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Journal

The Journal of Nutrition, 153(7)

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Publication Date

2023-07-01

DOI

10.1016/j.tjnut.2023.04.013

Peer reviewed

The Journal of Nutrition 153 (2023) 2073–2084

American Society for Nutrition
EST. 1928
Excellence in Nutrition Research and Practice

JN THE JOURNAL OF NUTRITION

journal homepage: https://jn.nutrition.org/

Nutritional Epidemiology

Effects of a School-Based Gardening, Cooking, and Nutrition Cluster Randomized Controlled Trial on Unprocessed and Ultra-Processed Food Consumption

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A B S T R A C T

Background: School-based gardening and nutrition education interventions report improvements in dietary intake, notably through fruit and vegetables. However, gardening, cooking, and nutrition randomized controlled trials are limited in evaluating dietary quality, and none have examined processed food consumption to date.

Objectives: The study examined the effects of Texas Sprouts (TX Sprouts), a gardening, cooking, and nutrition education intervention, compared with control on unprocessed and ultra-processed food (UPF) consumption in predominately low-income Hispanic children.

Methods: TX Sprouts was a school-based cluster randomized controlled trial that consisted of 16 elementary schools randomly assigned to either the TX Sprouts intervention ($n = 8$ schools) or control (delayed intervention; $n = 8$ schools) over 3 y (2016–2019). TX Sprouts schools received an outdoor teaching garden and 18 1-h lessons taught by trained educators throughout the school year. Dietary intake data via 2 24-h dietary recalls were collected on a random subsample ($n = 468$) at baseline and postintervention. All foods and beverages were categorized using the NOVA food classification system (e.g., unprocessed, processed, ultra-processed). Generalized linear mixed effects modeling tested changes in percent calories and grams of NOVA groups between the intervention and control estimates with schools as random clusters.

Results: Of the sample, 63% participated in the free and reduced-price lunch program, and 57% were Hispanic, followed by non-Hispanic White (21%) and non-Hispanic Black (12%). The intervention, compared to the control, resulted in an increase in consumption of unprocessed foods (2.3% compared with –1.8% g; $P < 0.01$) and a decrease in UPF (–2.4% compared with 1.4% g; $P = 0.04$). In addition, Hispanic children in the intervention group had an increase in unprocessed food consumption and a decrease in UPF consumption compared to non-Hispanic children (–3.4% compared with 1.5% g; $P < 0.05$).

Conclusions: Study results suggest that school-based gardening, cooking, and nutrition education interventions can improve dietary intake, specifically increasing unprocessed food consumption and decreasing UPF consumption.

This trial was registered at clinicaltrials.gov as NCT02668744.

Keywords: dietary intake, pediatric population, high-risk population, ultra-processed foods, school-based intervention

Introduction

Ultra-processed foods (UPFs) refer to derivatives of foods with a large amount of artificial additives and low nutrient content [1]. UPF consumption has steadily increased in tandem with obesity prevalence over the past 2 decades, contributing to 67% of total energy intake and affecting 19% of United States youth 2–19 y of age, respectively [2,3]. Dietary components that are high in UPF, such as sodium, saturated fat, added sugars, and refined grains, can be deleterious to health [4–9]. However,

Abbreviations used: ANOVA, analysis of variance; B, baseline; FRL, free and reduced-price lunch; NDS-R, Nutrition Data System for Research; PI, postintervention; REDCap, Research Electronic Data Capture; SSB, sugar-sweetened beverage; TX, Texas; UMPF, unprocessed or minimally processed food; UPF, ultra-processed food.

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https://doi.org/10.1016/j.tjnut.2023.04.013
Received 17 January 2023; Received in revised form 11 April 2023; Accepted 13 April 2023; Available online 26 April 2023

unprocessed or minimally processed foods (UMPFs) are natural, edible parts of plants and animals. Consumption of UMPF high in fiber, such as fruits, vegetables, and whole grains, has been associated with protective health benefits [5,8,10–13]. Despite the known negative health implications of UPF, children 6–11 y examined from 1999–2018 in the NHANES had the highest UPF energy contribution at 69% in 2017–2018, with larger increases observed in Mexican-American (7.7%) and non-Hispanic Black (10.3%) youths compared to non-Hispanic White counterparts (5.2%) [3]. Conversely, consumption of UMPF has decreased from 28.5%–23.5% of total energy in United States youth 2–19 y [3].

Although the national data has reported increased UPF and decreased UMPF consumption in Hispanic children has been reported at the national level, similar trends have been observed at the state level in Texas. The Texas School Physical Activity and Nutrition survey monitors the nutrition behaviors of school-aged children in various grades and racial/ethnic subpopulations [14]. School Physical Activity and Nutrition data from 2019–2020 indicated that a higher proportion of 2nd-grade Hispanic children (40.4%) had daily consumption of 1 or more sugar-sweetened beverages (SSBs) than their non-Hispanic Black (38.2%) and White (24.0%) counterparts [14]. In addition, a higher proportion of 4th-grade Hispanic children (6.6%) had daily consumption of 3 or more SSBs than non-Hispanic White children (5.7%) [14]. Furthermore, a higher proportion of 2nd-grade Hispanic children reported no fruit or vegetable consumption than non-Hispanic White children (fruit: 27.9% compared with 23.0% and vegetable: 26.1% compared with 22.4%) [14]. Chen et al. [15] examined the dietary intake of children from schools in a predominately Hispanic community in Texas and reported that children of Hispanic parents had lower diet quality, per the Healthy Eating Index, than their counterparts, and it was recommended that families of Hispanic origin need culturally specific education programs. A previous study that examined food insecurity in the current study population reported higher food insecurity in Hispanic than non-Hispanic White and Black children, and food insecurity was associated with lower vegetable and higher added sugar consumption [16].

School meals may contribute over 50% of daily caloric intake for those participating in the National School Lunch and Breakfast Programs; thus, schools have a prominent role in establishing healthy eating behaviors by providing nutritious foods and education, especially for food-insecure children [17–19]. Nutrition education is an important component of comprehensive health programs that can empower children to make healthy food choices that, in turn, improve health outcomes [20,21]. However, elementary students receive less than 8 hours of nutrition education each school year [22]. School-based nutrition education and gardening interventions have become increasingly popular to improve students' nutrition knowledge, academic performance, physical activity, cardiometabolic health, dietary quality, willingness to try, and attitudes toward fruits and vegetables [21,23–28]. Most gardening interventions focus on the dietary intake of fruits and vegetables, but none have examined the effects of consumption of processed foods in children using NOVA because of the limited dietary recall methodologies.

NOVA is a comprehensive framework that categorizes foods based on their degree of processing, considering the industrial methods and techniques used to alter the physical, chemical, and sensory properties of foods. The system consists of 4 main categories: UMPFs, processed culinary ingredients, processed foods, and UPFs. This system enables researchers to investigate the potential health effects of consuming different types of foods and allows policymakers to develop evidence-based guidelines for promoting healthy diets. Additionally, the NOVA system can be used to guide dietary interventions aimed at reducing the consumption of UPFs, which have been associated with an increased risk of obesity, diabetes, and other chronic diseases [1].

Therefore, this secondary analysis sought to examine the effect of Texas Sprouts (TX Sprouts), a school-based gardening, cooking, and nutrition education cluster randomized controlled trial, on UMPF and UPF consumption using NOVA. The intervention was culturally tailored for Hispanic children; thus, the interaction between the intervention group and ethnicity was examined. It was hypothesized that children in the TX Sprouts intervention would have increased intake of UMPFs and decreased intake of UPF compared to the control group. It was also hypothesized that Hispanic children would have a higher consumption of UPF at baseline (B) and a larger magnitude of improvement than non-Hispanic children. The impact of TX Sprouts on primary outcomes, including dietary intake (fruits and vegetables via screener), obesity prevalence, blood pressure, and diet quality (via Healthy Eating Index 2015), have been published [27,28].

Methods

Study design

This experimental study analyzes data on secondary outcomes from TX Sprouts. The study design, methodology, and primary outcomes of the TX Sprouts intervention, such as BMI (kg/m^2), BMI *z*-score, BMI percentile, waist circumference, body fat percentage, systolic and diastolic blood pressure, fruit and vegetable intake, and SSB consumption, have been described previously [27,29]. Briefly, TX Sprouts recruited 3rd–5th-grade students and their parents from 16 elementary schools in the surrounding Austin, TX, area. All schools had to meet the following inclusion criteria: *1*) >50% of Hispanic children; *2*) >50% of children enrolled in the free and reduced-price lunch (FRL) program; *3*) location within 60 miles of the University of Texas at Austin campus; and *4*) no pre-existing school garden or gardening program. The first 16 schools that met the criteria and agreed to participate were blocked and randomly assigned by the study biostatistician who was blinded to 1 of 2 arms: *1*) the intervention arm ($n = 8$ schools) or *2*) the delayed intervention arm ($n = 8$ schools), serving as the control group. TX Sprouts was conducted over 3 waves, each lasting 1 school year, from 2016–2019. The intervention arm had 3 schools for the 2016–2017 ($n = 6$ total) and 2017–2018 ($n = 6$ total) school years and had 2 schools for the 2018–2019 school year ($n = 4$ total). Measures were collected at the beginning and end of each school year, ~8–9 mo apart. This trial is registered at clinicaltrials.gov (NCT02668744).

TX Sprouts intervention description

In brief, TX Sprouts was a school-based gardening, cooking, and nutrition education intervention incorporating the social ecological-transactional model into its core curriculum. This model rationalizes how processes within each level of ecology (e.g., family, school, and community) exert reciprocal effects on one another to shape the course of child development [30].

Outdoor teaching gardens (~0.25 acres) were built in each intervention school in the spring prior to the academic year of B measures. Garden Leadership Committees were formed at each intervention school and were comprised of teachers, parents, and other community stakeholders who helped build and maintain the gardens. Each garden included raised vegetable beds, in-ground native and herb beds, a shed for gardening supplies and tools, a whiteboard, and seating for classes. All garden and classroom materials (rakes, hoses, tables, chairs, cooking grill, pots/pans, etc.) were provided to each school, and plants chosen to grow were decided based on seasonality, soil type, and recipes included in the curriculum, including culturally specific produce such as tomatoes, squash, peppers, and cilantro.

Full-time nutrition and garden educators taught 18 1-h lessons during the school day for all 3rd–5th-grade classes throughout the school year. Some educators and many resident teachers were bilingual and available on-site to aid in any translational needs for the lessons taught. Lesson topics included but were not limited to *1*) whole foods compared with processed foods, *2*) natural compared with added sugar, *3*) fiber and whole grains, *4*) food groups (e.g., the role of protein, carbohydrates, fruits, and vegetables), and *5*) eating healthy at school (e.g., fruits and vegetables, protein foods, and low-sugar/high-fiber carbohydrates). Every lesson included either a garden taste test or a cooking activity in addition to tastings of *aguas frescas*, which are fruit-infused waters with no added sugar. The curriculum was designed to be culturally tailored to Hispanic children, containing culturally relevant recipes, content, and activities. To ensure the fidelity of the curriculum, Hispanic families provided input on the design, and the curriculum was tested in several pilot studies [31–33]. Participants in the control schools were assessed concurrently with those in the intervention schools but received the TX Sprouts protocol as a delayed intervention the following academic year.

TX Sprouts also included monthly 60-min parent lessons (9 lessons total) that were adapted from the Los Angeles Sprouts study and paralleled the nutrition topics and activities taught to the children [32]. The parent curriculum focused on the importance of family eating, healthy shopping practices, and increasing home availability and access to healthy foods.

The dose and fidelity of the TX Sprouts intervention have been published [27]. Dosage was defined as the number of activities performed within each class divided by the number of activities scheduled. In brief, TX Sprouts successfully taught 100% of planned classes. Some classes were shortened because of testing, fire alarms, assemblies, and other unforeseen circumstances, but <1% of the 18 lessons were modified or shortened in the intervention schools. Lessons were designed to be taught outdoors in the teaching gardens, but 34% of lessons were taught indoors in a classroom during inclement weather. Parent participation was limited, with only 7% of participating parents attending ≥1 lesson, with <1% attending ≥50% of classes.

Recruitment

All 3rd–5th-grade students and parents of the recruited schools were contacted to participate via information tables at "Back to School" and "Meet the Teacher" events, flyers sent home with students and classroom announcements made by teachers. In addition, recruitment materials were available in both English and Spanish. Both parental consent and student assent were required for inclusion in the study. The study was conducted in accordance with the Declaration of Helsinki, and all procedures pertaining to human subjects were approved by the institutional review boards of the University of Texas at Austin and all associated school district review boards.

Demographic information

Age and sex were self-reported by study participants. The child's race and ethnicity were reported by each child's parent. In addition, individuals were self-reported as Asian/Pacific Islander, Black/African American, Hispanic/Latino (including Mexican-American, Central American, and others), Native American/American Indian, non-Hispanic White, or other race and ethnicity. For the interaction analyses, ethnicity was dichotomized as either Hispanic or non-Hispanic (i.e., Asian/Pacific Islander, Black, Native American/American Indian, and White).

Dietary measures

Dietary intake was collected using a validated 24-h dietary recall method on a random subsample of children [34]. Per the intervention protocol, 2 non-consecutive, unannounced 24-h dietary recalls were collected at B and postintervention (PI) (4 total dietary recalls) via telephone by trained staff and supervised by a Registered Dietitian using the Nutrition Data System for Research 2016 version (NDS-R), a computer-based software application that facilitates the collection of recalls in a standardized fashion [35–37]. NDS-R generated the food- and ingredient-level information needed to calculate NOVA values to assess diet quality [38–41].

Dietary intake data was governed by a multiple-pass interview approach [42]. Prior to the dietary recalls, Food Amounts Booklets, developed by the NCC at the University of Minnesota, were sent home with the students to mitigate under- and over-reporting of consumed foods. The booklets were provided in both English and Spanish and contained pictures of portion sizes to assist students in estimating portion sizes of foods and beverages reported during the dietary recall. Parents and/or guardians were requested to assist with information regarding food items, portion sizes, and cooking methods, and this methodology has been validated for children of this age [43]. Students received a $10 incentive upon completion of both 24-h dietary recalls. Quality assurance was conducted on all dietary recall data by additional trained research staff.

Processed food measurement

NOVA categorizes foods into 4 groups according to the degree of processing: *1*) UMPF, *2*) processed culinary ingredients, *3*) processed foods, and *4*) UPF. UMPF are the edible parts of plant and animal products, fungi, algae, and water, after separation from nature (e.g., fruit, leaves, seeds, roots, milk, eggs, and muscle). Processed culinary ingredients are substances derived from unprocessed foods through processes such as pressing, refining, grinding, milling, or drying (e.g., oils, butter, lard, sugar, and salt). Processed foods are made by adding salt, oil, sugar, or other substances from those in the previous 2 groups (e.g., canned foods preserved in brine; whole fruit preserved in syrup; ham and bacon; freshly baked bread; simple cheeses). UPF is primarily mass-produced, industrial-formulated food products (e.g., soft drinks; candy, pastries, cakes, and packaged desserts; mass-produced packaged bread; preprepared meat, cheese, and pizza dishes; reconstituted meat products; packaged soups) [1].

NDS-R files providing food- and ingredient-level information were used to categorize foods into appropriate groups. For example, the NDS-R "fruit excluding citrus juice" group (i.e., fruits excluding fruit in candy, ice cream, granola bars, pie, cake, and other baked goods) was matched with the NOVA classification of UMPF. Specifically, "fruit, apple, fresh, with skin" was considered UMPF, whereas "desserts, turnover, apple" was considered UPF. To ensure quality control, 4 trained data transcribers were divided into 2 pairs to manually match each NDS-R food group classification with the corresponding groups in NOVA. Thereafter, 3 laboratory supervisors convened on all discrepancies between the data transcribers to assess the proper NOVA classification. The mean percent of total calories and grams from the 2 dietary recalls was calculated for each NOVA group after all foods and ingredients were matched. Grams were included in addition to calories to account for UMPF and UPF with no energy content (e.g., water, unsweetened beverages, and artificially sweetened beverages).

Study participants

The participant CONSORT diagram is presented in Figure 1. All 3rd–5th-grade students in each school were recruited for the study ($n = 4239$). Both student assent and parental consent were obtained for 3302 students to participate in the TX Sprouts intervention. Of those, clinical data were collected on 3135 students. Sixteen students (8 male and 8 female) were randomly selected from each grade level at each school to be contacted for dietary recalls ($n = 48$/school). If any of the 16 originally selected students were unavailable or did not want to participate in recalls, then additional students were randomly selected to take their place. Two 24-h dietary recalls were collected on a subsample of 760 children at B, of which 468 had 2 recalls conducted PI. Students were excluded from analyses for missing demographic data ($n = 11$). After the statistical exclusion of outliers (described below, $n = 6$), the analytic sample consisted of 451 children ($n = 228$ control group; $n = 223$ intervention group).

Statistical analysis

Data were examined for normality, and outliers were excluded from analyses after examining histograms, box plots, and z-scores of energy intake. Participants were excluded if they had a z-score $>|-7|$ for energy intake. Generalized linear mixed effects modeling with the identity link was used to test changes in percent calories and grams of NOVA groups between the intervention and control estimates at the individual level with schools as random clusters. Each model was adjusted for age, sex, race/ethnicity, B dietary measure, and change in total energy. Because of the significant results observed for the UMPF and UPF groups, subsequent independent group t-tests were performed to examine differences in subgroup calorie and gram contribution by the

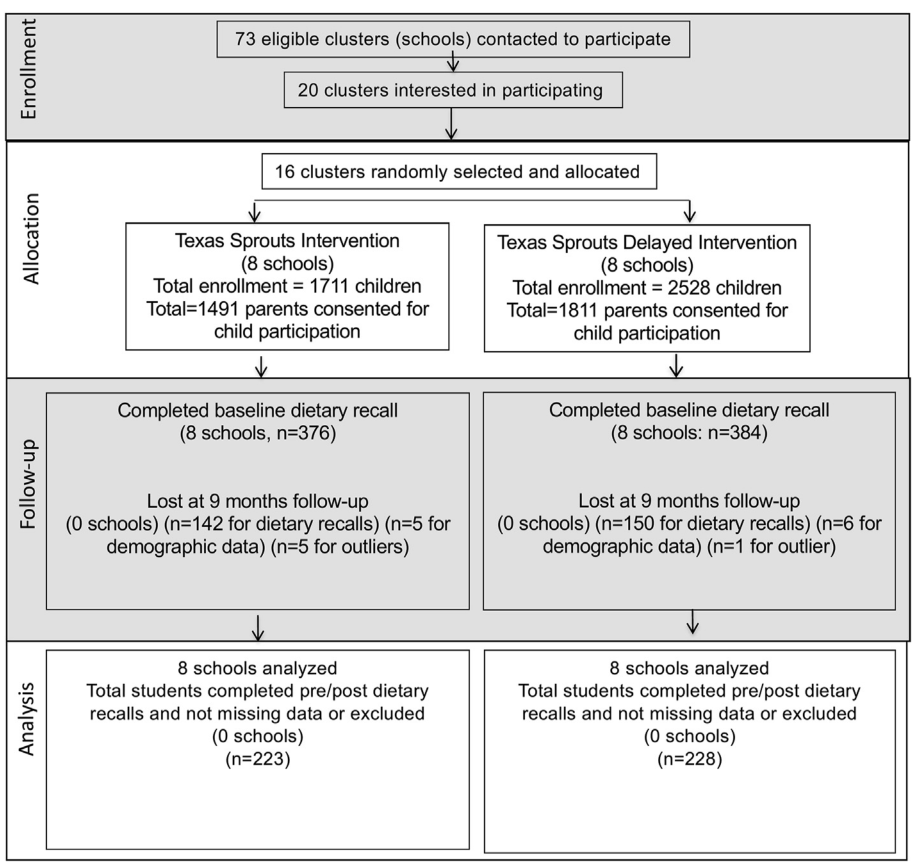

FIGURE 1. CONSORT diagram of the flow of participants included in this study examining the intervention effect on unprocessed or minimally processed and ultra-processed foods in predominately low-income, Hispanic children.

intervention group. Because of the large number of comparisons, the Benjamini-Hochberg procedure was applied to adjust the *P* value with a false discovery rate of 0.20. A product term between the intervention group (categorical, control as the reference group) and race/ethnicity (categorical, Hispanic as the reference group compared with non-Hispanic) was added separately to the adjusted models and was tested by the adjusted Wald test. Next, the interaction between the intervention group and race/ethnicity was examined. If the interaction was significant, results were stratified by race/ethnicity, and marginal effects of percent changes in calories and grams for NOVA groups were calculated separately by race/ethnicity. The χ^2 tests and univariate ANOVA were performed to examine differences in study participant characteristics (i.e., age, sex, race/ethnicity, FRL participation) between those with and without dietary recalls to test for potential bias in the sample. In addition to participant characteristics, differences in dietary caloric and gram intake between control and intervention groups were examined.

All values reported are untransformed values, and *P* values were obtained from models after adjusting for covariates. Analyses were performed using Stata version 17.0 (StataCorp LLC), and the significance was set at $P < 0.05$ [44]. The data were managed in Research Electronic Data Capture (REDCap) at the University of Texas at Austin.

Results

The total pediatric sample was 53% male, and the majority were Hispanic (57%), followed by non-Hispanic White (21%) and non-Hispanic Black (12%), with an average age of 9.3 y at B. The B means caloric intake for the total sample was 1446 ± 475, with UPF as the primary contributor providing 47.2% of energy, followed by UMPF (36.8%), processed foods (10.4%), and processed culinary ingredients (5.7%). The B means intake of grams for the total sample was 1289 ± 494, with UMPF as the primary contributor providing 61.2%, followed by UPF (30.7%), processed foods (6.8%), and processed culinary ingredients (1.3%). There were no significant differences in demographic characteristics (i.e., age, sex, race/ethnicity, and FRL status) between the subsample of children who completed dietary recalls and those in the clinical trial without recall data. Nor were there differences in demographic characteristics between the control and intervention groups at B.

Intervention effects on changes in percent calories and grams of NOVA groups are presented in Table 1. Changes in total caloric and total gram intake were not different between the control and intervention groups. Children in the intervention group had a percent increase in total calories and grams in UMPF, whereas those in the control group had a percent decrease (Calories: 0.8% compared with –1.2%; Grams: 2.3% compared with –1.8%; $P < 0.05$). Those in the intervention group also had a percent decrease in total grams in UPF, whereas the children in the control group had an increase (–2.4% compared with 1.4%; $P = 0.04$). There were significant interaction effects observed between the intervention group and race/ethnicity for UMPF and UPF. Hispanic children in the intervention group had an increase in percent calories and grams of UMPF and a decrease in percent calories and grams of UPF compared to non-Hispanic children (2.1% compared with –1.3% and –3.4% compared with 1.5%; $P < 0.05$).

Independent group t-test analyses on the dietary share (% total energy) of subgroups from UMPF and UPF are presented in Table 2 and Table 3. For UMPF, the mean change in plain milk and plain yogurt (% total energy) was significantly different between treatment groups, with the intervention group having a 1.0% increase compared to the control group having a 0.8% decrease, on average ($P < 0.01$). For UPF, the mean change in cakes, cookies, and pies (% total energy) was significantly different between treatment groups, with the intervention group having a 1.5% decrease compared to a slight 0.1% increase observed in the control group, on average ($P = 0.03$). There was also a significant difference in the mean change for ice cream and frozen yogurts (% total energy), with the intervention group having a 0.4% increase and the control group having a –0.9% decrease, on average ($P < 0.01$).

Proportions of B and PI top UMPF and UPF subgroup contributors were examined by treatment group. For the total sample, the top contributing foods for UMPF at B and PI were vegetables (B: 17.6%, PI: 17.0%), roots and tubers (B: 15.8%, PI: 15.5%), fruits and freshly squeezed juices (B: 14.2%, PI: 14.8%), meat (B: 12.5%, PI: 9.3%), and milk and plain yogurt (B: 12.5%, PI: 12.8%). However, the top contributing foods for UPF were bread (B: 17.1%, PI: 18.8%), sauces, dressings, and gravies (B: 11.6%, PI: 12.6%), reconstituted meat and fish products (B: 9.9%, PI: 11.6%), breakfast cereals (B: 8.4%, PI: 9.5%), and SSBs (B: 7.9%, PI: 8.8%).

Changes in the proportions of UMPF and UPF subgroup contributions by treatment group and race/ethnicity are presented in Figure 2. For UMPF, Hispanic children in the intervention group had increases in milk and plain yogurt; and pasta (whole wheat and rice), whereas non-Hispanic children had decreases in pasta (whole wheat and rice) and a smaller increase in milk and plain yogurt. Both Hispanic and non-Hispanic children had increases in fruits in the intervention group. For UPF, Hispanic children in the intervention group had decreases in reconstituted meat and fish products, whereas non-Hispanic children had increases in reconstituted meat and fish products.

Proportions of B and PI top UMPF and UPF subgroup contributors stratified by treatment group and race/ethnicity are presented in Supplemental Table 1 to provide context for the percent changes observed. Hispanic children had a higher total contribution from vegetables, including roots and tubers, and a lower total contribution from meat, milk, and plain yogurt compared to non-Hispanic counterparts, independent of the treatment group. The top contributors for UPF varied between race and ethnicity but not the treatment group. Reconstituted meat and fish products, bread and sauces, dressings, and gravies were consistent top contributors across all groups. Breakfast cereals were the top contributors observed more in Hispanic children than non-Hispanic children, whereas salty snacks served as a top contributor only for non-Hispanic children. Milk-based drinks were a top contributor for non-Hispanic children at B for the control group. Lastly, SSBs served as a top contributor for all groups except non-Hispanic at B.

TABLE 1

Effects of the Texas Sprouts intervention on dietary components of the NOVA Food Classification System in predominately low-income, elementary school-aged children[1]

Variables	Control (n = 228)			Intervention (n = 223)			Intervention effect P value
	Baseline mean ± SD	Post mean ± SD	Absolute change mean	Baseline mean ± SD	Post mean ± SD	Absolute change mean	
NOVA, the total sample							
Total energy (kcal)	1469 ± 464	1467 ± 468	–2.0	1423 ± 487	1457 ± 452	34	0.63
Unprocessed foods (% kcal)	37.0 ± 13.1	35.8 ± 13.3	–1.2	36.5 ± 13.6	37.3 ± 13.0	0.8	0.048
Processed culinary ingredients (% kcal)	5.9 ± 5.1	5.5 ± 4.3	–0.4	5.5 ± 5.2	5.2 ± 4.5	–0.3	0.48
Processed foods (% kcal)	10.2 ± 7.3	11.2 ± 7.9	1.0	10.5 ± 7.7	11.5 ± 7.1	1.0	0.84
Ultra-processed foods (% kcal)	46.9 ± 13.5	47.4 ± 14.5	0.6	47.5 ± 14.4	46.0 ± 15.0	–1.5	0.19
Total grams (g)	1284 ± 463	1289 ± 394	5.0	1294 ± 525	1334 ± 453	40.0	0.45
Unprocessed foods (% g)	61.7 ± 15.6	59.9 ± 17.7	–1.8	60.8 ± 17.3	63.1 ± 16.1	2.3	0.008
Processed culinary ingredients (% g)	1.3 ± 1.4	1.2 ± 1.2	–0.1	1.2 ± 1.1	1.0 ± 1.0	–0.1	0.11
Processed foods (% g)	6.6 ± 5.0	7.1 ± 6.2	0.6	7.0 ± 5.5	7.2 ± 5.2	0.2	0.81
Ultra-processed foods (% g)	30.4 ± 14.1	31.8 ± 16.8	1.4	31.0 ± 16.1	28.7 ± 16.0	–2.4	0.04
NOVA, race/ethnicity[2]							Race/ ethnicity interaction P value
Total energy (kcal)							0.13
Non-Hispanic	1478 ± 409	1535 ± 543	57.0	1575 ± 596	1613 ± 592	38.0	
Hispanic	1463 ± 499	1435 ± 443	–28.0	1364 ± 675	1372 ± 395	8.0	
Unprocessed foods (% kcal)							0.005
Non-Hispanic	34.7 ± 12.3	35.0 ± 13.8	0.3	33.3 ± 13.1	34.5 ± 13.2	1.2	
Hispanic	38.7 ± 13.4	36.6 ± 13.0	–2.2	39.2 ± 13.7	39.7 ± 12.7	0.5	
Processed culinary ingredients (% kcal)							0.92
Non-Hispanic	5.1 ± 5.0	5.5 ± 4.3	0.5	5.6 ± 4.7	5.2 ± 4.4	–0.4	
Hispanic	6.7 ± 5.4	5.6 ± 4.3	–1.1	5.3 ± 5.6	5.1 ± 4.6	–0.1	
Processed foods (% kcal)							0.24
Non-Hispanic	10.5 ± 7.3	10.9 ± 8.0	0.4	11.4 ± 8.0	11.3 ± 8.1	–0.1	
Hispanic	9.9 ± 7.4	11.4 ± 7.8	1.6	10.3 ± 7.7	11.9 ± 6.5	1.7	
Ultra-processed foods (% kcal)							0.05
Non-Hispanic	49.7 ± 13.0	48.5 ± 15.5	–1.1	49.7 ± 15.0	48.9 ± 15.9	–0.8	
Hispanic	44.7 ± 13.7	46.5 ± 13.8	1.7	45.3 ± 14.1	43.3 ± 13.7	–2.0	
Total grams (g)							0.04
Non-Hispanic	1250 ± 394	1232 ± 402	–18.0	1327 ± 586	1347 ± 509	20.0	
Hispanic	1308 ± 507	1330 ± 385	22.0	1266 ± 471	1323 ± 405	57.0	
Unprocessed foods (% g)							0.02
Non-Hispanic	60.1 ± 15.3	59.6 ± 16.9	–0.5	58.1 ± 17.1	60.9 ± 15.9	2.7	
Hispanic	62.7 ± 15.8	60.1 ± 18.3	–2.6	63.0 ± 17.1	64.9 ± 16.1	1.9	
Processed culinary ingredients (% g)							0.07
Non-Hispanic	1.2 ± 1.4	1.4 ± 1.4	0.1	1.4 ± 1.2	1.2 ± 1.1	–0.2	
Hispanic	1.4 ± 1.4	1.1 ± 1.0	–0.3	1.0 ± 0.9	0.9 ± 0.8	–0.1	
Processed foods (% g)							0.10
Non-Hispanic	6.7 ± 5.0	6.8 ± 6.6	0.2	7.8 ± 6.2	6.5 ± 5.0	–1.3	
Hispanic	6.6 ± 5.1	7.4 ± 6.0	0.8	6.3 ± 4.8	7.8 ± 5.4	1.5	
Ultra-processed foods (% g)							0.009
Non-Hispanic	32.1 ± 14.1	32.3 ± 15.9	0.2	32.7 ± 16.3	31.5 ± 16.2	–1.2	
Hispanic	29.3 ± 14.1	31.4 ± 17.4	2.1	29.7 ± 15.8	26.4 ± 15.5	–3.3	

[1] Generalized linear mixed effects modeling with the identity link tested changes in percent calories and grams of NOVA groups between the intervention and control estimates at the individual level with schools as random clusters. Each model was adjusted for age, sex, race/ethnicity, baseline dietary measure, and change in total energy.

[2] Race/ethnicity was coded as Hispanic or non-Hispanic.

Discussion

TX Sprouts was a school-based gardening, cooking, and nutrition education intervention designed to increase children's exposure to the farm-to-table process, including planting and growing foods, learning about the nutrients and benefits of those foods, and preparing those foods for consumption. As hypothesized, TX Sprouts increased UMPF consumption and decreased UPF consumption. To date, this is the first study to examine the effect of a gardening, cooking, and nutrition education intervention on processed food categories determined by NOVA. The TX Sprouts curriculum uniquely targeted reductions in UPF and increased in UMPF. Experiential learning in the garden, accompanied by educational interventions, is effective at facilitating healthy eating behavior change in children [45], and garden-based learning strategies often improve dietary intake, notably vegetable consumption [27,28,46–48].

The TX Sprouts lessons specifically addressed increasing unflavored milk and/or yogurt, reducing sugar and SSBs, selecting healthy food items at school, and eating healthfully

TABLE 2

Independent group t-test on proportions of daily energy and grams from unprocessed or minimally processed food subgroups in predominately low-income, elementary school-aged children

Variables		Control (n = 228)			Intervention (n = 223)			P value[1]
		Baseline mean ± SD	Post mean ± SD	Absolute change mean	Baseline mean ± SD	Post mean ± SD	Absolute change mean	
Unprocessed or minimally processed food subgroups								
Legumes	Energy (% kcal)	0.5 ± 2.0	0.6 ± 2.0	0.1	0.6 ± 2.3	0.6 ±1.8	–0.02	0.55
	Grams (% g)	0.6 ± 2.0	0.6 ± 1.7	–0.004	0.8 ± 2.2	0.8 ±2.0	0.05	0.84
Roots and tubers	Energy (% kcal)	2.5 ± 3.4	2.2 ± 3.2	–0.3	2.5 ± 3.7	2.3 ±3.1	–0.2	0.98
	Grams (% g)	3.9 ± 5.1	3.5 ± 5.0	–0.4	4.1 ± 5.8	3.8 ±4.7	–0.3	0.85
Vegetables	Energy (% kcal)	0.9 ± 1.3	0.8 ± 1.1	–0.1	1.0 ± 1.4	1.0 ±1.4	–0.03	0.81
	Grams (% g)	3.3 ± 3.6	3.5 ± 4.4	0.2	4.1 ± 4.8	4.1 ±4.7	0.05	0.83
Fruits and freshly squeezed juices	Energy (% kcal)	5.8 ± 5.8	5.8 ± 5.8	–0.001	6.3 ± 6.2	6.5 ±5.8	0.2	0.77
	Grams (% g)	11.7 ± 10.7	11.9 ± 10.7	0.2	12.7 ± 11.8	12.7 ±13.1	0.5	0.82
Meat	Energy (% kcal)	9.6 ± 7.9	8.5 ± 6.8	–1.2	9.6 ± 7.8	9.1 ±7.4	–0.5	0.47
	Grams (% g)	4.9 ± 4.3	4.3 ± 3.7	–0.6	4.8 ± 4.2	4.5 ±4.0	–0.2	0.45
Fish and seafood	Energy (% kcal)	0.3 ± 1.5	0.6 ± 2.1	0.3	0.4 ± 1.7	0.5 ±1.8	0.1	0.43
	Grams (% g)	0.3 ± 1.3	0.5 ± 1.6	0.2	0.2 ± 1.0	0.3 ±1.2	0.1	0.67
Eggs	Energy (% kcal)	1.4 ± 2.3	1.4 ± 2.4	0.05	1.6 ± 2.8	1.8 ±3.3	0.3	0.53
	Grams (% g)	1.1 ± 2.1	1.1 ± 2.1	0.01	1.2 ± 2.1	1.3 ±2.2	0.1	0.64
Milk and plain yogurt	Energy (% kcal)	6.6 ± 5.9	5.7 ± 5.7	–0.8	5.2 ± 5.2	6.2 ±5.5	1.0	0.006
	Grams (% g)	14.7 ± 12.4	12.7 ± 12.4	–2.0	11.0 ± 10.8	13.1 ±11.6	2.2	0.003
Grains	Energy (% kcal)	2.1 ± 4.0	2.5 ± 4.8	0.5	2.3 ± 4.8	2.1 ±4.1	–0.2	0.21
	Grams (% g)	1.6 ± 3.2	2.0 ± 3.9	0.4	1.8 ± 3.7	1.8 ±3.7	–0.01	0.40
Pasta (whole wheat and rice)	Energy (% kcal)	2.7 ± 4.4	2.6 ± 5.7	–0.1	2.6 ± 4.6	2.9 ±5.0	0.3	0.54
	Grams (% g)	1.6 ± 3.2	2.0 ± 3.9	0.4	1.8 ± 3.7	1.8 ±3.7	–0.01	0.42
Other[3]	Energy (% kcal)	4.6 ± 5.9	5.0 ± 5.6	0.4	4.4 ± 5.4	4.4 ±5.3	–0.002	0.58
	Grams (% g)	17.2 ± 14.9	17.8 ± 15.5	0.6	18.4 ± 16.8	18.1 ±16.6	–0.3	0.66

[2]Foods in this group consisted of water, herbs and spices, dry mixes and flour, unsweetened coffee or tea, and nuts and seeds.

[1] P values were adjusted for comparisons using the Benjamini-Hochberg procedure.

outside of home and school. This aligns with the findings that children in the TX Sprouts reported an increase in unflavored milk and plain yogurt and a decrease in highly processed and sweetened milk-based drinks, such as flavored milk and yogurts. Students in the intervention completed activities in choosing healthy drink options from school and fast-food restaurant menus and healthy snack alternatives, which recommended unflavored milk and unflavored yogurt in place of chocolate milk and flavored yogurt, for example. A systematic review of nutrition education interventions concluded that school-based interventions are ineffective in increasing dairy consumption in children [49]. However, the interventions included did not evaluate low-income or racial/ethnic minority populations, and no distinction was made between unflavored and flavored dairy products. School-based nutrition education interventions targeting low-income and racially/ethnically diverse children have reported increases in dairy, but there was no distinction made on flavored products [50,51]. The current intervention not only increased unflavored milk and plain yogurt intake but also reported reductions in flavored dairy products.

The TX Sprouts intervention reported decreases in several UPF subgroups, such as *1*) cookies, pies, and cakes; *2*) SSBs, specifically fruit juices with added sugars and sweetened tea; and *3*) and syrups, honey, and jam. These decreases track well with the concepts/activities taught in the TX Sprouts curriculum. Specifically, the TX Sprouts lessons taught students how to examine food packaging and labels to determine whether a food was highly processed and covered concepts on limiting added sugar and SSBs. A subsequent lesson covered choosing healthy options at school, such as whole fruit over fruit juice and limiting syrup, honey, and jam. TX Sprouts focused lessons on increasing water intake, and every lesson included *agua fresca* (fruit-infused water with no added sugar) tastings to encourage healthy SSB alternatives. A 16-wk randomized controlled trial in children 8–10 y showed that increased unflavored milk consumption also displaced SSB intake, similar to the results reported in the current study [52]. Children in the TX Sprouts intervention group had increased ice cream and frozen yogurt intake compared to the control. One possible rationale is that none of the TX Sprouts lessons targeted ice cream and frozen yogurt products. Instead, lessons that targeted reductions in sugary products focused on SSBs, candies, refined grains (e.g., cookies, cakes, and pancakes), and sweeteners (e.g., honey, syrup, and jam). Even so, the overall reduction in UPF was still significantly greater in the TX Sprouts group compared to the control.

The intervention may have been successful because many of the lessons taught children how to choose healthier foods and beverages at the school cafeteria. All TX Sprouts schools were Title I schools, and 63% of students in the study participated in the FRL program. School cafeterias provide an estimated 6–7% of UPF consumption, with 92% and 69% of the United States schools exceeding the *Dietary Guidelines for Americans (2020–2025)* added sugar recommendation in breakfast and lunch meals [3,53]. These findings highlight the importance of teaching children how to choose healthier foods and beverages at school, where they consume much of their daily dietary intake. The current intervention did not interact with food service providers or modify the school nutrition program, but it taught children how to choose healthier options than what is currently served. The curriculum encouraged the consumption of

TABLE 3

Independent group t-test on proportions of daily energy and grams from ultra-processed food subgroups in predominately low-income, elementary school-aged children

Variables		Control (n = 228)			Intervention (n = 223)			P value[1]
		Baseline mean ± SD	Post mean ± SD	Absolute change mean	Baseline mean ± SD	Post mean ± SD	Absolute change mean	
Ultra-processed food subgroups[2]								
Reconstituted meat and fish products	Energy (% kcal)	6.6 ± 7.4	6.5 ± 6.7	–0.1	6.9 ± 8.2	6.4 ± 7.0	–0.4	0.73
	Grams (% g)	2.7 ± 3.5	2.6 ± 3.0	–0.1	2.9 ± 4.2	2.6 ± 3.0	–0.3	0.64
Bread	Energy (% kcal)	10.2 ± 7.3	9.1± 7.0	–1.1	9.4 ± 6.7	9.7 ± 7.5	0.3	0.09
	Grams (% g)	4.6 ± 3.8	4.0 ± 3.5	–0.6	4.0 ± 3.2	4.1 ± 3.5	0.04	0.14
Cakes, cookies, and pies	Energy (% kcal)	3.5 ± 5.6	3.6 ± 5.4	0.1	4.6 ± 6.6	3.2 ± 5.7	–1.5	0.03
	Grams (% g)	1.2 ± 2.1	1.3 ± 2.2	0.1	1.6 ± 2.6	1.0 ± 7.9	–0.6	0.02
Ice cream and frozen yogurts	Energy (% kcal)	1.9 ± 4.5	1.0 ± 2.8	–0.9	1.2 ± 3.3	1.6 ± 4.7	0.4	0.008
	Grams (% g)	1.2 ± 3.0	0.7 ± 1.9	–0.5	0.8 ± 2.7	1.1 ± 3.5	0.2	0.04
Desserts and sugary products	Energy (% kcal)	0.6 ± 1.8	0.9 ± 2.6	0.3	0.7 ± 2.2	0.7 ± 2.3	–0.01	0.20
	Grams (% g)	0.3 ± 1.0	0.4 ± 1.2	0.1	0.3 ± 1.0	0.3 ± 1.3	0.03	0.72
Breakfast cereals	Energy (% kcal)	5.7 ± 6.0	5.6 ± 6.6	–0.1	5.0 ± 6.3	5.5 ± 6.6	0.6	0.36
	Grams (% g)	1.6 ± 1.7	1.6 ± 1.9	–0.1	1.4 ± 1.9	1.5 ± 1.8	0.2	0.34
Salty snacks	Energy (% kcal)	4.4 ± 6.6	5.3 ± 7.6	0.9	4.6 ± 7.2	4.3 ± 6.5	–0.3	0.16
	Grams (% g)	1.2 ± 1.9	1.3 ± 2.1	0.2	1.3 ± 2.6	1.0 ± 1.6	–0.3	0.09
Sweet snacks	Energy (% kcal)	1.7 ± 3.8	2.0 ± 4.8	0.3	2.0 ± 4.0	2.2 ± 4.6	0.2	0.79
	Grams (% g)	0.5 ± 1.0	0.6 ± 1.5	0.1	0.6 ± 1.4	0.6 ± 1.4	0.02	0.68
Frozen meals	Energy (% kcal)	1.4 ± 4.7	0.8 ± 3.3	–0.6	0.7 ± 2.9	0.8 ± 3.0	0.1	0.17
	Grams (% g)	0.6 ± 2.0	0.3 ± 1.1	–0.3	0.3 ± 1.5	0.4 ± 1.4	0.1	0.04
Pizza	Energy (% kcal)	0.2 ± 1.6	0.3 ± 1.6	0.1	0.3 ± 1.8	0.3 ± 2.4	0.01	0.76
	Grams (% g)	0.2 ± 1.0	0.2 ± 0.9	0.02	0.1 ± 1.0	0.2 ± 2.5	0.1	0.70
French fries and potato products	Energy (% kcal)	0.2 ± 1.8	0.03 ± 0.3	–0.2	0.2 ± 1.2	0.1 ± 0.5	–0.1	0.54
	Grams (% g)	0.1 ± 1.1	0.02 ± 0.3	–0.1	0.1 ± 0.7	0.03 ± 0.3	–0.1	0.50
Instant and canned soups	Energy (% kcal)	0.1 ± 0.5	0.08 ± 0.4	–0.1	0.1 ± 0.3	0.03 ± 0.1	–0.04	0.71
	Grams (% g)	1.1 ± 3.1	0.6 ± 2.7	–0.5	0.5 ± 1.5	0.4 ± 1.4	–0.1	0.20
Sauces, dressings, and gravies	Energy (% kcal)	1.7 ± 2.4	2.0 ± 3.2	0.3	1.8 ± 3.2	2.2 ± 2.8	0.4	0.77
	Grams (% g)	1.2 ± 2.0	1.2 ± 1.8	0.04	1.2 ± 2.1	1.3 ± 1.9	0.1	0.94
Milk-based drinks	Energy (% kcal)	3.3 ± 5.2	4.1 ± 5.9	0.8	4.6 ± 7.1	3.6 ± 5.3	–1.0	0.009
	Grams (% g)	4.9 ± 7.8	6.4 ± 9.0	1.5	6.1 ± 9.7	5.5 ± 8.4	–0.6	0.04
Carbonated soft drinks	Energy (% kcal)	1.4 ± 3.3	1.5 ± 3.0	0.05	1.1 ± 2.8	1.2 ± 2.8	0.2	0.75
	Grams (% g)	3.9 ± 8.5	4.1 ± 8.3	0.2	3.2 ± 7.9	3.5 ± 7.4	0.3	0.91
Other SSBs	Energy (% kcal)	1.7 ± 3.3	2.1 ± 3.6	0.4	2.1 ± 3.5	1.7 ± 2.7	–0.4	0.049
	Grams (% g)	4.7 ± 7.7	5.8 ± 9.4	1.1	5.6 ± 9.1	4.3 ± 7.6	–1.3	0.03
Other[3]	Energy (% kcal)	2.2 ± 3.1	2.5 ± 3.2	0.3	2.2 ± 2.8	2.4 ± 3.1	0.1	0.74
	Grams (% g)	0.6 ± 0.9	0.8 ± 1.4	0.3	0.8 ± 1.5	0.7 ± 1.3	–0.1	0.04

SSB, sugar-sweetened beverage.

[1] P values were adjusted for comparisons using the Benjamini-Hochberg procedure.

[2] The sandwiches and hamburgers subgroup was removed because of the intervention having no foods reported for this category.

[3] Foods in this group consisted of margarine and shortening, sweeteners and syrups, condiments, and imitation foods.

protein foods (e.g., plain milk, yogurt, eggs, and beans), low-sugar, high-fiber carbohydrates (e.g., oatmeal and whole grain products), and fruits and vegetables in school breakfast and lunches. Empowering children to make healthier decisions with what is currently served at school is an effective and practical course of action in schools with limited resources.

Another likely mechanism to explain these findings is that the TX Sprouts program had a heavy emphasis on teaching children how to cook. The TX Sprouts intervention incorporated a cooking component in 11 lessons, and all 18 lessons included a different *agua fresca* tasting. Numerous studies have shown that cooking increases the consumption of whole foods in children [54]. Cooking and food preparation has been linked to a higher intake of fruits, vegetables, and fiber in Hispanic youth [55,56], and culinary interventions increase intake and preference for whole foods, such as fruits, vegetables, and minimally processed whole grains [54,57]. As such, cooking allows students to learn about knife safety, cutting and preparing fruits and vegetables, and cooking recipes high in UMPF and low in UPF. Although children prepared and cooked the food in class during the school day, recipe cards were sent home with the children after each lesson to encourage cooking at home. The increase in scratch cooking in the school and possibly the home could have contributed to reductions in UPF and increases in UMPF.

Another possible explanation for the findings is that TX Sprouts was culturally tailored and included traditional Hispanic recipes high in whole foods (e.g., vegetable quesadillas, corn and black bean salad, jicama salad, wholegrain pasta with vegetables, and *aguas frescas)*. The standard American diet promotes high sugar and low fruit and vegetable intake, and the acculturation of Hispanic populations has been associated with unhealthy dietary intakes, such as low fruit and vegetable intake and high dietary fat, fast-food, and prepackaged food intake [58–61]. Compared to non-Hispanic children, Hispanic children

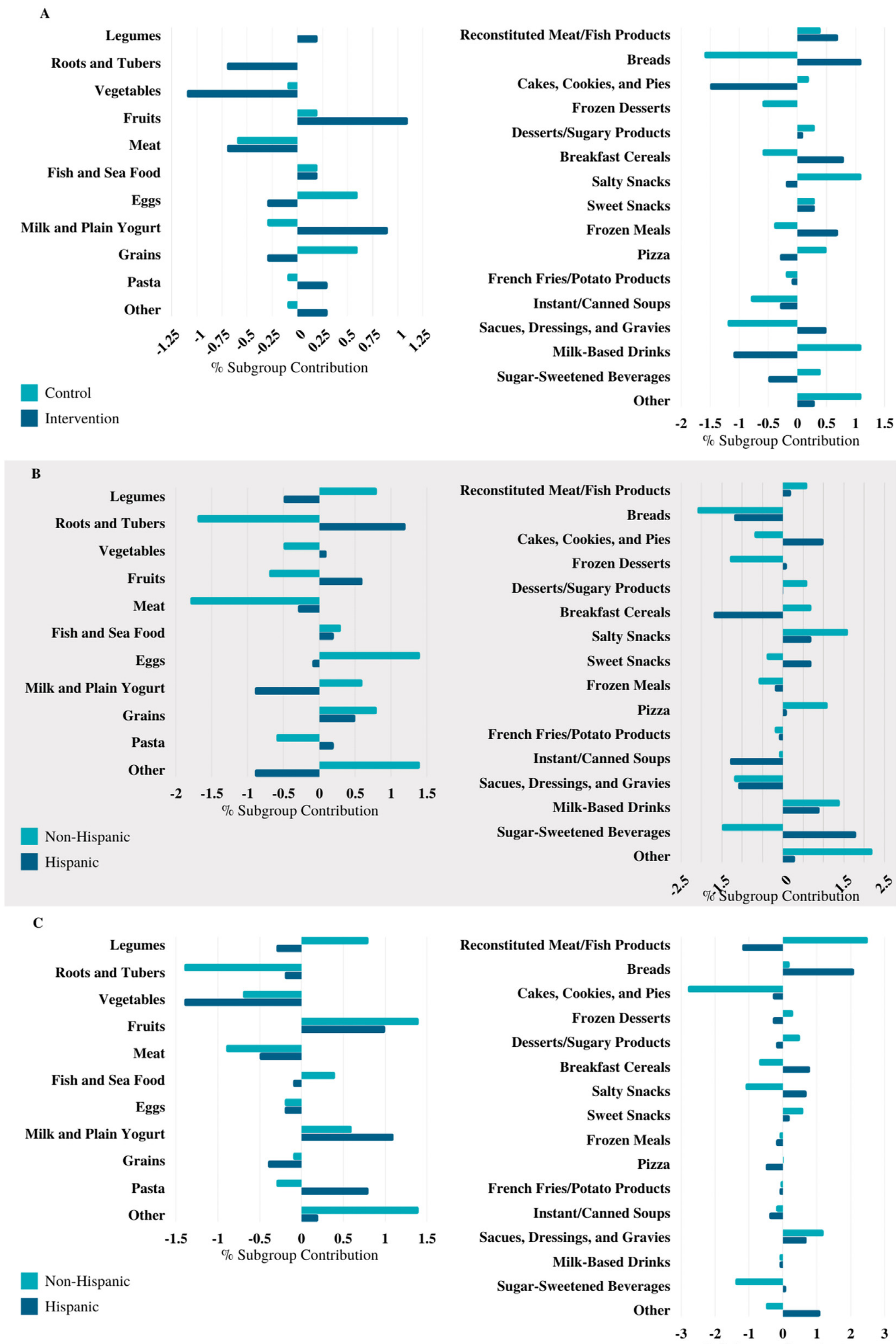

FIGURE 2. Changes in frequencies of foods in UMPF and UPF subgroups by treatment group and race/ethnicity (A) control vs. intervention; (B) control group by race/ethnicity; (C) intervention group by race/ethnicity). The "Other" subgroup for UMPF consisted of water, herbs and spices, dry mixes and flours, unsweetened coffee or tea, and nuts and seeds. The "Other" subgroup for UPF consisted of margarine and shortening, sweeteners and syrups, condiments, and imitation foods. UMPF, unprocessed or minimally processed food; UPF, ultra-processed food.

in the intervention group had increases in unflavored milk, plain yogurt, fruit, and pasta (whole wheat and rice) and decreased in reconstituted meat and fish product intake. The culturally tailored curriculum in TX Sprouts may have contributed to the more pronounced dietary improvements in UMPF and UPF observed in Hispanic children.

In terms of limitations to the present analyses, the intervention was implemented in Title I schools that were predominately Hispanic and provided culturally tailored education and activities [29], which may limit the generalizability of the study. In addition, the race/ethnicity interaction examined in the intervention was only between Hispanic and non-Hispanic children because of the limited number of other races and ethnicities included in the study. Thus, more granular racial/ethnic interactions should be evaluated in future studies. B dietary recalls were collected on a subsample of participants, with fewer recalls collected PI. However, there were no significant differences in demographic characteristics between the intervention and control groups and the B and PI groups with completed dietary recalls. The effects in this study were relatively small, and there is uncertainty in the sustainability of the results beyond the intervention. There is a need for future studies that are longer than 1 school year with more repeated measures to determine long-term effects. Lastly, an examination of UMPF and UPF consumption by location was not performed, so the impact of healthy eating in the school environment compared to the home environment is unclear.

In conclusion, this is the first study to show that a school-based gardening, cooking, and nutrition education intervention can increase UMPF and decrease UPF, with greater changes observed in Hispanic children compared to non-Hispanic children in the intervention group. Many school-based nutrition interventions show improvements in the dietary intake but lack examining dietary patterns and reporting of granular dietary data on foods with similar levels of processing but varied nutrient profiles. Because of the mounting evidence linking UPF consumption to consequential health outcomes, there is a need for school-based nutrition interventions to target UPF consumption and include a more robust dietary analysis to capture dietary quality and patterns that may contribute to adverse health outcomes in children.

Funding

This study was supported by the National Heart, Lung, and Blood Institute grant #R01HL123865.

Author disclosures

The authors report no conflicts of interest.

Author contribution

The authors' responsibilities were as follows– MRJ and JND: conceptualization, methodology, and writing—original draft preparation; MRJ: formal analysis and visualization; MRJ, SV, MJL, MSB, EAH, MB, JC, and JND: writing—review and editing; JND: supervision, project administration, and funding acquisition, and all authors: read and approved the final manuscript.

Data availability

Data described in the manuscript, code book, and analytic code will be made available upon request pending application.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.tjnut.2023.04.013.

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