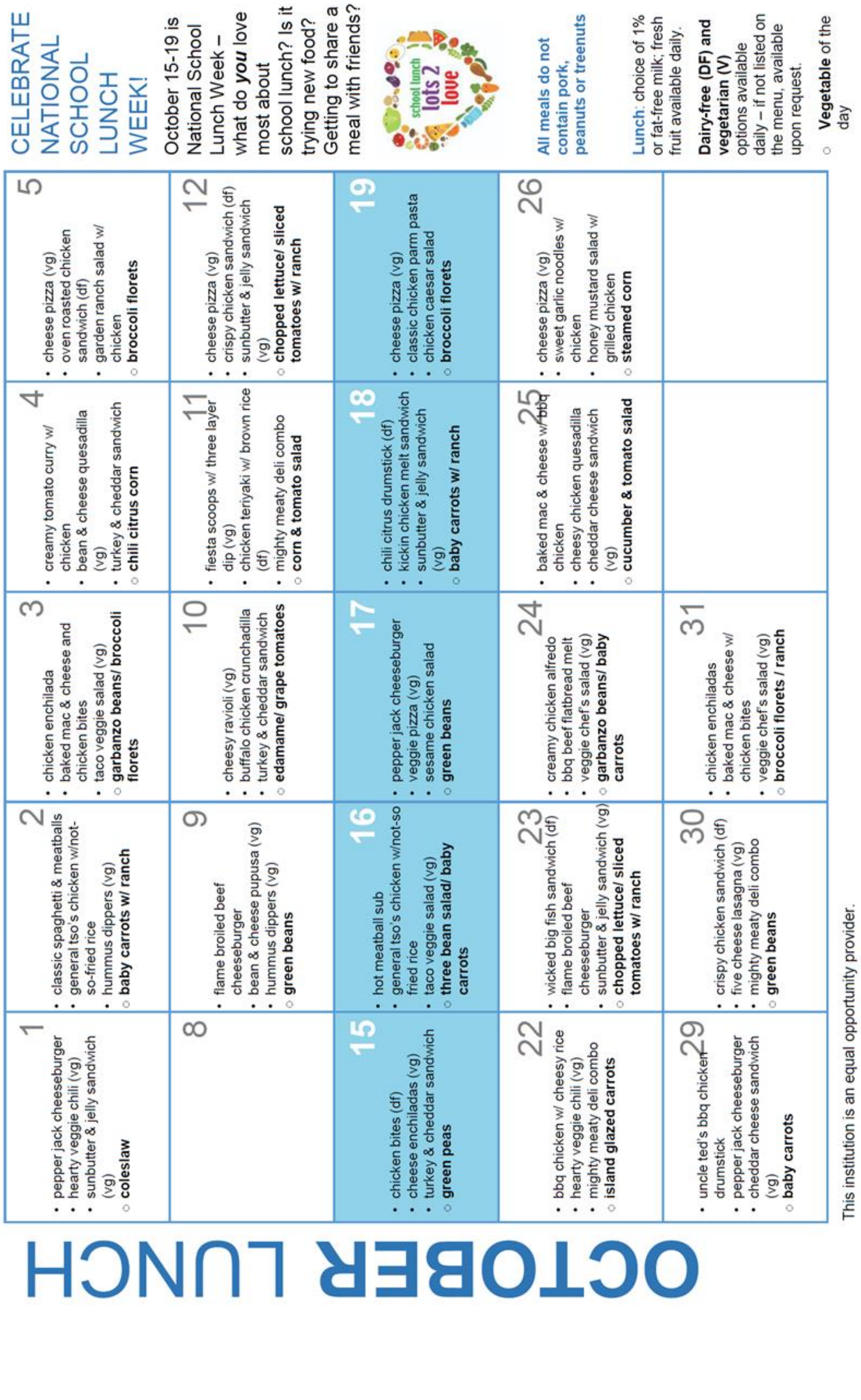
[a] Defined as students who did not select a lunch pre-intervention.
[b] Post-intervention consumption in intervention schools versus controls, adjusted for sex, grade, and repeated observations within individuals nested within schools
[c] $p < 0.05$

Supplemental Figures

Supplemental Figure 1.1 Mean (95% CI) nutrient content by lunch entrée type



Supplemental Figure 2.1. Example of pre-packaged lunch menu



OCTOBER LUNCH

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
1 • pepper jack cheeseburger • hearty veggie chili (vg) • sunbutter & jelly sandwich (vg) ○ **coleslaw**	2 • classic spaghetti & meatballs • general tso's chicken w/not-so-fried rice • hummus dippers (vg) ○ **baby carrots w/ ranch**	3 • chicken enchilada • baked mac & cheese and chicken bites • taco veggie salad (vg) ○ **garbanzo beans/ broccoli florets**	4 • creamy tomato curry w/ chicken • bean & cheese quesadilla (vg) • turkey & cheddar sandwich ○ **chili citrus corn**	5 • cheese pizza (vg) • oven roasted chicken sandwich (df) • garden ranch salad w/ chicken ○ **broccoli florets**
8	9 • flame broiled beef cheeseburger • bean & cheese pupusa (vg) • hummus dippers (vg) ○ **green beans**	10 • cheesy ravioli (vg) • buffalo chicken crunchadilla • turkey & cheddar sandwich ○ **edamame/ grape tomatoes**	11 • fiesta scoops w/ three layer dip (vg) • chicken teriyaki w/ brown rice (df) • mighty meaty deli combo ○ **corn & tomato salad**	12 • cheese pizza (vg) • crispy chicken sandwich (df) • sunbutter & jelly sandwich (vg) ○ **chopped lettuce/ sliced tomatoes w/ ranch**
15 • chicken bites (df) • cheese enchiladas (vg) • turkey & cheddar sandwich ○ **green peas**	16 • hot meatball sub • general tso's chicken w/not-so fried rice • taco veggie salad (vg) ○ **three bean salad/ baby carrots**	17 • pepper jack cheeseburger • veggie pizza (vg) • sesame chicken salad ○ **green beans**	18 • chili citrus drumstick (df) • kickin chicken melt sandwich • sunbutter & jelly sandwich (vg) ○ **baby carrots w/ ranch**	19 • cheese pizza (vg) • classic chicken parm pasta • chicken caesar salad ○ **broccoli florets**
22 • bbq chicken w/ cheesy rice • hearty veggie chili (vg) • mighty meaty deli combo ○ **island glazed carrots**	23 • wicked big fish sandwich (df) • flame broiled beef cheeseburger • sunbutter & jelly sandwich (vg) ○ **chopped lettuce/ sliced tomatoes w/ ranch**	24 • creamy chicken alfredo • bbq beef flatbread melt • veggie chef's salad (vg) ○ **garbanzo beans/ baby carrots**	25 • baked mac & cheese w/ bbq chicken • cheesy chicken quesadilla • cheddar cheese sandwich (vg) ○ **cucumber & tomato salad**	26 • cheese pizza (vg) • sweet garlic noodles w/ chicken • honey mustard salad w/ grilled chicken ○ **steamed corn**
29 • uncle ted's bbq chicken drumstick • pepper jack cheeseburger • cheddar cheese sandwich (vg) ○ **baby carrots**	30 • crispy chicken sandwich (df) • five cheese lasagna (vg) • mighty meaty deli combo ○ **green beans**	31 • chicken enchiladas • baked mac & cheese w/ chicken bites • veggie chef's salad (vg) ○ **broccoli florets / ranch**		

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CELEBRATE NATIONAL SCHOOL LUNCH WEEK!

October 15-19 is National School Lunch Week – what do *you* love most about school lunch? Is it trying new food? Getting to share a meal with friends?

All meals do not contain pork, peanuts or treenuts

Lunch: choice of 1% or fat-free milk; fresh fruit available daily.

Dairy-free (DF) and vegetarian (V) options available daily – if not listed on the menu, available upon request.

○ **Vegetable** of the day

Supplemental Figure 2.2. Example of on-site preparation lunch menu

K-8 October Menu

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
1 Turkey Sausage and Cheese on a Bagel Fresh Fruit Oven Baked Macaroni and Cheese[V] Or Beef Meatball Sub *Broccoli and/or Tomato and Cucumber Salad* Fresh Fruit	2 Homemade Oatmeal with Cinnamon and Raisins Fresh Fruit Beef Tacos on a Crunchy Shell with Fresh Toppings Or Steak and Cheese Croissant *Sizzlin' Black Beans and/or Baby Carrots* Fresh Fruit	3 Chicken and Cinnamon Waffle Breakfast Sandwich Fresh Fruit Cheese Bites[V] Or Chef Salad with Turkey and Cheese *Roasted Sweet Potato Wedges and/ or Garden Salad* Fresh Fruit	4 Egg and Cheese on a Biscuit Fresh Fruit BBQ Chicken Drumstick with Corn Bread Or Baked Fish Sandwich with Lettuce and Tomato *Mashed Potatoes and/or Garden Salad* Fresh Fruit	5 French Toast Sticks Fresh Fruit Buffalo Chicken Pizza or Cheese Pizza[V] Or Chicken Caesar Salad *Sweet Corn and/or Carrot and Celery Sticks* Fresh Fruit
8 Columbus Day No School	9 Whole Grain Waffles Fresh Fruit Chicken Tender and Cheese Bite Combo Or Cheese Bites[V] Or Garden Salad Topped with Tuna Salad *Roasted Sweet Potato Wedges and/or Cucumber Slices* Fresh Fruit	10 Breakfast Burrito Fresh Fruit Spaghetti and Meatballs with Garlic Bread Or Broccoli and Cheddar Croissant[V] *Broccoli and/or Garden Salad* Fresh Fruit	11 French Toast Sticks Fresh Fruit Mandarin Orange Chicken over Brown Rice Or Cheeseburger or Hamburger *Chickpea Salad and/or Roasted Sweet Potato Wedges* Fresh Fruit	12 Egg and Cheese on a Biscuit Fresh Fruit BBQ Chicken Pizza or Cheese Pizza[V] Or Garden Salad Topped with Buffalo Chicken Sweet Corn and/or Celery and Carrot Sticks Fresh Fruit
15 Turkey Sausage and Cheese on a Bagel Fresh Fruit Chicken Banh Mi Or Jamaican Beef Patty with Salsa Dipping Cup *Oven Baked Plantains and/or Citrus Spinach Salad* Fresh Fruit	16 Chicken and Cinnamon Waffle Breakfast Sandwich Fresh Fruit LOCAL Baked Fish in Chips with Brown Rice Or Cheese Bites[V] *Seasoned Potato Wedges and/or Tomato and Cucumber Salad* Fresh Fruit	17 French Toast Sticks Fresh Fruit Queso Blanco Nachos with Chicken and Fresh Toppings Or Cheeseburger or Hamburger *Sizzlin' Black Beans and/or Baby Carrots* Fresh Fruit	18 Egg and Cheese on a Biscuit Fresh Fruit Pollo Guisado over Brown Rice Or Crispy Chicken Sandwich on Hawaiian Bun with Lettuce and Tomato *Roasted Carrots and/or Garden Salad* Fresh Fruit	19 Breakfast Burrito Fresh Fruit Meatball Pizza or Cheese Pizza[V] Or Chef Salad with Turkey and Cheese *Chickpea Salad and/or Cherry Tomatoes* Fresh Fruit
22 Turkey Sausage and Cheese on a Bagel Fresh Fruit Oven Baked Macaroni and Cheese[V] Or Beef Meatball Sub *Broccoli and/or Tomato and Cucumber Salad* Fresh Fruit	23 Homemade Oatmeal with Cinnamon and Raisins Fresh Fruit Beef Tacos on a Crunchy Shell with Fresh Toppings Or Steak and Cheese Croissant *Sizzlin' Black Beans and/or Baby Carrots* Fresh Fruit	24 Chicken and Cinnamon Waffle Breakfast Sandwich Fresh Fruit Cheese Bites[V] Or Chef Salad with Turkey and Cheese *Roasted Sweet Potato Wedges and/ or Garden Salad* Fresh Fruit	25 Egg and Cheese on a Biscuit Fresh Fruit BBQ Chicken Drumstick with Corn Bread Or Baked Fish Sandwich with Lettuce and Tomato *Mashed Potatoes and/or Garden Salad* Fresh Fruit	26 French Toast Sticks Fresh Fruit Buffalo Chicken Pizza or Cheese Pizza[V] Or Chicken Caesar Salad *Sweet Corn and/or Carrot and Celery Sticks* Fresh Fruit
29 Whole Grain Waffles Fresh Fruit Homemade Steak and Cheese Sub Or Chicken Tender and Cheese Bite Combo Or Cheese Bites[V] *Roasted Sweet Potato Wedges and/or Garden Salad* Fresh Fruit	30 Turkey Sausage and Cheese on a Bagel Fresh Fruit BBQ Teriyaki Chicken, Broccoli, and Brown Rice Bowl Or Cheeseburger or Hamburger *Corn on the Cob and/or Citrus Spinach Salad* Fresh Fruit	31 Breakfast Burrito Fresh Fruit Spaghetti and Meatballs with Garlic Bread Or Broccoli and Cheddar Croissant[V] *Broccoli and/or Garden Salad* Fresh Fruit		

A variety of cold breakfast items offered daily!
Which may include: LOCAL 88 Acres bar, assorted ZeeZee bars, low sugar cereals, whole grain bagels, Safe + Fair graham sticks or cinnamon bitz or granola, fruited yogurt, cheese sticks, and hard boiled eggs

Possible Daily Vegetarian Grab and Go Lunch Options:

Peanut Butter and Jelly Sandwich[S V]

Yogurt and Granola Grab and Go[V]

Hummus and Veggie Grab and Go[V]

Did You Know?:

Breakfast and Lunch is FREE for all Students

Breakfast Milk Choices

1 % Plain & Nonfat Plain

Lunch Milk Choices

1% Plain, Nonfat Plain, & Chocolate

- All grain products are whole grain rich
- Meats are lean and cheeses are low fat
- A variety of fresh fruits and vegetables offered daily
- A variety of condiments are offered daily
- All menu items that contain peanuts or tree nuts as an ingredients are clearly named
- "S" indicates peanut butter will be replaced with Sunbutter (for Peanut Aware Schools)
- "V" indicates vegetarian meal options

Please Note:

- If you have a food allergy please speak to the school nurse and advise your kitchen manager
- Menu is subject to change

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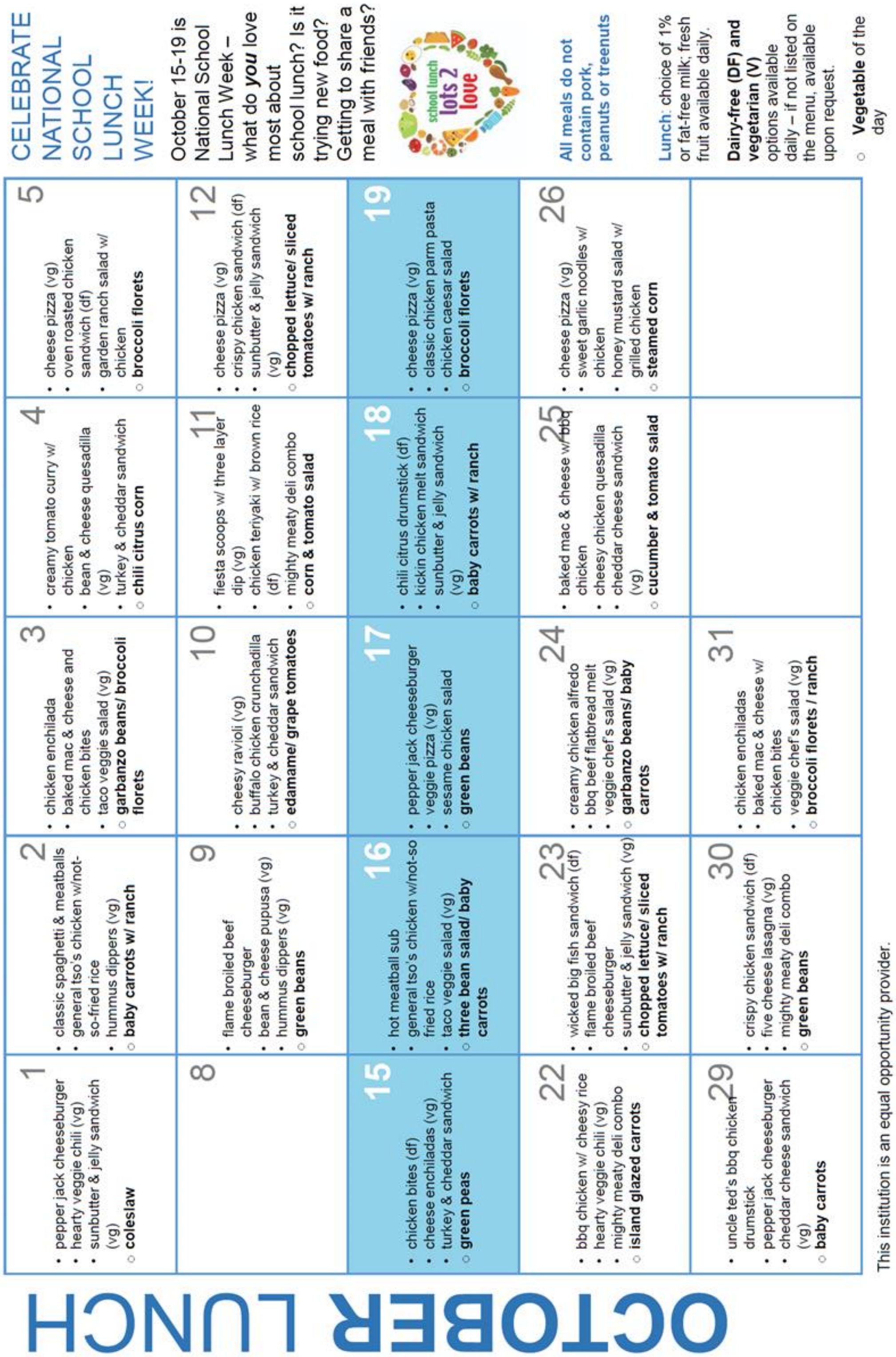
Supplemental Figure 3.1 Example of pre-intervention lunch menu



OCTOBER LUNCH

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8	9 • flame broiled beef cheeseburger • bean & cheese pupusa (vg) • hummus dippers (vg) ○ **green beans**	10 • cheesy ravioli (vg) • buffalo chicken crunchadilla • turkey & cheddar sandwich ○ **edamame/ grape tomatoes**	11 • fiesta scoops w/ three layer dip (vg) • chicken teriyaki w/ brown rice (df) • mighty meaty deli combo ○ **corn & tomato salad**	12 • cheese pizza (vg) • crispy chicken sandwich (df) • sunbutter & jelly sandwich (vg) ○ **chopped lettuce/ sliced tomatoes w/ ranch**
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October 15-19 is National School Lunch Week – what do ***you*** love most about school lunch? Is it trying new food? Getting to share a meal with friends?

school lunch lots 2 love

All meals do not contain pork, peanuts or treenuts

Lunch: choice of 1% or fat-free milk; fresh fruit available daily.

Dairy-free (DF) and vegetarian (V) options available daily – if not listed on the menu, available upon request.

○ **Vegetable** of the day

Supplemental Figure 3.2 Example of post-intervention lunch menu

Oct 1	**Oct 2**	**Oct 3**	**Oct 4**	**Oct 5**
Lunch: Hamburger / Cheeseburger Hamburger Cheeseburger Classic potato wedges Corn on the cob Grilled cheese (v)	**Lunch: Nachos** Taco seasoned chicken Taco seasoned beef Bean chili (v) Fresh salsa Corn tortilla chips Shredded cheddar cheese	**Lunch: Veggie Fried Rice** Vegetable fried rice (v) Teriyaki Chicken Marinated tofu (v) Roasted cauliflower Corn on the cob	**Lunch: Pasta Bar** Whole wheat penne Marinara sauce All-beef meatballs Roasted broccoli Shredded mozzarella cheese Chickpea salad (v)	**Lunch: Pizza Party!** Cheese pizza (v) Buffalo chicken or BBQ chicken pizza Sweet potato wedges
Oct 8	**Oct 9**	**Oct 10**	**Oct 11**	**Oct 12**
No School	**Lunch: Tacos** Chicken taco Fish taco Bean taco Brown rice Salsa Shredded cheddar cheese Yucca fries Lunch: Tacos	**Lunch: BBQ Chicken Drumstick** BBQ Chicken Drumstick Whole wheat penne Fresh pesto Roasted cauliflower Corn on the cob Black bean & corn salad Shredded cheddar cheese	**Lunch: Meatball Sub / Pasta** Beef meatballs Sub rolls Whole wheat spaghetti Marinara sauce Roasted broccoli Shredded mozzarella cheese Chickpea salad (v)	**Lunch: Pizza Party!** Cheese pizza (v) Buffalo chicken or BBQ chicken pizza Sweet potato wedges
Oct 15	**Oct 16**	**Oct 17**	**Oct 18**	**Oct 19**
Lunch: Burrito Bar Chicken burrito Bean burrito Shredded cheddar cheese Roasted corn Cilantro brown rice Fresh salsa Yucca fries	**Lunch: Vegetable Curry & Chicken Curry** Seasoned chicken Curry sauce Chickpea curry Brown rice Roasted carrots Roasted cauliflower Flatbread Hummus	**Lunch: Jerk Chicken Drumstick** Jerk chicken drumsticks Plantains Brown rice Black beans with sofrito Sweet potato wedges Grilled cheese (v)	**Lunch: Banh Mi Sandwich** Banh mi sandwich: Sub rolls Teriyaki chicken Marinated tofu (v) Brown rice Sweet potato wedges Rainbow coleslaw	**Lunch: Pizza Party!** Cheese pizza (v) Buffalo chicken or BBQ chicken pizza Sweet potato wedges
Oct 22	**Oct 23**	**Oct 24**	**Oct 25**	**Oct 26**
Lunch: Teriyaki Chicken Teriyaki chicken Marinated tofu (v) Lo mein noodles Roasted broccoli	**Lunch: Hamburger / Cheeseburger** Hamburger Cheeseburger Classic potato wedges Corn on the cob Grilled cheese (v)	**Lunch: Nachos** Taco seasoned chicken Taco seasoned beef Bean chili (v) Fresh salsa Corn tortilla chips Shredded cheddar cheese	**Lunch: Veggie Fried Rice** Vegetable fried rice (v) Teriyaki Chicken Marinated tofu (v) Roasted cauliflower Corn on the cob	**Lunch: Pizza Party!** Cheese pizza (v) Buffalo chicken or BBQ chicken pizza Sweet potato wedges
Oct 29	**Oct 30**	**Oct 31**		
Lunch: Pasta Bar Whole wheat penne Marinara sauce All-beef meatballs Roasted broccoli Shredded mozzarella cheese Chickpea salad (v)	**Lunch: Tacos** Chicken taco Fish taco Bean taco Brown rice Salsa Shredded cheddar cheese Yucca fries	**Lunch: BBQ Chicken Drumstick** BBQ Chicken Drumstick Whole wheat penne Fresh pesto Roasted cauliflower Corn on the cob Black bean & corn salad Shredded cheddar cheese		