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Using digital imagery to quantify students' added sugar intake at lunch in Title I schools with universal free meals

Elizabeth L. Adams[a], Hollie A. Raynor[b], Laura M. Thornton[c], Suzanne E. Mazzeo[d], Melanie K. Bean[a,*]

[a] Department of Pediatrics, Children's Hospital of Richmond at Virginia Commonwealth University, 2303 N. Parham Rd, Suite 1, Richmond, VA 23229, United States
[b] Department of Nutrition, University of Tennessee, 1215 W. Cumberland Ave., Knoxville, TN 37996, United States
[c] Department of Psychiatry, University of North Carolina at Chapel Hill, 101 Manning Drive, Chapel Hill, NC 27599, United States
[d] Department of Psychology, Virginia Commonwealth University, 806 W Franklin St., Richmond, VA, United States

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ABSTRACT

School meals are a major source of dietary intake for low-income students at high obesity risk. Associations between added sugar and obesity are well known, and the National School Lunch Program prohibits added sugar in fruit and juice; yet, no added sugar limits exist for other meal components. This study measured students' added sugar selection and consumption in school lunches and compared % of daily calories consumed from added sugar to the Dietary Guidelines for Americans (DGA) recommendations. In October 2016, this cross-sectional study was conducted in six Virginia Title I elementary schools (>90% racial/ethnic minorities; 100% free meals). Digital imagery plate waste methods assessed lunch consumption in N = 1155, 1st–5th graders. Added sugar (g, %kcal) in foods and beverages selected and consumed were quantified, and kcal of added sugar consumed was compared to DGA recommendations. Students consumed an average 6.6 g of added sugar from foods (grade differences; q = 0.0012), and 3.6 g of added sugar from beverages. Added sugar comprised ~10% of school lunch calories consumed from foods and ~35% of school lunch calories consumed from beverages. Added sugar in the total school lunch meal comprised ~2.5% of student's recommended daily calorie needs; thus, ~7.5% of daily calories from added sugar remained before students would have exceeded the DGA. Total added sugar consumption was within daily DGA recommendations. Findings contribute to previous reports that school-provided lunches are low in added sugar. Future research should examine added sugar consumed in school breakfast and lunch separately and combined.

1. Introduction

The Dietary Guidelines for Americans (DGA) recommends <10% of daily calories come from added sugars (U.S. Department of Health and Human Services and U.S. Department of Agriculture, 2015); yet, many children exceed this recommendation (Ervin et al., 2012). Reducing children's added sugar intake is imperative given the evidence linking added sugar intake, obesity, and cardiometabolic disease risk (Kavey, 2010; Keller and Bucher Della Torre, 2015; Seferidi et al., 2018; Vos et al., 2017). Low-income, racial/ethnic minority populations are of particular concern as they tend to have poorer dietary quality and are at greater risk for developing chronic diseases (Datar and Chung, 2015; U.S. Department of Agriculture, Food and Nutrition Services and Office of Research, Nutrition and Analysis, 2008; Ogden et al., 2010; U.S. Department of Health and Human Services, 2020). Regulations guiding school meals are essential to improve the nutritional quality of this high-risk population given these children rely on school meals for a large portion of their dietary intake (Mirtcheva and Powell, 2009).

In recent years, policymakers have taken action to improve the nutritional quality of school meals offered including the Healthy, Hunger-Free Kids Act (HHFKA) of 2010 (Healthy Hunger-Free Kids Act of 2010, 2010). Effective in 2012, the HHFKA implemented enhanced nutritional standards to the National School Lunch Program (NSLP) to improve their alignment with the DGA. Changes included offering more

Abbreviations: DGA, Dietary Guidelines for Americans; NSLP, National School Lunch Program.

* Corresponding author.
E-mail addresses: elizabeth.adams@vcuhealth.org (E.L. Adams), hraynor@utk.edu (H.A. Raynor), laura_thornton@med.unc.edu (L.M. Thornton), semazzeo@vcu.edu (S.E. Mazzeo), melanie.bean@vcuhealth.org (M.K. Bean).

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fruits, vegetables, and whole grains, while limiting solid fats and added sugars (U.S. Department of Agriculture, Food and Nutrition Service, 2012). Years later, the United States Department of Agriculture issued a final rule of 2016, which strengthened the implementation and evaluation of school wellness policies and required that all foods and beverages sold in schools be consistent with the federal regulations for nutrition standards (U.S. Department of Agriculture, Food and Nutrition Service, 2010). Specific to added sugar, the final rule of 2016 also included a requirement that added sugars be indicated on the Nutrition Facts Label (U.S. Department of Agriculture, Food and Nutrition Service, 2010). Since implementation of the HHFKA, some of these healthier mandates have been rolled back, while other changes have been proposed (U.S. Department of Agriculture, Food and Nutrition Service, 2018, 2020) and then repealed (Center for Science in the Public Interest et al., 2020). These rollbacks have been largely based on anecdotal concerns (e.g., lower consumption of school meals, increased plate waste), rather than on scientific evidence that often does not support these claims (Buscemi et al., 2018). Therefore, rigorous data on students' dietary intake during school lunch is critical to informing science-based policy decisions within the NSLP that impact >30 million children daily.

Since the adoption of the HHFKA, a few studies have demonstrated the nutritional quality of school lunches improved (Johnston et al., 2012; Vernarelli and O'Brien, 2017), and school meals were nutritionally superior to lunches packed from home (Johnston et al., 2012). Further, a nationally representative sample found that students who are eligible but do not participate in the NSLP consume double the amount of added sugar at lunch, compared with students participating in the NSLP (Vernarelli and O'Brien, 2017). Changes to the NSLP are an important positive step; yet, further improvements might be needed to enhance the nutrition of this vulnerable population. For example, the NSLP prohibits serving juice and fruit with added sugars; yet, there are no regulations around added sugar in other meal components. There is an ongoing discussion around restricting sugar-sweetened milk to reduce added sugar intake versus keeping sweetened milk to ensure adequate nutrient (e.g., calcium) intake (Cline et al., 2015; Goto et al., 2013; Murphy et al., 2008). Quantifying added sugar consumption from school lunch foods, beverages, and the total meal is needed to better identify sources of added sugar, which can help inform future NSLP policy decisions and provide some benchmark for how well the NSLP regulates added sugar across different meal components. Further, added sugar intake during school lunch can be compared to the DGA recommendations for added sugar consumption in a full day to give perspective on how school lunch meals fit into student's daily dietary recommendations. If children consume close to the DGA recommendations in school lunch alone, then perhaps stricter NSLP guidelines on added sugar would be beneficial. If children consume a small percentage of daily added sugar in school lunch alone, then current NSLP guidelines may be sufficient in limiting added sugar intake.

The purpose of this secondary analysis is to quantify the added sugar (grams [g] and %kcal) in all foods and beverages that students selected and consumed at school lunch in central Virginia Title I schools with universal free meals participating in the NSLP. The proportion of calories attributed to added sugar in students' school lunch was then compared to the DGA recommendations for added sugar consumption. It was hypothesized that total added sugar intake within the school lunch meal would be below the daily DGA recommendations, but relatively more added sugar would be consumed from school lunch beverages than from foods. Data were collected as part of a larger study examining how school salad bars relate to students' fruit and vegetable intake (Bean and Sova, 2020); thus, half of schools in the current analyses had salad bars and half served pre-portioned fruits and vegetables only. No hypotheses were generated for this secondary analysis around school salad bar status, given that school-level differences were not central to our research question. However, since school salad bars were part of the study design, the study aims were evaluated for the full sample and by school salad bar status.

2. Methods

2.1. Setting

This cross-sectional study was conducted in October 2016 in an elementary school district comprising 26 schools in central Virginia. Based on school-level demographics, almost all students identified as racial/ethnic minorities (>90% African American or Latinx) with an average NSLP participation >90%. All students were eligible for free meals under the Community Eligibility Provision of the Healthy Hunger-Free Kids Act (U.S. Department of Agriculture, Food and Nutrition Services, 2020). This secondary analysis used data from a study that examined how school salad bars were associated with student's intake of fruits and vegetables (Bean and Sova, 2020). All 22 Title I schools within this district were eligible to participate (17 had salad bars, 5 did not). Given the aims of the original study, 3 schools with a salad bar were randomly selected, which were then matched with a school that did not have a salad bar (i.e., offered pre-portioned fruits and vegetables), resulting in 3 matched pairs. School matching was based on student racial/ethnic minority status and principles of behavioral economics around promotion strategies (e.g., fruit and vegetable visibility, convenience, suggestive selling) assessed in a prior study (Bean et al., 2019) to describe the lunchroom environment.

2.2. Participants

All 1st–5th graders who were present and participated in the NSLP on the day of data collection were eligible. There were 2103 total students across all schools present, and most students (85.6–99.8%) participated in the NSLP that day. Parent notification with an opt-out option and verbal youth assent were used (<5% opted out). This study was approved by [redacted] Institutional Review Board.

2.3. Procedures

2.3.1. Obtaining digital images of the school lunch meal

There was one day of data collection for each pair of schools to ensure menu consistency within a pair. Menus were matched on the day of data collections for schools within a given matched pair. These data collection days represented a typical weekday and routine lunch menu.

Digital imagery plate waste methods were applied to quantify all foods and beverages consumed at lunch (Bean et al., 2018; Taylor et al., 2014; Williamson et al., 2003). These methods have been previously validated and/or used in school- and lab-based settings (Smith and Cunningham-Sabo, 2013; Swanson, 2008). Cafeteria assessors were trained to follow a standardized protocol that aligned with procedures used in other school lunch investigations (Bean et al., 2018; Cohen et al., 2013). Training included instructions and practice preparing trays and taking digital images of mock school lunch trays using iPads (Apple, Cupertino, CA) from an appropriate angle (~45°) and distance close enough for all contents on the tray to be fully captured (~1 ft away). Training also included strategies to minimize interference with school lunch flow while maximizing data quality. Cafeteria assessors underwent extensive supervised practice before study participation.

During school lunch, each student's tray was labeled with a unique number and their school grade, color-coded by sex. Cafeteria assessors took a pre-consumption digital image of each student's lunch tray as he/she exited the lunch line. At the end of lunch, students left their trays on the tables. Cafeteria assessors adjusted any visual obstructions that could interfere with rating and poured any remaining beverages into clear labeled measuring cups. A second post-consumption digital image was then taken. Pre- and post-consumption images were matched by number and subsequently rated in the laboratory.

2.3.2. Foods and beverages offered during school lunch

Schools followed Offer Versus Serve (U.S. Department of Agriculture, Food and Nutrition Service, 2012), allowing students to select which foods and beverages they wanted (had to choose three or more of the five meal components; one had to be a fruit or vegetable consistent with NSLP). Beverages offered were categorized as 100% fruit juice, sugar-sweetened fat-free milk (chocolate, strawberry), and low-fat/fat-free white milk. Students could select more than one beverage. If students selected a fruit juice and a milk, this counted as two meal components according to the NSLP (one fruit and one milk, respectively) (U.S. Department of Agriculture, Food and Nutrition Service, 2012). For these analyses, fruit juice was considered a beverage.

Prior to lunch, research staff purchased, weighed, and photographed three portions of each item offered at school lunch to use as reference portions. Weights were obtained using a calibrated food scale (Ozeri Pronto Digital Food Scale [Model ZK14-S; Ozeri Kitchen]), and the average was used as the reference weight for one portion of that item. For self-serve fruits and vegetables, reference portions (1/4 cup, 1/2 cup, 3/4 cup, and 1 cup) were prepared in triplicate, weighed, averaged, and photographed by lab dietitians as described elsewhere (Bean et al., 2018). Product information on each food and beverage was provided by the school district dietitian and entered into Nutrition Data Systems for Research (Nutrition Data Systems for Research, 2018) to obtain nutrient information.

2.3.3. Laboratory rating of digital images

Rating of the digital images was conducted by a separate team of laboratory raters, blinded to study hypotheses. Raters were trained in validated methods for visually assessing portions of foods and beverages captured in digital images (Bean et al., 2018; Taylor et al., 2014). Interrater reliabilities (IRR) were assessed, and raters had to achieve interclass correlations (ICC) ≥0.80 to initiate the study. IRRs were deemed excellent (0.84–0.94). Additional details on rater training can be found elsewhere (Bean et al., 2018a, 2018b).

Laboratory raters were instructed to view all images by zooming-in so that the image touched all four corners of the computer screen. For pre-consumption images, raters recorded which foods and beverages were selected. For self-serve items, portion selection was also estimated using reference photographs as a guide. Raters viewed post-consumption images and recorded the percent of each item that remained as plate waste in 20% increments (Bean et al., 2018; Connors and Rozell, 2004). Reference images and visual pie charts were used for assistance (Connors and Rozell, 2004; Comstock et al., 1981; Kirks and Wolff, 1985). The amount of each food or beverage missing was assumed to have been consumed. Items (or appropriate evidence [e.g., peel]) had to be present in the pre and post-consumption image to be rated, with the exception of items that could be fully consumed. If any item was present in the post-consumption, but not pre-consumption image, then the item was not rated as it could have been shared. Similarly, if evidence of an item (e.g., beverage carton) was absent in the post-consumption image, then the item was not rated as this suggested sharing, discarding, or removing items from the cafeteria. For quality control, the principal investigator (MKB) randomly selected ~20% of all ratable images from each school for double rating. Double ratings were counterbalanced across raters in a fully crossed design to permit reassessment of interrater reliabilities. ICC's were recalculated and remained excellent (0.81–0.90).

2.3.4. Added sugar selection and consumption

A total of twelve variables were calculated, corresponding to the amount (g) and %kcal of added sugar selected and consumed at school lunch for foods only, beverages only, and the total meal. *Grams of added sugar selected* = (# portions selected * grams of added sugar/portion). There are 3.87 kcal/g of added sugar; therefore kcal of added sugar selected (grams of added sugar * 3.87 kcal/g) was used to calculate *% kcal from added sugar selected* = [(kcal from added sugar selected in foods or beverages or the total meal/total kcal in foods or beverages or the total meal) * 100]. *Grams of added sugar consumed* = [(grams of added sugar selected in total meal foods or beverages) * (1 − %plate waste)]. Calculations for *%kcal from added sugar consumed* were conducted following the same calculations above but using consumption, rather than selection, values. Trays with no beverages selected, or no food or beverages consumed did not have calculated values for %kcal selected or consumed, respectively.

2.3.5. Added sugar consumption compared to total daily calorie recommendations

Student's sex- and age-specific daily calorie recommendations were obtained from Goran et al. (2018) in which student's daily calorie recommendations were based on child sex, age, and average weight for age according to World Health Organization and Center for Disease Control growth charts. Student age was inferred from grade level: 7 years (1st grade), 8 years (2nd grade), 9 years (3rd grade), 10 years (4th grade), and 11 years (5th grade). Student's %kcal from added sugar at school lunch, relative to total daily calorie recommendations, was calculated as [(kcal from added sugar in foods or beverages or total meal)/(total daily kcal recommendation) * 100].

3. Statistical analyses

Analyses were conducted using SAS version 9.4 (SAS Institute, Cary, NC) (SAS, 2011). Descriptive statistics [mean and standard deviation (SD)] were calculated for added sugar variables by child grade and sex. Daily calorie recommendations specific to child age and sex were obtained from Goran et al. (2018). The percentage and frequency of students who selected each type of beverage were calculated. Overall, 1362 image pairs were matched and rated. Trays were excluded if supplementary foods not part of the school lunch were present (n = 171), given portion sizes and nutritional information could not be determined. Thus 1,155 trays were included in analyses (school 1: n = 249; school 2: n = 180; school 3: n = 157; school 4: n = 207; school 5: n = 172; school 6: n = 190).

Multilevel mixed models were applied to evaluate differences between sex and among grades on the variables of interest. For all models, the unit of analysis was a school lunch tray that had a pre- and post-consumption image. Random effects were estimated for the intercept and accounted for clustering within schools. Covariates for all models were school salad bar status (had salad bar vs. not) and matched school pair, as the specific school lunch environment and menu might influence results. The interaction between grade and sex was initially included in all models, yet not retained because it was not significant in any model. To correct for multiple testing in the omnibus test, False Discovery Rate was applied (Benjamini and Hochberg, 1995). Corrected p-values (referred to as q-values) <0.05 are considered significant. Post-hoc pairwise comparisons for grade were then applied for all models where grade was significantly associated with the variable of interest; p-values <0.05 are considered significant.

4. Results

There were no differences in children's added sugar selection or consumption for foods, beverages, or the total lunch meal in schools with a salad bar versus schools without a salad bar (p's > 0.05); therefore, the following results are presented for all schools combined.

4.1. Grams of added sugar selected and consumed in school lunch

Among foods selected at school lunch, there was an average of 11.2 g of added sugar; of this, 6.6 g were consumed (Table 1). Significant grade differences were observed for added sugar consumed (q = 0.0004). Post hoc comparisons showed that 1st graders consumed less added sugar than 4th graders (5.5 g vs. 7.5 g, respectively; p = 0.0004) and 5th

Table 1
Mean (SD) for the amount of added sugar selected and consumed in just foods, just beverages, and the total meal during a school lunch meal in central Virginia Title 1 elementary schools receiving universal free meals. Results are presented overall, by sex, and for each student grade by sex.

	Overall	Overall		Grade 1		Grade 2		Grade 3		Grade 4		Grade 5	
		Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
	n = 1155	n = 528	n = 627	n = 119	n = 135	n = 100	n = 111	n = 106	n = 138	n = 119	n = 139	n = 84	n = 104
Amount of added sugar in foods selected													
g[a]	11.2 (6.4)	10.9 (6.2)	11.4 (6.6)	10.7 (4.9)	10.9 (5.7)	9.9 (6.7)	10.5 (6.1)	11.2 (5.7)	11.4 (6.1)	11.6 (6.6)	11.3 (6.2)	11.1 (7.0)	13.1 (9.1)
%kcals[b]	9.8 (4.7)	9.6 (4.6)	10.0 (4.8)	9.7 (4.6)	10.1 (5.3)	8.7 (5.1)	9.4 (4.5)	10.2 (4.1)	10.5 (4.5)	10.1 (4.5)	9.7 (4.0)	8.9 (4.8)	10.4 (5.6)
Amount of added sugar in foods consumed[c]													
g[d]	6.6 (6.4)	6.5 (5.9)	6.6 (6.7)	5.8 (4.7)	5.2 (5.3)	6.4 (6.2)	5.5 (5.7)	5.6 (4.8)	6.8 (6.0)	7.9 (6.4)	7.2 (6.7)	6.8 (7.2)	8.6 (9.3)
%kcals[e]	10.1 (7.6)	9.7 (7.2)	10.4 (7.9)	10.8 (8.9)	10.4 (8.4)	9.8 (7.5)	9.7 (8.6)	9.0 (6.8)	11.2 (7.6)	9.7 (6.3)	10.1 (7.3)	8.9 (6.2)	10.3 (8.0)
Amount of added sugar in beverages selected[f]													
g[a]	11.0 (7.9)	11.6 (8.2)	10.5 (7.6)	11.2 (7.7)	11.4 (7.6)	12.1 (8.7)	11.1 (8.7)	11.6 (9.5)	10.1 (7.8)	11.1 (7.3)	9.6 (7.3)	12.1 (8.1)	10.3 (6.3)
%kcals[b]	39.1 (21.5)	39.6 (21.5)	38.7 (21.5)	36.4 (19.8)	38.7 (18.6)	38.9 (23.0)	37.5 (23.0)	39.4 (21.4)	41.8 (25.5)	43.0 (21.9)	37.1 (18.6)	40.7 (21.1)	38.0 (21.4)
Amount of added sugar in beverages consumed[g]													
g[d]	3.6 (5.2)	3.4 (5.0)	3.8 (5.3)	4.5 (5.4)	5.8 (5.7)	3.8 (5.4)	3.6 (5.1)	3.4 (5.2)	3.4 (5.6)	2.9 (4.8)	3.1 (4.7)	1.9 (3.8)	3.0 (4.8)
%kcals[e]	35.9 (19.5)	36.0 (20.2)	35.8 (18.9)	35.2 (19.6)	35.3 (16.3)	33.3 (20.2)	35.2 (23.0)	34.8 (19.6)	37.9 (23.7)	38.2 (22.4)	35.5 (13.8)	41.0 (18.7)	34.9 (17.4)
Amount of added sugar in total meal selected													
g[a]	22.2 (9.8)	22.5 (10.2)	21.9 (9.5)	21.9 (9.0)	22.3 (8.5)	22.0 (11.3)	21.7 (9.6)	22.8 (11.0)	21.6 (9.5)	22.8 (10.3)	20.9 (9.4)	23.2 (9.1)	23.3 (10.6)
%kcals[b]	15.8 (6.6)	15.9 (6.7)	15.8 (6.5)	15.5 (6.4)	16.3 (6.5)	15.6 (7.5)	15.6 (6.4)	16.6 (7.1)	16.4 (6.5)	16.2 (6.5)	15.0 (6.5)	15.5 (6.2)	15.6 (6.3)
Amount of added sugar in total meal consumed[h]													
g[d]	10.2 (8.0)	9.9 (7.6)	10.4 (8.2)	10.3 (7.0)	11.0 (7.2)	10.2 (8.2)	9.1 (7.3)	9.0 (6.6)	10.2 (7.4)	10.7 (8.4)	10.3 (8.6)	8.7 (7.9)	11.6 (10.5)
%kcals[e]	14.9 (10.8)	14.3 (10.8)	15.3 (10.8)	16.4 (11.0)	18.7 (10.7)	15.2 (11.5)	15.0 (12.8)	14.5 (12.8)	15.7 (11.3)	12.7 (8.6)	13.1 (9.0)	12.3 (9.2)	13.9 (9.4)

Sample sizes were derived from school lunch trays with a pre and post-consumption image successfully matched and rated; [a]grams of added sugar selected was calculated as (# portions selected * grams of added sugar/portion); [b]%kcal from added sugar selected was calculated as [(kcal from added sugar selected in total meal or foods or beverages)/(total kcal in total meal or foods or beverages) * 100]; [c]trays excluded if no food was consumed; [d]grams of added sugar consumed was calculated as [grams of added sugar selected in total meal, foods or beverages * (1 − plate waste)]; [e]%kcal from added sugar consumed was calculated as [(kcal from added sugar consumed in total meal or foods or beverages)/(total kcal in total meal or foods or beverages) * 100]; [f]trays excluded if no beverages were selected; [g]trays excluded if no beverages were consumed; [h]trays excluded if no food/beverages were consumed.

graders (7.8 g; p = 0.0001) whereas 2nd graders consumed less added sugar than 5th graders (5.9 g vs. 7.8 g, respectively; p = 0.0232). No grade (q = 0.07) or sex (q = 0.19) differences were observed for added sugar selected, and no sex (q = 0.80) differences were observed for added sugar consumed. Among beverages selected at school lunch, there was an average of 11.0 g of added sugar, with 3.6 g consumed. Significant sex differences were not observed for either grams selected (q = 0.42; Table 1) or consumed (q = 0.42). Significant grade differences were not observed for added sugar selected (q = 0.72); however, grade differences were observed for added sugar consumed (q = 0.0001), with 1st graders consuming more than all other grades (p's < 0.02). On average, students selected 22.2 g of added sugar in their total school lunch meal, and 10.2 g were consumed. No significant differences for grade nor sex were observed for added sugar selected or consumed (q's > 0.05).

4.2. %kcal of added sugar consumed in school lunch

The %kcal in students' food, beverage, and total school lunch meal selection and consumption are listed in Table 1. Added sugar comprised ~10% of school lunch calories consumed from all foods combined, and ~35% of school lunch calories consumed from just beverages. For the total school lunch meal, ~15% of calories consumed were from added sugar.

4.3. Beverage selection

Students' beverage selections were further explored given the substantial relative percent contribution of added sugar from beverages (Table 2). Most students selected fat-free sugar-sweetened milk, followed by 100% fruit juice and fat-free/low-fat white milk. Approximately 23% of students did not select any drink, whereas 20.5% selected two beverages, and 0.2% selected three beverages. Of the students with two or three beverages, 99.2% (n = 237) selected at least one milk and one juice.

4.4. Added sugar consumption compared to daily calorie recommendations

Fig. 1 displays the percent of added sugar consumption from foods and beverages, relative to total daily calorie recommendations. Students consumed, on average, 1.6% of recommended daily calories from added sugar in foods and 0.9% of recommended daily calories from added sugar in beverages, totaling 2.5% of recommended daily calories from added sugar in their total school lunch meal. This left 7.5% of recommended daily calories from added sugar before students would have exceeded the DGA of consuming <10% of daily calories from added sugars in the full day.

5. Discussion

Among Title I schools with universal free meals in central Virginia, students consumed ~2.5% of their recommended daily calorie intake from added sugars at school lunch. School lunches provide about one-third of children's daily calories (Fox et al., 2012), and in this sample, added sugar consumed from school lunch was less than one-third of the DGA recommendations to consume <10% of calories from added sugar in a full day. Despite the limited policies that only regulate the amount of added sugar in juice and fruit in school lunches, these positive findings suggest that students consume what might be considered an appropriate amount of total added sugar from their school lunch meal. Overall, these data support the high nutritional quality of school lunches as it relates to added sugar content.

Epidemiological data suggest children consume excessive added sugar in a given day (Ervin et al., 2012). In this study, students' added sugar consumption for school lunch was less than one-third of the DGA recommendations to consume <10% of calories from added sugar in a full day. Considering that lunch is one of three daily meals consumed, this appears to be an appropriate amount of added sugar for school lunches. Recent data suggest that children consume a greater percentage of calories from added sugar while at home (Ervin et al., 2012), and school lunches appear nutritionally superior to lunches provided from other sources (e.g., brought from home) (Johnston et al., 2012; Vernarelli and O'Brien, 2017). For this study, it was observed that some students supplemented their school lunch with foods not served in schools that were often high in added sugar (e.g., candy). The nutrient profiles of these supplementary items were not able to be quantified in this study; yet, it is important for future research to do so to inform how supplementary foods impact student's added sugar consumption at lunch. If students consume excess added sugar at school lunch, largely due to the supplementary foods not available in schools, then perhaps school food policies could regulate the supplementary foods students are

Table 2
Number (%) of students in central Virginia Title I elementary schools receiving universal free meals who select each beverage at school lunch. Results are presented overall, by sex, and by student grade for each sex.

	Overall	Overall		Grade 1		Grade 2		Grade 3		Grade 4		Grade 5	
		Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
	n = 1155	n = 528	n = 627	n = 119	n = 135	n = 100	n = 111	n = 106	n = 138	n = 119	n = 139	n = 84	n = 104
100% fruit juice	308 (26.7)	157 (29.7)	151 (24.1)	36 (30.3)	35 (26.0)	32 (32.0)	23 (20.7)	26 (24.5)	33 (23.9)	28 (23.5)	23 (16.5)	35 (41.7)	37 (35.6)
FF SS milk	695 (60.2)	330 (62.5)	365 (58.2)	85 (71.4)	91 (67.4)	62 (62.0)	67 (60.4)	65 (61.3)	72 (52.2)	66 (55.5)	67 (48.2)	52 (61.9)	68 (65.4)
Chocolate	543 (47.0)	262 (49.6)	281 (44.8)	67 (56.3)	62 (45.9)	45 (45.0)	49 (44.1)	57 (53.8)	57 (41.3)	54 (45.4)	52 (37.4)	39 (46.4)	61 (58.7)
Strawberry	152 (13.2)	68 (12.9)	84 (13.4)	18 (15.1)	29 (21.5)	17 (17.0)	18 (16.2)	8 (7.5)	15 (10.9)	12 (10.1)	15 (10.8)	13 (15.5)	7 (6.7)
FF/LF white milk	130 (11.3)	65 (12.3)	65 (10.4)	16 (13.4)	16 (11.9)	15 (15.0)	16 (14.4)	15 (14.2)	17 (12.3)	11 (9.2)	12 (8.6)	8 (9.5)	4 (3.8)
Beverages selected													
0	262 (22.7)	106 (20.1)	156 (24.9)	14 (11.8)	25 (18.5)	19 (19.0)	23 (20.7)	21 (19.8)	35 (25.4)	33 (27.7)	53 (38.1)	19 (22.6)	20 (19.2)
1	654 (56.6)	293 (55.5)	361 (57.6)	72 (60.5)	78 (57.8)	53 (53.0)	72 (64.9)	65 (61.3)	84 (60.9)	67 (56.3)	70 (50.4)	36 (42.9)	59 (56.7)
2	237 (20.5)	127 (24.1)	110 (17.5)	33 (27.7)	32 (23.7)	28 (28.0)	16 (14.4)	19 (17.9)	19 (13.8)	19 (16.0)	16 (11.5)	28 (33.3)	25 (24.0)
3	2 (0.2)	2 (0.4)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.9)	0 (0.0)	0 (0.0)	0 (0.0)	1 (1.2)	0 (0.0)

FF = fat-free; SS = sugar sweetened; LF = low-fat.

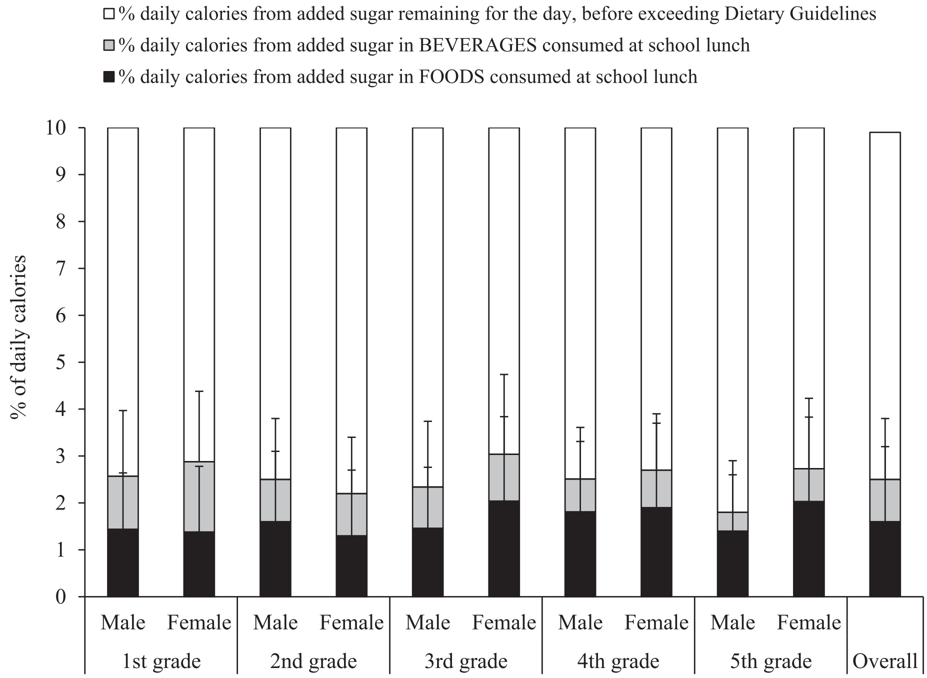

Fig. 1. Students' % calorie consumption from added sugars in foods (black) and beverages (gray) at school lunch, relative to their total daily calorie recommendations according to Goran et al. (Swanson, 2008). The white portion of each bar indicates the % of daily calories from added sugars remaining for the day, before students would have exceeded the Dietary Guideline recommendation of consuming <10% of total daily calories from added sugars.

allowed to bring into schools. To inform future work in this area, consumption of added sugar in both school breakfast and lunch should be quantified using similar plate waste analysis methods to better understand how school meals as a whole contribute to added sugar intake. It may be that items offered for school breakfast contain more added sugar than items offered for school lunch (Goel et al., 2019). If so, some students may be consuming excess added sugar across both school meals. Future research should also quantify children's added sugar consumption across a full day (e.g., via combined plate waste and 24-h recalls) in order to examine the relative contribution of added sugar consumed in school meals relative to daily consumption.

Findings from this study also have important and timely implications for school nutrition policies. The Child Nutrition Reauthorization Act, typically passed every 5 years, has not been updated since the HHFKA in 2010. This reauthorization process currently underway provides an opportunity to improve regulations that govern child nutrition programs; therefore, empirical data such as these are critical to providing scientific evidence to inform policy changes. The DGA, also updated every 5 years, informs the NSLP guidelines, and forthcoming changes to the DGA have been proposed around added sugar intake (Dietary Guidelines Advisory Committee, 2020). The Scientific Report of the 2020 Dietary Guidelines Committee recommended decreasing the guidelines around added sugar intake from <10% to <6% of energy from added sugar per day (Dietary Guidelines Advisory Committee, 2020). If this is put into effect in the 2020–2025 DGA, then school nutrition policies may follow suit with initiatives to lower added sugar in school meals. Given that sugar-sweetened beverages are the greatest source of added sugar for school-aged children (Bowman et al., 2019), reducing sweetened beverages that are offered as part of the NSLP might be a feasible strategy to achieve these targets. In recent years, there have been ongoing discussions around added sugar in school beverages and restricting sugar-sweetened milk as a way of lowering added sugar consumption; yet, the concern in doing so is that total milk consumption may decrease, leading to lower intakes of important nutrients such as calcium and vitamin D (Vernarelli and O'Brien, 2017; Cline et al., 2015; Goto et al., 2013). A recent systematic review stated that multiple industry-funded studies have shown not consuming flavored milk is associated with lower milk intake (Patel et al., 2018). However, other studies have shown that simple strategies, such as emoticon placement or awarding small prizes, can increase the sales of white fat-free milk without impacting total milk purchases (Emerson et al., 2017; Siegel et al., 2015). In this study, when differentiating between sources of added sugar, students consumed more grams of added sugar from foods (6.6 g) than from beverages (3.6 g), and when expressed as %kcal, added sugar comprised 10% of kcal consumed from all foods and 35%kcal consumed from just beverages. More research is needed to weigh the pros/cons of offering versus restricting sugar-sweetened milk during school lunch on students nutrient and added sugar intake; yet, this study suggests that in school lunch alone, students in this population consumed a low amount of added sugar, even with the current NSLP guidelines of offering sugar-sweetened milk.

Digital imagery is a validated plate waste method that yields a large amount of data in a short amount of time (e.g., a few seconds per tray) and is minimally intrusive (e.g., compared to weighing foods), with images rated in an unhurried laboratory setting (Taylor et al., 2014; Williamson et al., 2003; Smith and Cunningham-Sabo, 2013; Swanson, 2008; Bean et al., 2018; Cohen et al., 2013). The limitations of this method includes the inability to account for possible sharing, overestimation of intake if items were spilled, and exclusion of images with un-ratable items or supplementary foods not part of the school lunch. Further, there was only one day of data collection for each pair of Title I schools in this relatively homogenous district; thus, findings might not be generalizable across days, different schools, or in other districts. It is important for future research to examine these patterns of added sugar intake in other populations in order to gather support for NSLP participation. Last, students' total daily calorie recommendations were based on Goran et al. (2018), which was developed specifically for examining children's added sugar intake. Goran et al. (2018) recommendations are based on average weight for age data using World Health Organization and Center for Disease Control growth charts, and this study population of low-income students may not be of average weight. One of the largest strengths of this study is that students were mostly racial/ethnic monitories in Title I schools with universal free meals. This represents a high-risk and understudied population that can greatly benefit from school food policies to improve nutritional quality. Further, this is the first study to our knowledge that uses digital imagery to quantify added sugar consumption following changes to the NSLP guidelines.

6. Conclusion

Added sugar consumption during a school lunch meal appeared modest for low-income students in Title I schools with universal free meals in central Virginia. This study does not suggest the need for additional added sugar regulations within the NSLP, as the current regulations kept added sugar consumption from school lunches within reasonable limits. Given the nutritional concerns of this high-risk population, it is important that these children receive optimal nutritional quality across a full day; therefore, future research should quantify added sugar consumed from other sources (e.g., home, school breakfast) and across a full day to inform future policy mandates.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Author contributions

MKB and ELA formulated the research question. MKB, HAR, LMT, and SEM designed the study. MKB and SEM implemented the study procedures. LMT analyzed the data. ELA and MKB drafted the initial version of the manuscript. All authors reviewed and contributed substantially to subsequent drafts of the manuscript and approved the final version as submitted.

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