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Adolescents Perceive a Low Added Sugar Adequate Fiber Diet to be More Satiating and Equally Palatable Compared to a High Added Sugar Low Fiber Diet in a Randomized-Crossover Design Controlled Feeding Pilot Trial

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Abstract

Background—High added sugar (AS) intake is associated with obesity and poor diet quality. Guidelines recommended limiting AS to 5–10% of total energy intake, but palatability and feasibility of this AS intake level is uncertain.

Objective—To compare adolescents' perceptions of hunger, fullness, and palatability in response to a low AS adequate fiber (LASAF; 5% total energy from AS and 13.5 g fiber/1,000 kcal) and a high AS low fiber (HASLF; 25% total energy from AS and 8.2 g/1,000 kcal) diet.

Design—Adolescents (n=32, age: 15.3±1.6 yrs, BMI percentile: 47±4, 15 male) completed a randomized, crossover, controlled feeding study. Participants consumed calorie-matched LASAF and HASLF diets for 7 days, separated by a 4 week washout. Body weight was monitored daily on each diet. Hunger, fullness, and palatability were assessed via 100 mm visual analogue scales at the end of each feeding period. Differences were assessed with paired sample t-tests. Data are expressed as mean±SD.

Results—Participants remained weight stable, and no difference in weight change between diet conditions was detected (LASAF: −0.06±0.7 vs. HASLF: −0.02±0.6 kg, p=0.751). Less hunger

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(LASAF: 24.1 ± 14.6 vs. HASLF: 32.1 ± 17.6 mm, $p=0.024$) and greater fullness (LASAF: 70.2 ± 12.3 vs. HASLF: 61.3 ± 18.1 mm, $p=0.006$) were reported on the LASAF compared to the HASLF. Participants reported the diets to be equally palatable (LASAF: 39.6 ± 12.9 vs. HASLF: 37.2 ± 17.8 mm, $p=0.440$).

Conclusions—Adolescents perceive a LASAF diet to be as palatable as a HASLF diet, but more satiating. LASAF diets should be investigated as a strategy for weight control in adolescents.

Keywords

added sugar; appetite; fiber; dietary guidelines; weight management adolescents

1. Introduction

Adolescents in the United States consume approximately 17% of total energy intake (~380 kcal/d) from added sugars (AS)¹. This intake level of sugars added to foods during processing, preparation, or at the table² exceeds that of all other age groups¹. Consumption of hypercaloric diets high in AS has been implicated in the development of obesity, cardiovascular disease, (CVD), and dental caries in children and adolescents³. Therefore, the American Heart Association recently recommended intake of AS be limited to 25 g/d (or 100 kcal/d) for this segment of the population³. This is equivalent to an intake of no more than 5% of total energy intake coming from AS on a 2,000 kcal diet, and is consistent with recommendations from other organizations, including the World Health Organization and the Dietary Guidelines for Americans (DGA)^{4,5}.

Reducing AS consumption may be an effective strategy to decrease disease risk by increasing diet quality (e.g., reducing empty calories and increasing dietary fiber)⁶. Analysis of National Health and Nutrition Examination Survey data shows that as AS content of the diet (as a percentage of total energy) increases, there is a reduction in nutrient adequacy (as a percentage of Dietary Reference Intakes)^{3,7}. Specifically, nutrient intake is lowest when AS intake exceeds 25% of total energy intake⁷. Seventeen percent of adolescent males and 20.3% of adolescent females consume a diet containing greater than 25% of total energy from AS, which is more than any other life stage group⁷. It is well established that the atherosclerotic progression leading to CVD starts in childhood, and is heavily influenced by lifestyle factors such as dietary intake and body weight³. In addition to improving dietary quality, it has also been suggested that a reduction in AS intake to recommended levels could have significant impact on weight management strategies over the lifespan by promoting a decrease in total energy intake^{4,8–10}. Therefore, adolescence may be a critical period for adherence to AS guidelines in order to establish healthy dietary habits to reduce risk of weight gain and chronic diseases.

Decreasing AS intake is challenging due to their widespread incorporation in the food supply^{11–13}. The addition of sugar to food products acts to enhance texture, add body to improve mouthfeel, extend shelf life, and perhaps most importantly, increase palatability^{14,15}. Based on 2016 and previous consumer surveys conducted by the International Food Information Council, the majority of respondents cite 'taste' as the biggest influencer of their food and beverage purchasing decisions¹⁶. Thus, it makes sense

that food manufacturers would add extrinsic sugar sources to their products in order to increase consumption and sales. However, to date, no randomized controlled trials have evaluated adolescents' hunger and satiety ratings of low vs high AS diets, making it difficult to determine the feasibility and palatability of AS intake guidelines.

The purpose of this investigation was to compare adolescents' perceptions of hunger, fullness, and palatability in response to diets of low (5% total energy) and high (25% total energy) AS content. These levels were selected for comparison due to their public health relevance. The 5% of total energy low AS diet is in line with current recommendations³, and the 25% of total energy high AS diet is associated with a high risk of nutrient inadequacy, when consumed chronically⁷. The low AS diet also had adequate fiber content (LASAF; 13.5 g fiber/1,000 kcal) and the high AS diet had low fiber content (HASLF; 8.2 g fiber/1,000 kcal) according to IOM guidelines¹⁷, as occurred naturally when creating diets comprised of similar foods and matched macronutrient intake.

2. Materials and Methods

2.1. Participants

Non-obese (BMI <95th percentile for age and sex) adolescents (12–18 years) without food allergies/intolerances were eligible for enrollment in this randomized, crossover, controlled feeding study. The Virginia Tech Institutional Review Board approved the study protocol. All participants provided written informed assent and a parent/legal guardian provided written informed consent prior to participation.

2.2. Study Design

This investigation was a sub-study of a trial designed to determine the validity and sensitivity of a fingerstick blood $\delta^{13}\text{C}$ AS biomarker (Clinical Trials ID: NCT02455388)^{18,19}. Following baseline assessments, participants completed two 7-day controlled feeding periods, consisting of a LASAF (5% total energy from AS and 13.5 g fiber/1,000 kcal) and a HASLF (25% total energy from AS and 8.2 g fiber/1,000 kcal) diet, in a randomized, counter-balanced order (e.g. Sequence A: LASAF first and HASLF second or Sequence B: HASLF first and LASAF second), stratified by sex. A washout period of at least 4 weeks separated each feeding period. Diets were created using Nutrition Data System for Research (NDS-R) software, version 2013²⁰ and consisted of 3-day rotating menus at five energy levels (2000, 2500, 3000, 3500 and 4500 kcals) for both the LASAF and HASLF conditions. The LASAF and HASLF diets were matched for macronutrient composition (55% carbohydrate, 15% protein, and 30% fat), percentage of AS from solid (67%) and liquid (33%) sources¹², percentage of protein from animal (42%), dairy (20%), and vegetable/egg (38%) sources²¹, and were designed to consist of similar foods [see Table 1 for sample menu]. Unavoidably, in addition to differences in fiber content, the diets also differed in energy density (LASAF: 0.97 kcals/g; HASLF: 1.30 kcals/g) and Healthy Eating Index (HEI)-2010 scores (a measure of diet quality based on adherence to US Dietary Guidelines; LASAF: 74; HASLF: 52)²² [see Supplemental Table 1 for subgroup HEI scores]. Participants were provided two optional 150 kcal snack modules daily. The snack modules matched the composition of the base diets for each AS level (5% vs 25%),

macronutrient composition, percentage of AS from liquid vs solid sources, and protein sources. Lastly, three optional sucralose (Splenda®) packets were included with each day's food intake for participants to use at their discretion. This was done in order to increase adherence to the diets. Trained metabolic kitchen research assistants prepared diets under the supervision of a doctoral-level Research Registered Dietitian Nutritionist.

Participants reported to the Metabolic Kitchen and Dining Laboratory each morning of the 7-day feeding period, following an overnight fast. Breakfast was consumed on-site and the remainder of the day's food and beverages were packed into a cooler. Participants were instructed to consume all foods provided and to report deviations from study protocol to research staff. Coolers were returned the following morning and compliance was assessed via weigh-back methodology using a digital benchtop scale (Practum 5101-1S, Sartorius; Goettingen, Germany), query of participants regarding adherence, and daily measurement of body weight on a digital scale. Actual nutrient intake per participant was calculated in NDS-R by subtracting food returned (e.g., residue in food containers) from food provided.

2.3. Measurements

At baseline, participants' height and body weight were determined without shoes, in light clothing to the nearest 0.1 cm and 0.1 kg, respectively using a wall-mounted stadiometer (Seca Model 216, Seca; Chino, CA) and digital scale (Scale-Tronix 5002, Welch Allyn; Skaneateles Falls, NY). Body weight was also measured daily during each of the 7-day feeding periods in order to ensure compliance and weight stability. Habitual energy intake was assessed with four 24-hour record-assisted dietary recalls collected by trained research assistants using the multipass method²³ on non-consecutive days, including one weekend day^{24,25}. Intake was reported by the participant, with a parent/guardian serving as a proxy respondent as needed. Recalls were analyzed using NDS-R (version 2013) software. Usual physical activity was assessed via the Physical Activity Questionnaire for Adolescents (PAQ-A)²⁶. The assigned energy level of the provided diets was estimated using the 2005 Institute of Medicine (IOM) equations for pediatric populations¹⁷, with an appropriate activity level according to the PAQ-A.

At the conclusion of each of the two 7-day feeding periods, participants were asked to rate their appetite (hunger and fullness) on each diet as well as how palatable they perceived both the LASAF and HASLF to be using 100 mm visual analogue scales (VAS)^{27,28}. Hunger was rated by VAS with the question "In general, in the past 7 days, how hungry did you feel on this study diet?" and anchored by "Not hungry at all" on the left and "Extremely hungry" on the right. Satiety was rated by VAS with the question "In general, in the past 7 days, how full did you feel on this study diet?" with the anchors "Not at all full" and "Extremely full". Palatability was rated by VAS with the question "In general, in the past 7 days, how pleasant (good tasting) did you find the food?" with the anchors "Not at all pleasant" and "Very pleasant".

2.4. Statistical Analyses

Statistical analyses (SPSS v. 24.0) included descriptive statistics and paired sample t-tests to determine differences in adolescents' reported hunger, fullness, and palatability of the

LASAF and HASLF diet conditions and differences in consumption of optional sucralose packets and snack modules. Independent sample t-tests were used to test for sex differences, differences between Splenda vs non-Splenda users, and order effects. Continuous data are represented as mean $\pm$ SD, unless otherwise noted. Significance level was set *a priori* at 0.05.

3. Results

3.1. Participant Characteristics

A total of 32 participants completed the trial and were included in this analysis (Figure 1). Participants' average age was 15.3 $\pm$ 1.6 years with a mean BMI in the 47 $\pm$ 4th percentile for age and sex. Both sexes were equally represented in the trial (17 females and 15 males), and all participants identified as Caucasian. Baseline estimated energy needs (from PAQ-A²⁶ and IOM equation¹⁷) were 2,903 $\pm$ 715 kcals, which was similar to self-reported baseline energy intake (four 24-hour dietary recalls) of 2,519 $\pm$ 577 kcals. Baseline self-reported AS intake was 12.2 $\pm$ 3% of total energy intake (76 $\pm$ 26g/day).

3.2. Adherence to Controlled Feeding Protocol

Adherence was high (>98%) to both the LASAF and HASLF diets. In concordance with this, and as intended, participants consumed equal number of calories from the mandatory meals and snacks on each diet (LASAF: 2,730 $\pm$ 109 vs. HASLF: 2,713 $\pm$ 109 kcals/day, $p=0.262$) and remained weight stable (± 0.5 kg) during the two 7-day controlled feeding periods. No difference in weight change between diet conditions was detected (LASAF: -0.06 ± 0.7 vs. HASLF: -0.02 ± 0.6 kg, $p=0.751$).

3.3. Hunger, Fullness, and Palatability

VAS scale ratings of hunger, fullness, and palatability on both the LASAF and HASLF diets are presented in Figure 2. Participants reported less hunger (LASAF: 24.1 $\pm$ 14.6 vs. HASLF: 32.1 $\pm$ 17.6 mm, $p=0.024$) and greater fullness (LASAF: 70.2 $\pm$ 12.3 vs. HASLF: 61.3 $\pm$ 18.1 mm, $p=0.006$) on the LASAF as compared to the HASLF diet. Palatability ratings did not differ between the two controlled feeding diets (LASAF: 39.6 $\pm$ 12.9 vs. HASLF: 37.2 $\pm$ 17.8 mm, $p=0.440$).

3.4. Optional Sucralose and Snack Module Intake

Participants consumed a greater number of the three optional sucralose packets on the LASAF as compared to the HASLF diet (LASAF: 0.29 $\pm$ 0.08 vs. HASLF: 0.07 $\pm$ 0.03 packets/per day, $p=0.004$). Participants consumed fewer of the two optional 150 kcal snack modules on the LASAF as compared to the HASLF diet (LASAF: 0.3 $\pm$ 0.05 vs. HASLF: 0.7 $\pm$ 0.1 modules/day, $p=0.001$). This resulted in a lower total energy intake (base diet plus optional snack modules) on the LASAF as compared to the HASLF diet (LASAF: 2,776 $\pm$ 606 vs. HASLF: 2,816 $\pm$ 645 kcals/day, $p=0.027$).

3.5 Sex-Differences, Sucralose Users vs Non-Users, and Order Effect

The overall cohort findings were robust to analysis of sex-based differences, sucralose users vs. non-users, and order of consumption of the LASAF and HASLF diets. The only sex

difference that appeared was that males reported less hunger on the LASAF diet than female participants (male: 18.4 ± 14.3 vs. female: 29.1 ± 13.3 mm, $p=0.037$). Participants were grouped into sucralose users vs. non-users groups on each of the diets depending on if they elected to use any of the 3 optional daily sucralose packets. No differences between sucralose users ($n=6$) vs non-users ($n=26$) were detected for weight change, optional module intake, or ratings of hunger, fullness, and palatability on the HASLF diet ($p>0.05$ for all). On the LASAF diet no differences were detected between sucralose users ($n=14$) vs non-users ($n=18$) for weight change, optional module use, or reported hunger and satiety ($p>0.05$ for all). However, sucralose users rated the LASAF diet to be more palatable as compared to non-users (users: 45.8 ± 10.0 vs. non-users: 35.5 ± 13.1 mm, $p=0.022$). The only order effect detected was that participants who completed the LASAF diet 1st and the HASLF diet 2nd (Sequence A) consumed less of the two daily 150 kcal snack modules on the HASLF diet as compared to participants who complete the HASLF diet 1st and the LASAF diet 2nd (Sequence B) (Sequence A HASLF: 0.5 ± 0.5 vs. Sequence B HASLF: 0.9 ± 0.5 modules/day, $p=0.013$).

4. Discussion

This study is the first randomized-controlled feeding trial to evaluate adolescents' appetite and palatability ratings of LASAF and HASLF diets. The findings indicate that a LASAF diet is associated with decreased hunger ratings and increased fullness ratings as compared to a HASLF diet. Adolescents perceived the LASAF and HASLF diets to be equally palatable, though use of optional sucralose packets was higher on the LASAF as compared to the HASLF. Furthermore, average daily optional 150-kcal snack module intake was lower on the LASAF as compared to the HASLF.

Prior research evaluating the appetite and energy intake response to AS intake in children through young adults has primarily been: acute, evaluating the influence of a single test meal; focused specifically on sugar-sweetened beverages; and/or evaluating high vs. low glycemic index meals/diets^{29–32}. Consistent with findings of the current trial, Warren et al. found that pre-adolescent children reported greater hunger following a high glycemic index breakfast as compared to two low-glycemic index breakfasts³⁰. Researchers observed a greater *ad libitum* energy intake at a buffet lunch following the high glycemic as compared to the low glycemic index breakfasts³⁰. Similarly, Penaforte et al. evaluated hunger, satiety, and *ad libitum* energy intake in young women following a breakfast pre-load consisting of bread, margarine, juice and coffee²⁹. Interestingly, participants were able to add as much sugar as they wanted to their breakfast beverages. Based on the amount added, participants were then divided in to two groups for comparison of appetite and lunchtime *ad libitum* energy intake. Participants in the high sugar group reported greater hunger 30 minutes and 180 minutes post breakfast and consumed ~166 kcals more at the *ad libitum* lunch than the low sugar group²⁹. While the current trial was not designed to evaluate *ad libitum* energy intake, the greater hunger levels, and greater optional snack module intake resulting in a slightly higher total energy intake (~40 kcals/d) on the HASLF diet concurs with prior trials suggesting diets high in AS may promote increased energy intake³³. Overtime, this could lead to weight gain and adverse cardiometabolic health outcomes^{3,34,35}. Conversely, a recent study in minority adolescents reported that no differences in appetite, *ad libitum* energy

intake, nor appetite related peptides were found following a high sugar/low fiber or low sugar/high fiber breakfast and lunch pre-load³². The authors did not address why this was, as the analysis was changed following the null results to pool the two different test meals together and evaluate if habitual sugar-sweetened beverage or fiber intake influenced these outcomes. Therefore, additional research will be required to more clearly determine the influence LASAF and HASLF diets have on appetite measures and *ad libitum* energy intake in adolescents, both acutely and chronically.

The sensory properties of food, particularly palatability, are also important factors in determining consumption^{14,16}. As such, the addition of extrinsic sugars, either during processing by food manufacturers or during preparation prior to consumption by individuals, is common^{11,12}. This has led to recommendations from Registered Dietitian Nutritionists^{36,37} and professional organizations^{38,39} suggesting use of AS in order to encourage consumption of 'nutritious' foods that are less palatable in their unsweetened state, such as dairy products, oatmeal, grain-based cereals, and vegetables. A series of trials by Capaldi and Privitera investigated if the addition of sucrose could increase the liking for sour (grapefruit juice) and bitter (broccoli or cauliflower) foods⁴⁰. In the first trial, pre-school aged children who initially reported disliking grapefruit juice increased their liking of the beverage when sweetened with sucrose during a 20-day 'training period'. This increased liking of grapefruit juice persisted when the sucrose was removed the day after and two weeks after the 20-day 'training period'⁴⁰. In the second trial, following baseline rankings of unsweetened broccoli and cauliflower, undergraduate students were randomized to a 3-day 'training period' during which they consumed either unsweetened broccoli and sweetened cauliflower or unsweetened cauliflower and sweetened broccoli. Pleasantness ratings increased during the 'training' days for both broccoli and cauliflower, but more so for the sweetened vegetable in each group. Following the training period, students again consumed and rated the unsweetened vegetables. In agreement with the first experiment in children, undergraduate students rated the vegetable that was sweetened during 'training' as more pleasant when it was presented in its unsweetened state following 3-days of 'training'⁴⁰. These findings suggest that incorporation of AS into 'nutritious' items can be used to help 'train' people to like them in their unsweetened state. However, it is worth noting that simple exposure over 3-days to unsweetened vegetables increased ratings of pleasantness in the trial by Capaldi and Privitera. Since participants in the current trial were only queried about palatability of the LASAF and HASLF diets at the end of each 7-day controlled feeding period, it is possible that initial perceived palatability of the LASAF diet was less than the HASLF, and that over the 7-day period adolescents became adapted to the LASAF diet and perceived it as more palatable by the end of the week. Trials focused on reducing sodium intake suggest that overtime adherence to a low sodium diet causes changes in salt preference; increasing the perceived palatability of food without added salt and decreasing the palatability of salted foods⁴¹. It is possible that a similar adaptation to a lower AS diet would also occur. Thus, repeated consumption could be an effective strategy for improving dietary intake patterns.

Furthermore, since participants in the current trial reported the LASAF diet to be as palatable as the HASLF diet, this recommendation to add sugar to 'nutritious foods' in order to increase dietary quality may not be warranted. Instead, it is possible that incorporation of

small amounts of non-nutritive sweeteners can be used instead to increase palatability, and promote adherence to LASAF diets. A trial in adults comparing perceived bitterness of vegetables when treated with bitter masking agents (e.g., aspartame or one of two sodium salts) found that aspartame was the most effective at decreasing bitterness, and may even lead to increased liking of bitter vegetables (such as Brussels sprouts)⁴². This research team also cited unpublished data indicating that when matched on sweetness, aspartame and sucrose result in similar levels of liking, thus suggesting that non-nutritive sweeteners could be utilized to increase palatability without the addition of calories from AS⁴². While concerns have been raised about the use of non-nutritive sweeteners (particularly in children⁴³), the totality of evidence available indicates that when consumed in moderation, they are safe and potentially effective at decreasing reliance on AS⁴⁴. Nonetheless, as the literature base grows it will be important to potentially alter dietary recommendations regarding non-nutritive sweetener use accordingly.

4.1. Strengths and Limitations

To our knowledge, this is the first investigation to evaluate adolescents' ratings of appetite and palatability on a LASAF as compared to a HASLF diet. The randomized crossover controlled feeding design allowed for tight dietary control, thus overcoming limitations of nutritional science research that utilizes self-reported dietary intake. Another strength of the current trial is the focus on AS content of the diet as a whole, not simply a narrow focus on liquid sources of AS. In addition, the incorporation of the optional snack modules allows us to speculate about free-living energy intake when following a LASAF and a HASLF diet. This investigation provides novel information on adolescents' perceptions of a LASAF diet that meets current dietary intake recommendations, and suggests adherence to this diet is feasible in this demographic group.

Despite these strengths, there are limitations to the current study. First, this trial was not designed at the onset to compare appetite and palatability ratings of the two diets, and this work is preliminary in nature. Thus, the trial was not powered off of these specific outcomes and per our post hoc power analysis, our sample size of $n=32$ provided 0.50 power to detect differences in hunger and fullness ratings. Future work, on a larger sample size and incorporating a broader BMI percentile range (e.g., including overweight/obese adolescents), pre-intervention and meal-to-meal, not just post-intervention, VAS ratings, and physiological measures of appetite regulation (e.g., gut peptides) would provide a more generalizable and thorough comparison of adolescents' perceptions of LASAF and HASLF diets. Second, this trial was short-term, and only required participants to consume a LASAF and a HASLF diet for 7 days each. Thus, it is unknown how appetite and palatability ratings would differ if participants consumed these diets for a longer time period. Third, the HASLF diet contained 25% of calories from AS. This is above the amount typically consumed by adolescents (~17%)¹, and above the typical consumption of adolescents enrolled in the current trial (~12% based on self-report). It is possible that a 17% AS diet could be perceived as more palatable than either a 5% or 25% AS diet. Similarly, the study diets provided 33% of AS calories from liquids. This is less than recent estimates indicating adolescents consume over 50% of their AS calories from beverages³. Fifth, as dietary intake was controlled in an effort to keep participants weight stable, it cannot be concluded that a

lower AS diet would lead to better weight management. One can only speculate that due to the greater fullness and lower hunger ratings, as well as lower optional snack module intake reported on the LASAF, adolescents may elect to decrease total food intake while on a LASAF eating pattern as compared to a HASLF. Future trials in which adolescents (and particularly overweight/obese adolescents) are provided *ad libitum* LASAF and HASLF diets would be warranted to assess the true influence AS content may have on food intake behaviors, appetite regulation, and body weight. In addition, provision of 3 optional sucralose packets per day may be considered a limitation since palatability ratings of low and high AS diets may differ if consumption of non-nutritive sweeteners was not allowed. Similarly, trials focused specifically on how non-nutritive sweetener use influences appetitive outcomes in adolescents is also warranted, as some rodent data suggest non-nutritive sweeteners may disrupt learned cues regarding sweet taste and energy intake and thus have implications for appetite and body weight regulation⁴⁵. Finally, as fiber content and energy density differed on the two diets, the impact AS composition independently has on hunger, satiety, and palatability cannot be made. It is likely that the greater volume of food provided on the LASAF diet compared to the HASLF diet is an important contributing factor to the lower hunger and greater fullness reported by participants⁴⁶. However, real world substitutions of high AS foods for lower AS options would be expected to increase fiber intake and decrease energy density. Thus, this study is likely representative of the real-world impact of consumption of a reduced AS diet.

5. Conclusions

Adolescents perceived eucaloric low (5%) and high (25%) AS diets to be equally palatable, but reported less hunger and greater fullness on the LASAF diet. Consumption of optional snack modules was greater on the HASLF as compared to the LASAF. These findings suggest adolescents may adhere to AS and fiber intake recommendations since they found the diets to be equal in taste. They also suggest that in free-living situations adolescents may reduce total energy intake when adhering to lower AS intake recommendations. Healthcare professionals can utilize these findings to assist adolescent patients/clients in altering food choices to create a diet that is palatable and still meets AS and fiber intake guidelines. Another important consideration is food cost, and future work should examine if reducing dietary AS content and increasing fiber content can be achieved without simultaneously increasing food costs. The results of this preliminary analysis should be confirmed in a larger, more diverse sample in order to determine if differences exist between ethnic/racial groups, habitual AS intake levels, and weight status.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Abbreviations

AS	added sugar
LASAF	low added sugar adequate fiber

HASLF	high added sugar low fiber
CVD	cardiovascular disease
DGA	Dietary Guidelines for Americans
NDS-R	Nutrition Data System for Research
g	gram
PAQ-A	Physical Activity Questionnaire for Adolescents
IOM	Institute of Medicine
VAS	visual analogue scale

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Highlights

- Adolescents rate both 5% and 25% added sugar diets as equally palatable.
- Adolescents reported less hunger on the 5% added sugar, adequate fiber diet.
- Adolescents reported greater fullness on the 5% added sugar, adequate fiber diet.

Figure 1.

Figure 2.

Table 1

Sample Menu for the Low Added Sugar Adequate Fiber and High Added Sugar Low Fiber Diets

LASAF^a Diet	HASLF^b Diet
Breakfast: Oatmeal (plain; 29g ^c) Blueberries (frozen, unsweetened; 158g) Whole milk (265g) Banana (fresh; 120g)	Breakfast: Maple-and-brown sugar oatmeal (42g) Dried cranberries, sweetened (57g) Whole chocolate milk (245g)
Morning Snack: String cheese (25 g)	Morning Snack: String cheese (28g)
Lunch: Peanut butter (22g) Jelly (sugar-free preserves; 15g) White bread (86 g) Carrots (fresh; 70g) Ranch dressing (reduced calorie; 32g) Orange juice (318g) Orange-flavored 'juice' drink (72g)	Lunch: Peanut butter (28g) Jelly (reduced-sugar preserves; 23g) White bread (86g) Carrots (fresh; 80g) Ranch dressing (reduced calorie; 33g) Orange-flavored 'juice' drink (258g)
Afternoon Snack: Strawberries (fresh, 200g) Granola bar (apple crisp variety; 21 g)	Afternoon Snack: Granola bar (nut and chocolate variety; 35g)
Dinner: Chicken breast (baked; 102g) Barbeque sauce (18g) White rice (instant; 125g) Butter (18g) Green beans (steamed from frozen; 130g) Iceberg lettuce (90g) Carrots (fresh; 70g) Ranch dressing (reduced calorie; 32g)	Dinner: Chicken breast (baked; 102g) Barbeque sauce (15g) Dinner roll (white; 28g) Butter (12g) Green beans (steamed from frozen; 120g) Iceberg lettuce (90g) Carrots (fresh; 80g) Ranch dressing (reduced calorie; 33g)
Optional 'Lunchable' Style Snack Modules (2 provided): Turkey (deli, regular fat; 14g) Cheddar cheese (regular fat; 6g) Wheat crackers (13g) Carrots (fresh; 30g) Orange juice (70g) Orange-flavored 'juice' drink (5g)	Optional 'Lunchable' Style Snack Modules (2 provided): Turkey (deli, regular fat; 14g) Cheddar cheese (regular fat; 7g) Wheat crackers (7g) Commercial fruit leather (14g) Orange-flavored 'juice' drink (27g)
Optional:	Optional:

LASAF^a Diet	HASLF^b Diet
Splenda® (3 packets)	Splenda® (3 packets)

Diets were matched on macronutrient composition (55% carbohydrate, 15% protein; 30% fat), percent of AS^d calories from solid and liquid forms (66% and 33%, respectively), and percent of calories from meat, dairy, and vegetable protein sources (42%, 20%, and 38%, respectively). Diets differed in AS^d composition (LASAF: 5%; HASLF: 25% total energy), fiber content (LASAF: 13.5 g/1,000 kcal; HASLF: 8.2 g/1,000 kcal) and energy density (LASAF: 0.97 kcal/g; HASLF: 1.30 kcal/g).

^aLASAF: Low added sugar adequate fiber;

^bHASLF: High added sugar low fiber;

^cg: gram;

^dAS: Added sugar