

The Impact of a Water Promotion and Access Intervention on Elementary School Students in the Presence of Food Insecurity

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Authorship:

Ms. Leslie Gerstenfeld conceived and implemented this evaluation, performed data analysis and interpretation, drafted the initial manuscript, and reviewed and revised the manuscript critically for important intellectual content.

Ms. Lauren Blacker participated in data collection, helped lead the intervention, performed data cleaning and data analysis, and provided input in data interpretation, and reviewed and revised the manuscript critically for important intellectual content.

Dr. Charles McCulloch contributed to study conceptualization, study design, data collection, provided specific expertise in data analysis and interpretation and reviewed and revised the manuscript critically for important intellectual content.

Dr. Lorrene Ritchie contributed to study conceptualization, study design, led the collection, cleaning, and analysis of food and beverage diary data, provided input on interpretation of study findings, and reviewed, and revised the manuscript critically for important intellectual content.

Ms. Valeria Ordonez conducted data collection, data entry and cleaning, and provided details on study implementation.

Dr. Laura Schmidt contributed to the study conceptualization, and interpretation, reviewed and revised the manuscript critically for important intellectual content.

Dr. Anisha Patel conceptualized, designed, and implemented the study, led the development of the intervention, reviewed and revised the manuscript critically for important intellectual content.

All authors conceptualized ideas and study design, interpreted findings, and reviewed drafts of the manuscript and approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

Ethical Standards Disclosure: This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving research study participants were approved by the Internal Review Board of Stanford University (Internal Review Board Number 42210). Written informed consent was obtained from the primary caregiver of all subjects/patients. Written assent was obtained from all student participants.

Abstract

Objective: School-based interventions encouraging children to replace sugar-sweetened beverages (SSBs) with water show promise for reducing child overweight. However, students with child food insecurity (CFI) may not respond to nutrition interventions like children who are food-secure.

Design: The Water First cluster randomized trial found that school water access and promotion prevented child overweight and increased water intake. This secondary analysis used mixed-effects regression to evaluate the interaction between the Water First intervention and food insecurity, measured using the Child Food Security Assessment, on child weight status (anthropometric measurements) and dietary intake (student 24-hour recalls).

Setting: Eighteen elementary schools (serving $\leq 50\%$ children from low-income households), in which drinking water had not been previously promoted, in the San Francisco Bay Area.

Participants: Students in fourth-grade classes (n=1056).

Results: Food insecurity interacted with the intervention. Among students with no CFI, the intervention group had a lower prevalence of obesity from baseline to 7 months (-0.04, confidence interval [CI] -0.08 to 0.01) compared to no CFI controls (0.01, CI -0.01 to 0.04) (p=0.04). Among students with high CFI, the intervention group had a pronounced increase in the volume of water consumed between baseline and 7 months (86.2%, CI 21.7 to 185.0%) compared to high CFI controls (-13.6%, CI -45.3 to 36.6%) (p=0.02).

Conclusions: Addressing food insecurity in the design of water promotion interventions may enhance the benefit to children, reducing the prevalence of obesity.

INTRODUCTION

Childhood overweight and obesity is associated with an increased risk of diabetes, cardiovascular disease, adult overweight and consumption of ultra-processed foods including sugar-sweetened beverages (SSBs).⁽¹⁻³⁾ Drinking water during meals has been shown to reduce hunger and promote satiety but may not impact calories consumed.^(4,5) Substitution of water for SSBs has been associated with reduced caloric intake, increased energy expenditure, and increased fat oxidation in studies of obese adults and children.^(6,7)

Food insecurity, a chronic lack of "access to enough food to support an active, healthy life," is a risk factor for childhood overweight and obesity.⁽⁸⁻¹³⁾ People experiencing an unpredictable food supply may be more prone to weight gain to buffer for times of food scarcity.^(14,15) The stress of an unreliable food supply may impact self-regulation in the presence of food, decreasing satiety and increasing emotional overeating.⁽¹⁶⁻¹⁸⁾ Childhood food insecurity is associated with higher consumption of total calories, fat, sugar and fiber.^(11,19) Mothers, infants, and toddlers with food insecurity were more likely to consume SSBs and consume them more frequently than those who were food secure.^(20,21) Low-income households are commonly found in areas where there is a high concentration of unhealthy food outlets, many of which sell SSBs.⁽²²⁾ The relative affordability of SSBs, and the ubiquity of SSBs, and SSB advertisements in these communities promote the sale of SSBs over healthier beverage options.⁽²³⁾

School-based drinking water interventions that promote the substitution of water for SSBs have been shown to increase water consumption, reduce SSB consumption, decrease flavored milk purchases, and reduce the prevalence of childhood overweight.⁽²⁴⁻²⁶⁾ The Water First drinking water access and promotion intervention increased the frequency of water consumption and reduced overweight prevalence among low-income, ethnically diverse, fourth-grade students in the San Francisco Bay Area.⁽²⁷⁾ Studies found that adults with food insecurity experienced reduced benefits from nutrition interventions, but little is known about the impact of food insecurity on children's responses to nutrition interventions.^(28,29) Informed by this research, we hypothesized that students experiencing food insecurity would be less likely to benefit from the intervention. This would in turn reduce the impact of the Water First intervention in preventing unhealthy weight gain among students.

METHODS

The Water First cluster randomized controlled trial was a drinking water promotion and access intervention conducted with predominantly low-income and ethnically diverse fourth grade students.⁽³⁰⁾ Enrolled schools served low-income households ($\geq 50\%$ of students eligible for free and reduced-priced meals) and were not already promoting drinking water by offering appealing water stations and/or providing cups or reusable water bottles. A total of 26 elementary schools (cohorts of 6-8 schools per year) in four school districts in the San Francisco Bay Area, California, were enrolled from August 2016-March 2020. Half of the schools within each district cohort participated in the intervention while half served as controls. Data from eight schools enrolled in the 2019-2020 cohort were incomplete due to COVID related school closures and therefore omitted from this analysis.^(27,30)

Intervention

In each intervention school, a tap water dispenser with disposable cups was installed in the cafeteria and two reusable water bottle filling stations were installed in additional high traffic locations, including areas where students had physical education classes or recess. Students in schools randomized to the intervention were given reusable water bottles and engaged with Water First staff in eight 15-minute classroom activities highlighting the health, financial and environmental benefits of drinking water. Schoolwide activities included assemblies and awarding of small prizes to students drinking water. Details of the study protocol are published elsewhere.⁽³⁰⁾

Data Collection

At three time-points, baseline (at the start of the school year), and 7- and 15-months later, Water First staff measured students' height and weight using methodology consistent with National Health and Nutrition Examination Survey Anthropometry Procedures Manual,⁽³¹⁾ and students completed surveys reporting frequency of beverage consumption. Diary-assisted 24-hour dietary recalls were conducted at baseline and 7-months. Surveys at 15-months captured students' self-reported child food insecurity status.⁽³⁰⁾

-Outcome Variables

The primary outcome for the Water First study was prevalence of overweight (body mass index [BMI] for age and gender: $\geq 85^{\text{th}}$ percentile). Secondary weight status outcomes included prevalence of obesity (BMI for age and gender: $\geq 95^{\text{th}}$ percentile), BMI, BMI percentile, and BMI z-score.^(30,32) Dietary intake, also a secondary outcome, was assessed in two ways. Diary-assisted 24-hour dietary intake recalls conducted by trained researchers using the multiple-pass method were used to evaluate water, food, and beverage intake over the previous 24 hours.⁽³³⁾ Food and beverage calories were estimated using the United States Department of Agriculture's Food and Nutrient Database for Dietary Studies.⁽³⁴⁾ An adapted instrument for students, used in prior studies,^(30,35) was used to assess the frequency of student intake of plain water, SSBs, juice, flavored milk and plain milk.

Food Insecurity

Food insecurity was quantified using five of the nine statements from the Child Food Security Assessment (CFSA).^(11,36,37) The US Department of Agriculture Food Security Survey Module for Youth was not used as it includes questions only on food quality and quantity and is designed only for children 12 years and Older.⁽³⁸⁾ In contrast, the CFSA was developed based on interviews with children as young as 7 years old and taps into children's cognitive, emotional, and physical awareness of food insecurity.^(36,37,39) To achieve a reasonable student survey length, 5 items from the CFSA were selected as the most accurate for assessing student awareness of food insecurity and reliably measuring food insecurity in children ages 7 years and up.^(11,37) Students were asked how often in the previous 12 months did they experience the following:

1. We can't get the food we want because there is not enough money.
2. I worry about how hard it is for my parents to get enough food for us.
3. I worry about not having enough to eat.
4. I feel hungry, because there is not enough to eat.
5. I get really tired, because there is not enough to eat.

In accordance with the assessment guidelines, responses were coded as 0 (never), 1 (1 or 2 times), and 2 (many times) and summed across all statements for a relative child food insecurity (CFI) score (0-10).⁽¹¹⁾ The CFI score was categorized into 3 subgroups: score=0 (no CFI), score=1 or 2 (medium CFI), and score>2 (high CFI).⁽⁴⁰⁾ These cutoffs were selected based on

distribution to establish categories with similar sample sizes and to provide meaningful interpretation of results. The distribution of CFI scores is presented in Table 1.

Covariates

Covariates were prespecified in the Water First study protocol to adjust for potential imbalance that is more common in clustered randomized controlled trials than trials that randomize at the individual level. Covariates assessed via student self-report at baseline included: age, gender, race/ethnicity, physical activity, and screen time. Physical activity was assessed using questions from the Physical Activity Questionnaire for Older Children and Adolescents.⁽⁴¹⁾ Students were asked how many times in the previous seven days did they spend their free time doing things that involved physical effort that made them breath hard or sweat. Reporting categories were never (0 times), sometimes (1-2 times), often (3-4 times), quite often (5-6 times) and very often (7 or more times) in the previous seven days. Screen time was reported as a continuous variable summed over three categories: playing video or computer games, watching movies or programs on TV or computer, or doing other things on a computer or phone such as searching the internet, social media, email, or texting. Students reported during the previous day how much time they had spent for each category: no time at all, less than an hour, 1-2 hours, 2-3 hours, 3-4 hours, 4-5 hours, or 5 or more hours.

Data Analysis

Using Stata Version 17, mixed effects logistic regression models including a three-way interaction between food insecurity, the intervention and time were employed to predict differential changes in weight status, number of times per week different beverages were consumed, and food and beverage calorie intake. Models controlled for covariates listed above. Potential clustering of students in classes and schools was addressed in the models through inclusion of random effects for the school, class, and student. To achieve convergence of obesity regression models, the covariates were limited to race/ethnicity and potential clustering was addressed through inclusion of random effects for students.

Dietary intake data were log transformed prior to regression analysis to account for the skew of variable distributions. Regression coefficients were subtracted from baseline estimates for each

time-period and exponentiated to estimate percent changes in median predicted values for dietary intake outcome variables.

Differences in predicted estimates resulting from interaction of the intervention with food insecurity over time were evaluated for statistical significance. Because of the poor precision in estimating interaction terms, it has been suggested to raise the p-value to declare statistical significance of an interaction term to as high as $p < 0.20$.⁽⁴²⁾ To balance multiple testing concerns with this poor precision, we elected to declare interactions with $p < 0.05$ as statistically significant. Outcomes found to be significantly modified by food insecurity and the intervention over time were further evaluated by food insecurity subgroups.

RESULTS

The study sample included 1,056 students for whom food insecurity status was reported (85% of the total sample – 193 students [15%] were lost to follow up or did not respond to the food insecurity questions). At baseline, study students had a mean age of 9.6 years (standard deviation [SD] = 0.41), 47.4% were female, and 63.6% were of Mexican American/Latino/Hispanic race/ethnicity. There were significantly fewer Asian/Native Hawaiian and Other Pacific Islanders in the intervention group ($n=62$) compared to the control group ($n=85$) ($p=0.005$). No other significant differences were found in demographic variables between the intervention and control groups. The food insecurity score distribution was skewed (mean 1.8, SD 2.1) with 65% of students reporting some level of food insecurity in the previous 12 months (Table 1).

CFI status significantly interacted with the prevalence of obesity ($p=0.04$) and the volume of water consumed ($p=0.04$). No significant interaction was observed for the Water First primary outcome, overweight. There were also no significant interactions for other secondary outcomes including: BMI z-score, BMI percentile, overall calories, food calories, beverage calories, SSB calories, and frequency of milk, flavored milk, SSB, 100% juice and water intake.

Subgroup analyses of significant interactions were conducted to understand the predicted outcomes associated with the prevalence of obesity and the volume of water consumed within each CFI category. Among students with no CFI, those exposed to the intervention had a

reduced prevalence of obesity between baseline and 7-months (-0.04, confidence interval [CI] -0.08 to 0.01) compared to an increase among no CFI controls (0.01, CI -0.01 to 0.04) ($p=0.04$) (Table 2). Among students with high CFI, the intervention group had significant increases in volume of water consumed between baseline and 7-months (86.2%, CI 21.7 to 185.0) compared to a decrease (-13.6%, CI -45.3 to 36.6) observed in the high CFI control group ($p=0.02$). There was no evidence of significant interaction between the intervention and CFI relative to other outcomes of interest.

DISCUSSION

Consistent with our hypothesis, the Water First intervention did not reduce the prevalence of obesity among children with food insecurity even though it was effective for others.⁽²⁷⁾ The change in the prevalence of obesity was significantly lower among students with no CFI in the intervention group (-13.8%) compared to the control group (4.5%). There was no significant difference between the change in the prevalence of obesity over time among students with CFI in the intervention group compared to those in the control group, suggesting that students with no CFI may have benefitted more from the intervention.

Among students with high CFI, those in the intervention group significantly increased their volume of water intake during the trial. Increased water intake is likely to be attributable to the intervention, which focused on water promotion. Concomitant reductions in SSB consumption were not observed in students with CFI exposed to the intervention. This study was not equipped to investigate the intervention's mechanisms of action, but the literature suggests a range of possible mechanisms. Prior studies find that adults and children with food insecurity frequently eat beyond satiety, and experience emotional overeating.⁽¹⁸⁾ Moreover, the SSB industry selectively price and market their products to low-income consumers,⁽²³⁾ and SSB intake may be habitual in households with food insecurity as a low-cost source of calories.⁽²¹⁾ High calorie, low nutrient diets have been identified as a potential link between food insecurity and poor health outcomes that may be impacted by interventions.^(20,21)

As a result of these possible mechanisms, children with food insecurity could experience higher barriers to drinking water over SSBs that were not overcome by the Water First intervention.

Results suggest that water promotion efforts should be designed in ways that enhance the benefit to children with food insecurity. Like other studies,^(24–26) Water First focused on making changes to the school environment and did not evaluate or impact the availability of water outside of school. Nor did it alter the widespread availability of ultra-processed foods, including SSBs, in the child's food environment at home or in the community.⁽⁴³⁾ Future studies should attempt to maximize the benefit of water promotion by engaging parents in the intervention with the intent of impacting the food environment both inside and outside school, especially in low-income communities.

A strength of this study is the use of student self-reporting to define food insecurity. Self-reporting has been identified as a more accurate assessment of CFI compared to parent reporting. Even when parents reported shielding children from household food insecurity, children reported household food insecurity.^(36,44)

This study has several limitations. As a result of incomplete food insecurity data, the control group included significantly more Asian/Native American and other Pacific Islanders than the intervention group; analyses controlled for within person changes so any potential bias should be minimal. Estimation of interaction terms coupled with multiple testing issues introduce poor precision to regression models used in this evaluation; selecting a significance level of $p < 0.05$ is conservative but these precision concerns may limit the relevance of the results presented in this study. The Water First cluster randomized controlled trial was not powered to evaluate subgroup interaction effects on the intervention. CFI was only measured at the 15-month follow up and therefore may not accurately reflect changes in the level of food insecurity in the study population throughout the study period.

CONCLUSION

School-based drinking water interventions may be impacted by the presence of CFI among students. Future, adequately powered studies may enhance the understanding of the interaction between nutrition interventions and food insecurity. Consideration of food insecurity in the design of nutrition interventions may maximize the benefits to all populations.

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The Consort Flowchart

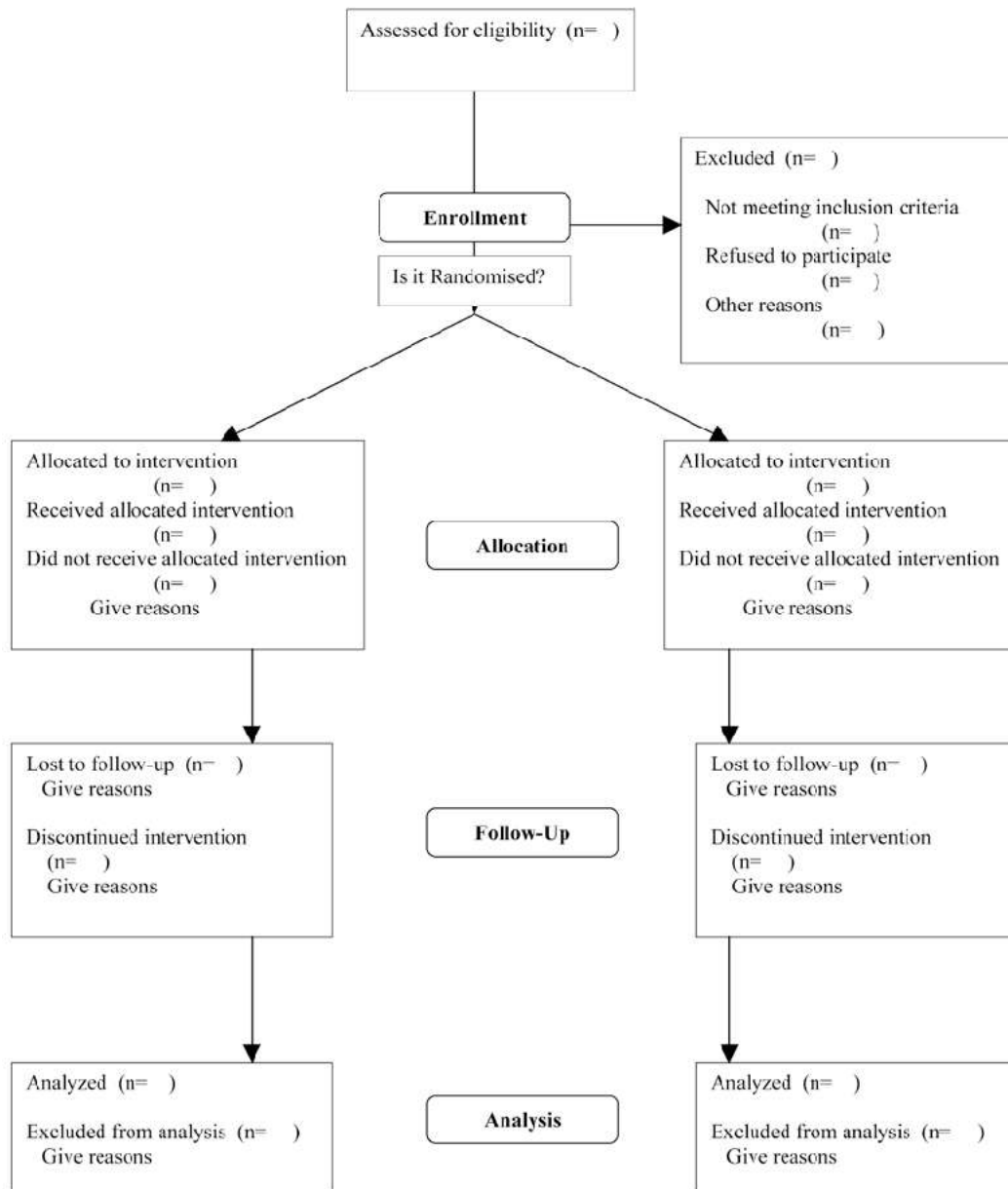


Table 1. Baseline Characteristics of Water First Food Insecurity Study Participants

Characteristic	Total (N=1056)		Intervention (n=547)		Control (n=509)		P value
	No./ Mea n	(%/S D)	No./ Mea n	(%/S D)	No./ Mea n	(%/S D)	
Student participants per school, mean (SD)^a	58.7	(18.8)	60.7	(16.6)	56.6	(21.6)	NS
Age in years, mean (SD)^b	9.6	(0.41)	9.6	(0.38)	9.6	(0.43)	NS
Female, No. (%)^c	500	(47.4)	255	(46.6)	245	(48.1)	NS
Race/ethnicity, No. (%)^c							
Mexican American, Latino, Hispanic	672	(63.6)	369	(67.5)	303	(59.5)	Ref
Asian/Native Hawaiian & Other Pacific Islander		(13.9)	62	(11.3)	85	(16.7)	0.005
Non-Hispanic Black/African American	147	(4.3)	21	(3.8)	24	(4.7)	NS
Non-Hispanic White	45	(7.2)	36	(6.6)	40	(7.9)	NS
Other (American Indian/Alaska Native, Multiple)	76	(11.0)	59	(10.8)	57	(11.2)	NS
116							
Physical activity times/week, No. (%)^c							
0 times	105	(10.0)	59	(10.8)	46	(9.0)	NS
1-2 times	406	(38.5)	213	(39.0)	193	(38.0)	Ref
3-4 times	218	(20.7)	107	(19.6)	111	(21.8)	NS
5-6 times	137	(13.0)	70	(13.0)	66	(13.0)	NS
7 or more times	189	(17.9)	96	(17.6)	93	(17.6)	NS
Screen time yesterday in hours, mean (SD)^b	3.1	(2.9)	3.2	(2.7)	3.0	(3.0)	NS
Child food insecurity score (0-10), mean (SD)^b	1.8	(2.1)	1.8	(2.1)	1.8	(2.1)	NS

Child food insecurity category^b						
No food insecurity (score = 0), No. (%)	374 (35.4)	194 (35.5)	180 (35.4)	NS		
Medium food insecurity (score 1-2), No. (%)	370 (35.0)	186 (34.0)	184 (36.2)	NS		
High food insecurity (score 2-10), No. (%)	312 (29.6)	167 (30.5)	145 (28.5)	NS		
Baseline prevalence overweight/obesity (%)^d	518 (49.1)	272 (49.7)	246 (48.3)	NS		
Baseline prevalence of obesity (%)^e	325 (30.8)	178 (32.5)	147 (28.9)	NS		

Abbreviations: SD, standard deviation; No., number; NS = not significant; Ref, reference values

Notes:

- a. Student participants per school assessed using linear regression clustering on school.
- b. Differences in age, hours of screen time yesterday, and food insecurity score by intervention status were assessed using mixed effects linear regression models accounting for school and class effects.
- c. Percentage of female students, race/ethnicity and frequency of physical activity/week were assessed using mixed effects logistic regression models accounting for school and class effects.
- d. Overweight/obesity is defined as body mass index for age and gender: $\geq 85^{\text{th}}$ percentile.
- e. Obesity is defined as body mass index for age and gender: $\geq 95^{\text{th}}$ percentile.

Table 2: Changes in Prevalence of Obesity and Water Intake from Pre- to Post-Intervention by Child Food Insecurity Categories

Outcome Variable	No Food Insecurity (Child Food Insecurity Score of 0) ^a Prevalence of Obesity at Baseline and Change over Baseline/ Baseline and Percent Change (95% CI)			Medium Food Insecurity (Child Food Insecurity Score of 1 to 2) ^a Prevalence of Obesity at Baseline and Change over Baseline/ Baseline and Percent Change (95% CI)			High Food Insecurity (Child Food Insecurity Score >2) ^a Prevalence of Obesity at Baseline and Change over Baseline/ Baseline and Percent Change (95% CI)		
	Intervention	Control	p ^b	Intervention	Control	p ^b	Intervention	Control	p ^b
Weight Status									
Prevalence of Obesity^c									
Baseline prevalence	0.29 (0.22, 0.35)	0.22 (0.20, 0.24)	ref	0.23 (0.19, 0.27)	0.25 (0.20, 0.31)	ref	0.24 (0.19, 0.28)	0.23 (0.19, 0.26)	ref
Prevalence Changes 7 months minus Baseline	-0.04 (-0.08, 0.01)	0.01 (-0.01, 0.04)	0.04	0.02 (-0.02, 0.06)	-0.01 (-0.05, 0.02)	0.19	-0.01 (-0.04, 0.02)	-0.01 (-0.04, 0.02)	0.82
Prevalence Changes 15 months minus Baseline	-0.04 (-0.08, 0.01)	0.01 (-0.01, 0.03)	0.06	0.01 (-0.02, 0.04)	-0.01 (-0.05, 0.03)	0.52	0.02 (-0.01, 0.06)	-0.02 (-0.04, 0.01)	0.08
24-hr Diary Assisted Dietary Intake^d									
Plain water (fluid ounces)									

Baseline	6.12 (4.50, 8.42)	7.54 (5.44, 10.48)	ref	5.68 (4.09, 7.91)	3.75 (2.71, 5.21)	ref	3.58 (2.54, 5.04)	4.57 (3.15, 6.63)	ref
% Changes 7 months minus Baseline	-20.5 (-46.5, 18.0)	-7.3 (-38.3, 39.4)	0.6 0	8.6 (-27.9, 63.6)	39.3 (-6.9, 108.5)	0.40	86.2 (21.7, 185.0)	-13.6 (-45.3, 36.6)	0.0 2

Abbreviations: 95% CI, 95th percentile confidence interval; ref, reference values

Notes:

- a. Child Food Insecurity Score based on student survey responses to 5 questions from the Child Food Security Assessment. Responses were coded as 0 (never), 1 (1 or 2 times), and 2 (many times) and summed across all statements for a relative food insecurity score (0-10).⁽¹¹⁾ The child food insecurity score was categorized into 3 categories: score=0 (no child food insecurity), score=1 and 2 (medium child food insecurity), and score>2 (high child food insecurity).⁽⁴⁰⁾
- b. p = p value calculated from analysis of regression model for interaction of food insecurity-intervention-time
- c. Multilevel mixed effects logistic regression models used to examine intervention impacts on changes in outcomes adjusting for intervention status, timepoint and race/ethnicity. Models included random effects for students.
- d: Multilevel mixed effects logistic regression models used to examine intervention impacts on changes in outcomes, adjusting for intervention status, timepoint, age, race/ethnicity, gender, screen time, physical activity and time. Models included random effects for school, class, and student change over time.