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Research Article

The Effect of Offering a High-Fiber Snack in the Morning and the Afternoon on Overall Diet Quality and Dietary Fiber Intake in a Sample of School-Age Children

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Abstract

Diet quality in American children is suboptimal, contributing to the risk for overweight, obesity, and development of other chronic diseases. The objective of this community-based, randomized, controlled nutrition intervention was to assess the effect of serving high-fiber snacks (mean fiber content 5.1 g) twice daily on children's diet quality and fiber intake. Participants (n=81) were healthy children 7 – 11 years of age attending a local elementary school. Children were cluster-randomized by classroom to either receive two high-fiber snacks per day for eight weeks (intervention), or to consume their regular snack foods (control). Study participants completed 24-hour diet recalls at baseline and at week 4 of the intervention. Revised Children's Diet Quality Index (RC-DQI) scores and fiber intake were calculated based on two-day average intake at both time points using the Nutrition Data System for Research (NDS-R). Intervention group RC-DQI component scores for whole grain and iron intake were higher at week 4 compared to baseline ($p<0.001$ and $p<0.05$, respectively), dietary fiber intake increased by an average of 2.41 g/day ($p<0.05$), and caloric intake did not change. No food group or nutrient intakes were displaced by the addition of the high-fiber snacks. In conclusion, high-fiber snacks served at school can significantly improve dietary fiber intake without negatively affecting children's energy intake, thus contributing to better diet quality in school-age children.

ABBREVIATIONS

EAR: Estimated Average Requirement; EER: Estimated Energy Requirement; RC-DQI: Revised Children's Diet Quality Index; RDA: Recommended Dietary Allowance; RTE: Ready to Eat; WG: Whole Grain

INTRODUCTION

Adequate dietary fiber intake is associated with better diet quality. This can largely be attributed to the vitamins, minerals, and other nutrients found in most high-fiber foods [1,2]. The dietary fiber intake of children in the U.S. is approximately one-half of the recommended levels [3,4], contributing to suboptimal diet quality.

Dietary intake of foods associated with health benefits such as whole grains, milk, fruits, vegetables and legumes among U.S. children is dramatically lower than the targets set forth by the Dietary Guidelines for Americans (DGA) [5,6]. For example, analysis of nationally representative data suggest that the proportion of children between the ages of 4 and 18 years old who meet the minimum My Plate [7] food group recommendations for whole grains is as low as 1% [6]. Whole grains, fruits, vegetables and legumes are nutrient-rich foods that provide vitamins, minerals, and dietary fiber. In contrast, the prevalent food intake pattern in the U.S is high in so-called nutrient-poor foods that contain "empty calories", namely solid fats and added sugars (SoFAS), which are reflected in the MyPlate dietary guidance tool

as "empty calories" [7,8]. More than 90% of children ages 4 to 18 years old exceed the maximum recommended daily empty calorie allowance [6]. Therefore, the majority of children in the U.S consume inadequate amounts of nutrient-rich, high-fiber foods yet exceed the recommended intake of nutrient-poor energy-dense foods.

While analysis of individual food groups and nutrient intakes is important, comparisons between children's diets and the standards for "good diet quality" are best assessed using composite diet assessment tools. Diet quality scores quantify inadequate or excess consumption of food groups and macro- and micronutrients. Thus, these tools help evaluate the balance of foods contributing to a healthy diet versus those foods that increase the risk of suboptimal nutritional status, excessive energy intake, and the risk for acute or chronic disease. For example, dietary fat and sodium may be included as individual components of an index because they are closely associated with disease risk [9,10]. One composite assessment tool that specifically addresses the unique nutritional needs of children is the Revised Children's Diet Quality Index (RC-DQI), which measures overall diet quality using 13 individual dietary components [9].

The school environment is an important contributor to pediatric nutrition as most children have at least one meal and one snack per day at school [11]. Snack foods contribute significantly to children's total daily energy and nutrient intake [12] and are typically comprised of energy-dense, nutrient-poor foods such as sweets, sugar-sweetened beverages, and high-fat baked goods [12,13]. Thus, modifying children's school snacks is a prime opportunity for nutrition intervention.

This community-based, randomized, controlled nutrition intervention was conducted to test the hypotheses that the provision of high-fiber snacks and one serving of milk twice a day would:

a) improve participants' diet quality

b) increase participants' daily dietary fiber intake

To our knowledge, this is the first intervention conducted in a large sample of elementary school children ages 7 – 11 years old to specifically increase dietary fiber consumption and improve overall diet quality.

MATERIALS AND METHODS

The protocol for this study was approved by the Institutional Review Board of Purdue University. Permission of the local county school board and of the administrators and teachers at the school was obtained prior to participant recruitment. Written informed consent was obtained from children and their parents prior to enrollment in the study; children's verbal assent was obtained at each snack occasion and children's refusal to consume a snack was accepted.

Subjects

Children ages 7–11 years were recruited through an elementary school (grades 2 to 5) in northwestern Indiana. Families were informed of the study through packets that were distributed at school and sent home with the children. Participants (n=81) were randomized by classroom (n=11) into an intervention or control group before beginning study procedures. One child dropped out due to the family moving out of the area, and the remaining 80 children completed the study. Five children were excluded from analysis as they were noncompliant with snack consumption (consumed less than 50% of all snacks), and an additional six children were excluded because they could not be reached for diet recalls at both baseline and week 4 of the intervention. Therefore, 69 children (85.2%) were included in the diet analysis, with 33 children in the intervention group and 36 in the control group.

Study Procedures

This study was an eight-week cluster randomized, controlled, community-based intervention trial. Parent/child dyads completed a screening survey to determine the presence of exclusion criteria (such as food allergies, gastrointestinal disorders, and medications that may affect gastrointestinal function). Basic socio-demographic information was collected using a questionnaire with standard questions adopted from the National Health and Nutrition Examination Survey (NHANES). Children reported their gastrointestinal health using a child-appropriate questionnaire to assure that the increased availability of high-fiber foods did not result in effects such as abdominal discomfort or constipation.

Children were randomized by classroom into an intervention or control group before beginning study procedures. During the intervention period, children in the intervention group were given a choice of two grain-based, high-fiber snacks every morning and afternoon while children in the control group consumed their usual snacks. The intervention group also received two snack choices for two snack occasions for every weekend day; all uneaten portions of the snacks were returned to the researchers on Mondays. The study snacks provided 3–9 g of dietary fiber per serving and were matched to provide a total of 10–12 g of dietary fiber per day if the children consumed one snack serving at each occasion.

Before starting the trial, two baseline 24-hour diet recalls were conducted via telephone with each child to assess usual dietary intake. The same procedures (multiple-pass and interviewer-administered telephone interviews) used for NHANES dietary data collection were employed [14]. Dietary recalls were collected again after four weeks of the intervention. The recalls were conducted primarily with the children, with parental help encouraged for younger participants. Children and parents utilized the "Food Amounts Booklet" provided by Nutrient Data System for Research (NDS-R) to assist with portion size estimation. One recall was conducted for a weekday (Monday-Thursday) and one for a weekend day (Friday-Sunday) and both recalls were collected within a 10-day period. Recall data were entered into NDS-R version 2011, developed by the Nutrition Coordinating Center (NCC), University of Minnesota, Minneapolis, MN. All research staff conducting 24-hour recalls

were trained in the use of NDS-R and certified for child intake assessment following standardized procedures. Upon completion of the training a mock 24-hour recall was conducted and inter-interviewer reliability was tested. Inter-interviewer reliability was deemed satisfactory as estimated total kcal consumed was within 5%.

Diets entered into NDS-R were reviewed for reliability. At the end of each recall, the researcher would ask if the amount of food the child ate was "usual" for him/her; if not, the recall was discarded as unreliable and another recall was taken at a later date if possible. Recalls that included less than 500 kcal or more than 3500 kcal were considered biologically implausible and were followed up with a phone call to the parent/child to confirm the foods and amounts eaten. If these recalls were not confirmed by the parent/child they were discarded as unreliable.

When both recalls were completed, total dietary intake was calculated and the two-day average intake estimate generated to represent usual intake at that time point. If only one recall was completed for the child (n=10 (9 at baseline and 1 at week 4)), the dietary information from that one recall was used.

RC-DQI Assessment Tool

The RC-DQI consists of 13 dietary component scores that are calculated based on a population's estimated food and beverage intake and how reported intake compares to dietary intake recommendations [9]. The population's total score is the sum of all 13 component scores. The RC-DQI components can be weighted to measure specific foods and nutrients of interest in target populations by adjusting the number of points assigned to individual components of the index. For the purposes of this study, the weight of the fat and linoleic acid components were modified from the original designation of 5 points each [9] to 2.5 points each, reducing the total score from 95 to 90; all other component weights were maintained. Added sugar, fruit, vegetables, excess juice, dairy, iron, and energy balance were each scored out of 10 points, total grain and whole grain were each scored out of 5 points, and total fat, linoleic acid, linolenic acid, and DHA and EPA (combined) were each scored out of 2.5 points, for a maximum total score of 90 points (Table 1). Added sugar, total fat, fatty acids, excess juice, and dairy are analyzed as moderation components and total grains, whole grains, fruit, vegetables, and iron are analyzed as adequacy components. Energy intake levels falling within 90 – 100% of the sex- and age-specific estimated energy requirement received 10 points; excess or inadequate energy intake resulted in a lower energy balance score.

Study Foods

The intervention snacks were commercially available foods selected based on dietary fiber content. All foods were pre-tested in a child population not participating in the study to assure general acceptability of the foods. Based on limited refrigeration and food preparation space within the school, only foods that were shelf-stable were included in the study: breakfast cereals, breads, crackers and cereal bars. The snacks contained on average 157 kcal and 5.1 g of fiber per serving; consuming 100% of both snacks would result in an intake of 314 kcal and 10.2 g of fiber per day, on average. Approximately one-half of the snacks contained added sugars. Specifically, among the presweetened cereals that were offered, four of the eight varieties provided qualified as having a "higher" sugar content (>21.2 g total sugars/100 g) and the remainder were "lower" in sugar (≤ 21.2 g total sugars/100 g) [15]. Two food choices were offered at each snack occasion (morning and afternoon). Children selected the item they preferred and were invited to take additional servings if desired. In addition to the high-fiber snacks, one cup of skim milk was provided at each snack occasion to help children meet the possible need for increased fluid intake. Snack consumption was monitored by researchers and consumption was recorded as 'none', 'one-quarter', 'half', 'three-quarters' or 'all'. Only children who consumed on average at least 50% of the snacks over the course of the study were included in the data analysis. The children's acceptance and verbally reported liking of the foods were generally high.

Analysis

Demographic data were used to describe the sample. Dietary data were exported from NDS-R into Microsoft Excel (2010) and then transferred to Stata 11.2 (Stata Statistical Software: Release 12. College Station, TX: Stata Corp LP). Two-day average consumption of total energy, food groups, and nutrients was calculated for the intervention and the control group and used to estimate children's component and total RC-DQI scores (described in detail elsewhere [10]). Other nutrients of interest in the pediatric population were also calculated, including fiber, fluids, sodium, carotenoids, vitamin C and vitamin D. The means and standard deviations for food group and nutrient intakes were calculated for baseline and week 4 of the intervention to examine potential changes. Within- and between-group differences were assessed using two-sided student's t-tests. Linear regression, controlling for baseline values, age, gender, and self-reported race/ethnicity was performed to determine the effect of the intervention on children's overall diet quality and individual RC-DQI component scores after four weeks of the intervention. Statistical significance was assumed at $p<0.05$.

RESULTS

Sample Characteristics

Approximately 30% of eligible children chose to sign up for the study. Of the 69 children included in the analysis, 33 were cluster randomized to the intervention group and 36 to the control (Table 2). A total of 129 and 133 recalls were collected at baseline and week 4 of the intervention, respectively. Not all children completed both 24-hour recalls; at baseline 13% of subjects provided single recalls and 7.2% of subjects provided single recalls at week 4. Subjects did not report a higher incidence of adverse gastrointestinal symptoms, (including constipation, abdominal pain, or flatulence) at week 4 of the intervention compared to baseline.

Between-Groups Comparison of RC-DQI Measurements and Additional Dietary Components of Interest at Baseline and Week 4

Total RC-DQI scores were not significantly different between

Table 1: Components and scoring scheme of the RC-DQI for boys and girls ages 7 – 11 years old.

RC-DQI Component	Score	Criteria to Achieve Max. Score										Sources of Scoring Criteria
Gender		Boys					Girls					
Age		7	8	9	10	11	7	8	9	10	11	
Added sugar [a,b]	10	≤10% of total energy intake										WHO[j]
Fat[a,b]	2.5	25-35%										AMDR[k]
Linoleic acid (18:2)[a,b]	2.5	≤5-10% of total energy										(n-6 f.a.[l])
Linolenic acid (18:3)[a,b]	2.5	0.6-1.2% of total energy										(n-3 f.a.[l])
DHA[c] and EPA[a,b,d]	2.5	≤10% of α-linolenic acid										(more potent n-3 f.a.[l])
Total grains[e,f]	5	5	5	7	7	7	4	4	6	6	6	MPFG[m]
Whole grains[e,f]	5	2.5	2.5	3.5	3.5	3.5	2	2	3	3	3	MPFG[m]
Fruit[e,f]	10	2	2	2	2	2	1.5	1.5	2	2	2	MPFG[m]
Vegetables[e,f]	10	2	2	4	4	4	2	2	3	3	3	MPFG[m]
Excess juice[b,g]	10	12	12	12	12	12	12	12	12	12	12	AAP[n] age-appropriate limit
Dairy[b,e,f]	10	2	2	3	3	3	2	2	3	3	3	MPFG[m] and AAP[n]
Iron[h]	10	≤4.1 4.2-9.9 ≥10		≤5.9 6.0-7.9 ≥8			≤4.1 4.2-9.9 ≥10		≤5.7 5.8-7.9 ≥8			≤EAR=0 points EAR-RDA= 5 points ≥RDA= 10 points
Energy balance[i]	10	EER: 1393	EER: 1453	EER: 1530	EER: 1601	EER: 1691	EER: 1298	EER: 1360	EER: 1415	EER: 1470	EER: 1538	Energy ± 10% of EER
Total Points	90											

[a]In percent of total energy
[b]Overconsumption: (maximum points – [actual intake/ideal intake×100]%), lowest possible score: zero points
[c]Docosahexaenoic acid
[d]Eicosapentaenoic acid
[e]InMyPlate servings, per age-appropriate energy patterns
[f]Underconsumption: (maximum points – [actual intake/ideal intake×100]%)
[g]Units = fluid ounces
[h]Units = mg
[i]Scoring: 10 points if total kcal consumed ≥0.9×lowest point of EER range and ≤1.1×highest point of EER range. Overconsumption: (10 points – [actual intake/highest EER point x 100]%). Underconsumption:(10 – [actual intake/lowest EER point ×100]%). Lowest possible score = zero.
[j]World Health Organization
[k]Acceptable macronutrient distribution range
[l]f.a. = fatty acid
[m]MyPlate food group
[n]American Academy of Pediatrics

groups at baseline. However, at baseline, the component score for dietary fat intake was lower in the intervention group ($p<0.05$), and scores for total grain and whole grain were higher in the intervention group ($p<0.05$ and $p<0.001$, respectively). At week 4 the difference in dietary fat scores between the two groups was no longer present; however, intervention group scores for total grain and whole grain were increased, such that between groups differences for both were highly significant ($p<0.001$). Average dietary fiber intake was higher in the intervention group compared to the control group (12.17 versus 10.11 g/day) at baseline ($p<0.05$). At week 4, dietary fiber intake increased to 14.58 g/day in the intervention group while remaining relatively stable at 10.00 g/day in the control group, (p-value for between-groups difference at week 4 was <0.001). The proportions of participants with minimum and maximum component RC-DQI scores are shown in Supplemental Table 1.

Within-Groups Comparison of RC-DQI Measurements and Additional Nutrients of Interest at Baseline and Week 4

No significant changes were observed in the control group for total RC-DQI score or individual component scores from baseline to week 4 (Table 3a). In the intervention group, the score for whole grain increased from 1.95 points at baseline to 3.10 at week 4, ($p=0.001$). Iron scores improved from baseline to week 4 in the intervention group, ($p<0.05$). Scores ranged from zero to the maximum number allotted for each component of the RC-DQI unless otherwise indicated in Table 3a.

Average energy intake, average intake of several dietary components of interest (food groups, macronutrients, and micronutrients), and average fluid intake (mean ± SD) are presented in Table 3b for the control and intervention groups,

Table 2: Participant demographic characteristics (in percent).

	Intervention (n=33)		Control (n=36)	
Age Groups[a]	7-8	9-11	7-8	9-11
Total Participants (n)	7	26	4	32
Gender[b]				
Male (%)	12.1	42.4	5.6	52.8
Female (%)	9.1	36.4	5.6	36.1
Racial/Ethnic Group[b,c]	(n=31)		(n=30)	
Asian (%)	0	6.5	0	0
African American (%)	0	3.2	0	0
Hispanic/Latino (%)	3.2	3.2	6.7	13.3
White (%)	16.1	61.3	6.7	70.0
Other (%)	3.2	3.2	0	3.3

[a]Divided by Dietary Reference Intake (DRI) age ranges
[b]Some percentages do not sum to 100 due to rounding
[c]Information on racial/ethnic group was not available for some subjects.

Table 3: Control and intervention group consumption patterns at baseline and week 4 (mean ± SD).

A. RC-DQI component scores, (range is listed in parentheses if it was not zero to maximum)							
Component	Max Points	Control Group		P-value	Intervention Group		P-value
		Baseline	Week 4 of Intervention		Baseline	Week 4 of Intervention	
Added sugar	10	5.10 ± 4.05	4.89 ± 3.59	0.379	5.30 ± 3.96	5.22 ± 4.12	0.454
Total fat	2.5	2.43 ± 0.13 (1.90-2.50)	2.40 ± 0.18 (1.78-2.50)	0.080	2.32 ± 0.21 (1.79-2.50)	2.34 ± 0.27 (1.51-2.50)	0.387
Linoleic acid	2.5	2.30 ± 0.38 (0.85-2.50)	2.30 ± 0.32 (1.44-2.50)	0.497	2.25 ± 0.45 (0.81-2.50)	2.35 ± 0.23 (1.67-2.50)	0.131
Linolenic acid	2.5	2.10 ± 0.53 (0.90-2.50)	2.16 ± 0.53 (0.62-2.50)	0.276	2.16 ± 0.51 (0.70-2.50)	2.04 ± 0.47 (0.63-2.50)	0.173
DHA & EPA	2.5	1.59 ± 1.08	1.33 ± 1.16	0.138	1.24 ± 1.10	1.11 ± 1.12	0.305
Total grains	5	3.70 ± 1.35 (0.89-5.00)	3.77 ± 1.07 (1.63-5.00)	0.395	4.34 ± 1.01 (1.63-5.00)	4.58 ± 0.68 (2.75-5.00)	0.077
Whole grains	5	0.73 ± 1.01 (0.00-4.18)	0.96 ± 1.31 (0.00-4.56)	0.141	1.95 ± 1.66	3.10 ± 1.78	0.001*
Fruits	10	4.25 ± 3.87	4.04 ± 3.76	0.371	4.44 ± 3.90	4.20 ± 3.60	0.396
Vegetables	10	4.00 ± 2.42	3.26 ± 2.29 (0.08-10.00)	0.060	3.33 ± 2.60	3.46 ± 2.28 (0.13-9.98)	0.405
Excess juice	10	10.00 ± 0.00 (10.00-10.00)	10.00 ± 0.00 (10.00-10.00)	n/a	9.96 ± 0.21 (8.82-10.00)	10.00 ± 0.00 (10.00-10.00)	0.162
Dairy	10	6.81 ± 2.48 (1.14-10.00)	6.88 ± 2.67 (2.99-10.00)	0.445	6.97 ± 2.64	6.75 ± 2.79 (0.91-10.00)	0.341
Iron	10	7.50 ± 3.87	8.33 ± 3.16	0.187	8.79 ± 2.80	9.55 ± 1.46 (5.00-10.00)	0.048*
Energy balance	10	7.50 ± 2.05 (3.23-10.00)	8.22 ± 0.27 (3.70-10.00)	0.125	8.36 ± 1.56 (4.97-10.00)	8.30 ± 0.32 (3.59-10.00)	0.435
Total score	90	58.20 ± 12.30 (25.90-74.00)	58.55 ± 9.77 (39.90-74.90)	0.434	61.39 ± 9.14 (37.60-78.50)	62.98 ± 8.65 (46.10-80.90)	0.177

B. Average consumption levels of nutrients and food groups of interest, (range listed in parentheses)						
Dietary Component	Control Group		P-Value	Intervention Group		P-Value
	Baseline	Week 4 of Intervention		Baseline	Week 4 of Intervention	
Energy and Food Groups						
Energy (kcal)	1405.5 ± 500.0 (465.9-2411.2)	1401.1 ± 409.5 (672.1-2610.1)	0.480	1535.5 ± 372.6 (786.1-2405.6)	1571.9 ± 412.7 (709.5-2414.3)	0.307
Total grains (servings[a])	5.16 ± 2.30 (1.07-9.21)	5.08 ± 1.95 (2.27-10.39)	0.428	6.17 ± 2.40 (1.95-14.86)	6.86 ± 1.77 (3.30-10.38)	0.055
Whole grains (servings[a])	0.47 ± 0.63 (0.00-2.51)	0.59 ± 0.81 (0.00-2.73)	0.184	1.18 ± 1.03 (0.00-3.64)	2.08 ± 1.39 (0.00-5.60)	0.001*
Fruits (servings[a])	0.93 ± 0.95 (0.00-3.33)	0.95 ± 1.06 (0.00-4.00)	0.444	1.08 ± 1.21 (0.00-4.82)	0.97 ± 1.03 (0.00-4.32)	0.310
Vegetables (servings[a])	1.32 ± 0.76 (0.00-3.05)	1.18 ± 1.14 (0.03-6.64)	0.264	1.17 ± 1.27 (0.00-6.77)	1.05 ± 0.60 (0.04-2.13)	0.314
Dairy (servings[a])	2.25 ± 1.17 (0.34-5.64)	2.13 ± 0.97 (0.77-3.96)	0.258	2.18 ± 1.04 (0.00-5.04)	2.22 ± 1.79 (0.27-5.95)	0.418
Macronutrients and Micronutrients						
Added Sugars (g)	53.50 ± 30.66 (12.73-135.20)	57.27 ± 34.80 (15.86-204.90)	0.289	59.46 ± 31.32 (5.39-137.67)	61.40 ± 37.90 (5.46-179.69)	0.365
Total Fat (g)	51.27 ± 20.17 (13.57-100.01)	50.81 ± 15.95 (18.04-84.28)	0.448	56.17 ± 18.71 (17.94-91.73)	54.49 ± 22.50 (21.61-103.31)	0.334
Saturated Fat (g)	18.99 ± 8.28 (3.74-36.21)	17.93 ± 6.39 (6.79-31.04)	0.232	19.43 ± 6.97 (8.35-32.75)	19.23± 9.15 (6.68-40.85)	0.444
Linoleic acid (g)	8.92 ± 4.08 (1.07-21.54)	9.69 ± 4.08 (2.33-19.11)	0.155	10.30 ± 4.45 (1.62-18.96)	10.65 ± 5.26 (4.33-30.30)	0.368
Linolenic acid (g)	1.06 ± 0.59 (0.18-2.63)	1.04 ± 0.49 (0.15-2.10)	0.431	1.14 ± 0.59 (0.26-2.88)	0.93 ± 0.41 (0.22-2.18)	0.044*
EPA (mg)	10.90 ± 27.94 (0.00-149.50)	4.85 ± 7.56 (0.00-42.00)	0.061	8.17 ± 9.89 (0.00-57.00)	6.42 ± 6.75 (0.00-25.50)	0.215
DHA (mg)	17.74 ± 26.50 (0.00-139.00)	19.64 ± 28.18 (0.00-147.00)	0.321	19.77 ± 19.40 (0.00-95.00)	19.61 ± 23.90 (0.00-94.50)	0.488
Fiber (g)	10.11 ± 4.49 (1.62-21.86)	10.00 ± 4.49 (2.98-20.12)	0.435	12.17 ± 4.38 (4.13-27.62)	14.58 ± 5.06 (6.93-24.67)	0.014*
Calcium (mg)	869.10 ± 383.45 (256.81-1823.45)	829.47 ± 383.04 (276.46-2383.36)	0.279	850.63 ± 345.05 (399.67-1876.68)	953.13 ± 398.33 (192.86-1901.26)	0.081
Iron (mg)	10.69 ± 4.81 (2.17-23.40)	10.86 ± 4.93 (4.83-32.18)	0.430	13.46 ± 6.21 (4.96-30.82)	16.21 ± 6.71 (6.91-34.36)	0.006*
Sodium (mg)	2435.63 ± 888.20 (342.63-4017.93)	2339.95 ± 913.94 (951.01-5225.89)	0.313	2559.70 ± 666.60 (1425.50-4238.73)	2780.63 ± 934.79 (1239.73-5468.37)	0.126
Vitamin A (Retinol Activity Equivalents)	624.19 ± 361.29 (27.82-1913.22)	525.15 ± 280.41 (129.74-1567.62)	0.098	625.38 ± 284.06 (138.46-1311.76)	666.23 ± 363.53 (225.84-1889.47)	0.273
Carotenoids (mcg)	6245.33 ± 4250.14 (41.90-16315.01)	5365.06 ± 3697.86 (347.87-17181.22)	0.152	6102.10 ± 5409.20 (283.57-22458.54)	5987.33 ± 4767.09 (453.54-19868.85)	0.452
Vitamin C (mg)	43.86 ± 29.16 (1.60-109.76)	40.84 ± 33.94 (4.82-139.84)	0.323	44.10 ± 38.79 (3.54-186.48)	44.30 ± 26.81 (2.69-128.66)	0.487
Vitamin D_3 (mcg)	5.86 ± 3.21 (1.28-14.35)	5.25 ± 2.84 (1.28-12.55)	0.138	5.41 ± 2.80 (0.83-13.12)	5.54 ± 3.05 (0.85-13.37)	0.399
Fluids						
Water (servings[a])	0.67 ± 0.60 (0.00-2.03)	0.57 ± 0.64 (0.00-2.40)	0.176	0.93 ± 0.88 (0.00-3.11)	0.60 ± 0.70 (0.00-2.72)	0.003*
100% Juice (servings[a])	0.75 ± 1.16 (0.00-4.13)	0.42 ± 0.71 (0.00-2.91)	0.065	0.42 ± 1.12 (0.00-5.03)	0.73 ± 1.24 (0.00-4.31)	0.074
Sweetened juice (servings[a])	0.24 ± 0.45 (0.00-1.78)	0.23 ± 0.36 (0.00-1.25)	0.463	0.35 ± 0.73 (0.00-3.21)	0.21 ± 0.48 (0.00-2.17)	0.049*

Soft drinks (servings[a])	0.25 ± 0.41 (0.00-1.50)	0.40 ± 0.61 (0.00-2.25)	0.107	0.15 ± 0.32 (0.00-1.44)	0.31 ± 0.48 (0.00-1.79)	0.007*
Milk (servings[a])	1.46 ± 0.98 (0.00-4.29)	1.34 ± 0.81 (0.00-3.33)	0.257	1.40 ± 0.88 (0.00-3.91)	1.44 ± 0.96 (0.00-3.56)	0.377
Total fluids (servings[a])	3.36 ± 1.76 (0.98-8.88)	2.97 ± 1.16 (0.92-5.81)	0.094	3.27 ± 1.33 (1.50-6.41)	3.29 ± 1.22 (1.03-5.75)	0.458

[a]One serving of total grains, whole grains, fruits, vegetables, dairy or protein foods was defined as the amount specified in the MyPlate guidelines; one serving of water, sweetened juice, soft drinks, or milk was defined as 237 mL (8 fluid oz.) while one serving of 100% juice was defined as 177 mL (6 fluid oz.); total fluid is the summation of the beverage servings listed.
*Indicates significant difference, $p<0.05$, compared to baseline
**Indicates significant difference, $p<0.001$, compared to baseline

at baseline and week 4. No significant changes in intake were observed in the control group between baseline and week 4. Congruent with the improvement in the intervention group RC-DQI whole grain score at week 4, whole grain intake and dietary fiber intake increased significantly at week 4, ($p=0.001$ and $p=0.014$). Average iron intake improved in the intervention group from a mean (± SD) of 13.46 mg (± 6.21) at baseline to 16.21 mg (± 6.71) at week 4, ($p = 0.006$) while total energy intake remained constant. Total average fluid intake was maintained despite decreases in the consumption of water and sweetened juices; however, total fluid intake was low as compared to recommended intake [16]. Milk intake was also unchanged from baseline to week 4.

Linear Regression Results

Analysis of linear regression models mirrored results obtained from t-tests. In short, participation in the intervention was a significant predictor of increased component scores for whole grains, total grains, and iron intake ($p=0.0001$, $p=0.002$ and $p=0.044$, respectively). Gender and age were not significant predictors for any component score. Race/ethnicity was significant in predicting higher fat intake for white/Caucasian participants ($p=0.017$) and higher dairy intake for Hispanic/Latino participants and participants of other races, ($p=0.013$ and $p=0.033$, respectively). Conversely, race/ethnicity was a negative predictor of dairy intake among white/Caucasian participants ($p=0.047$).

DISCUSSION

The objective of our study was to improve diet quality and dietary fiber intake in a sample of 7 – 11 year old elementary school children by providing the students a choice of two high-fiber, grain-based snacks twice a day. The most accepted snack foods were cereals, usually fortified with iron, which led to the increased RC-DQI score for iron consumption. Because only grain-based, high-fiber foods were chosen for this intervention, the consumption of whole grains increased significantly, improving the point-scores of the RC-DQI whole grain component in the intervention group. Despite those improvements, which were directly related to the consumption of the study foods, the overall effect on total diet quality remained constant, which confirmed the finding that no spontaneous displacement of usual food intake occurred in response to the intervention.

Although pre-sweetened cereals were a favorite with the children, average intake of added sugars and total calories did not change significantly from baseline to week 4. It has previously been demonstrated that children who consume ready to eat (RTE) cereals, regardless of sugar content, have been shown to have lower rates of overweight and obesity and higher intake of dietary fiber and whole grains than children who do not consume cereal [17]. Therefore, adding palatable, high-fiber snack foods to children's diets can positively influence adequacy components of diet quality, such as fiber and iron, without negatively impacting moderation components such as added sugars and total energy. Schools play a key role in determining children's dietary intake and are opportune venues through which to implement the provision of healthy, high-fiber snacks.

At baseline, the overall diet quality in this sample was similar to estimates shown by a number of international studies [1,5,18] and mirrored the sub-optimal intake of whole grains and dietary fiber prevalent among U.S. children [5]. Overall, although the high-fiber snacks each contributed on average 5.1 g/serving of dietary fiber to the diet, average daily dietary fiber intake increased by only 2.41 g/day (instead of an expected 10.2 g); thus, spontaneous compensation took place. Curiously, the source of this compensation is not obvious because neither RC-DQI component scores nor actual intake of food groups and nutrients changed significantly between baseline and week 4, (with the exception of whole grains and iron). Therefore, the spontaneous changes in daily food intake that may occur upon a nutrition intervention need to be further investigated.

As in all nutrition intervention studies, this study had limitations. One shortcoming was the lack of racial/ethnic variation in the sample, which is typical of the geographical region but limits the generalizability of the results. Additionally, although the children generally reported high liking of the study snacks, a tiring effect was observed over the course of the 8-week study. This may prove problematic in long-term high-fiber snack implementation, but could be addressed by offering a greater variety of foods. Finally, no physiological data were collected to validate the children's reported diet intake, such as blood carotenoid levels for vegetable consumption. Thus, our results may have been subject to reporting bias. However, the use of two 24-hour recalls to estimate usual food intake is the commonly accepted standard and we are confident in the data collection and analysis methodologies that were employed. The data from the age- and location-matched control group in this study as well as the direct observation of snack consumption in the schools impart high confidence in the results of this study.

CONCLUSION

This study provides strong evidence that offering grain-based, high-fiber snack foods such as RTE cereals to school-age children is an effective strategy for increasing children's dietary fiber, whole grain, and iron consumption without significantly increasing added sugar or total energy intake. In the long-term, implementation of healthy school snacks such as those offered here could contribute to improved diet quality among children, reducing risk for overweight, obesity, and the development of other chronic diseases.

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Supplemental Table 1: Proportion of children in control and intervention groups (%) with minimum and maximum RC-DQI component scores.

	Control Group (n=36)				Intervention Group (n=33)			
	Minimum Points (%)		Maximum Points (%)		Minimum Points (%)		Maximum Points (%)	
	Male (n=21)	Female (n=15)	Male (n=21)	Female (n=15)	Male (n=18)	Female (n=15)	Male (n=18)	Female (n=15)
Baseline								
Added sugar	28.6	6.7	28.6	20.0	38.9	6.7	22.2	13.3
Fat	-	-	66.7	53.3	-	-	50.0	26.7
Linoleic acid	-	-	61.9	73.3	-	-	55.6	73.3
Linolenic acid	-	-	47.6	53.3	-	-	44.4	53.3
DHA & EPA	23.8	13.3	57.1	46.7	33.3	40.0	27.8	33.3

Grains	-	-	19.0	46.7	-	-	55.6	40.0
Whole grains	38.1	53.3	-	-	27.8	6.7	11.1	-
Fruit	33.3	13.3	14.3	20.0	27.8	26.7	16.7	20.0
Vegetables	9.5	-	-	13.3	16.7	-	-	13.3
Juice	-	-	100.0	100.0	-	-	100.0	93.3
Dairy	-	-	9.5	20.0	5.6	-	11.1	26.7
Iron	23.8	6.7	57.1	80.0	-	13.3	94.4	66.7
Energy balance	-	-	23.8	26.7	-	-	27.8	33.3
Week 4								
Added sugar	28.6	13.3	9.5	13.3	33.3	13.3	16.7	40.0
Fat	-	-	47.6	66.7	-	-	55.6	46.7
Linoleic acid	-	-	57.1	46.7	-	-	55.6	66.7
Linolenic acid	-	-	52.4	46.7	-	-	16.7	33.3
DHA/EPA	19.0	60.0	47.6	26.7	44.4	40.0	27.8	33.3
Grains	-	-	23.8	33.3	-	-	55.6	66.7
Whole grains	61.9	26.7	-	-	5.6	-	22.2	20.0
Fruit	42.9	13.3	19.0	13.3	16.7	20.0	22.2	-
Vegetables	-	-	4.8	-	-	-	-	-
Juice	-	-	100.0	100.0	-	-	100.0	100.0
Dairy	-	-	23.8	40.0	-	-	16.7	26.7
Iron	14.3	-	76.2	73.3	-	-	100.0	80.0
Energy balance	-	-	14.3	40.0	-	-	33.3	26.7

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