Dietary Sugar Intake among Preschool-aged Children: Cross-sectional Associations of Intake of Total, Added and Free Sugar with Anthropometric Measures

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Abstract

Background: Excessive intake of sugar in young children is a public health concern. The objectives of our study were to examine children's intakes of total, free and added sugar and to investigate their cross-sectional associations with body weight, BMI Z-scores, percent fat mass and waist circumference among preschool-aged children.

Methods: The study sample included n=109 children (77 families) between the ages of 1.5 to 5 years. Total sugar daily intake was determined using ESHA Food Processor software; free and added sugar daily intakes and food sources were determined through manual inspection of 3-day food records. Anthropometric measures were completed by trained research staff. Linear regression models with generalized estimating equations were used to estimate associations between sugar intakes and anthropometric measures.

Results: Mean daily intakes ± standard deviation (SD) were 86 ± 26 g; 31 ± 15 g and 26 ± 13 g for total, free and added sugar, respectively. Approximately 80% of children had free sugar intakes greater than the 5% of daily energy recommendation by the World Health Organization. The most frequent food sources of free and added sugar consumed were bakery products (e.g., cakes, cookies and breads). A weak inverse association between free sugar and waist circumference (β= -0.02; 95% CI= -0.04, -0.0009), was found but no significant associations were found between sugar and other anthropometric measures.

Interpretation: Free and added sugar intake of the majority of preschool-aged children in our study exceeds current recommendations. Further investigation into long-term sugar intake and association with anthropometric measures among preschool-aged children is warranted.

Introduction

Dietary patterns that begin in early childhood can continue into adulthood and thus, early years are crucial for nutrition interventions and habit formation.[1] Infants have a natural affinity towards sweet foods overall and also pre- and post-natal exposures are important.[2,3] Genetic, parental and cultural influences can increase preferences for sugary foods in children.[2] However, there is a lack of high quality research data on the dietary intake of sugars among young Canadian children, especially infants and toddlers.[4] Given that cardiometabolic risk markers may begin to emerge as young as 3 years of age,[5] it is important to understand sugar intake patterns and explore associations between intake of sugar and cardiometabolic risk markers (including anthropometric measures) in early life. This information will help inform policy and behavior change interventions focused on early prevention.

Adverse effects of excessive sugar intake are a cause for global public health concern in all age groups.[6] Overconsumption of sugar has been associated with increased risk of excessive weight gain, dental decay, poor diet quality and nutritional inadequacy in children and adolescents <19y.[4,7,8] Excessive sugar intake has also been implicated in the development of high blood pressure and lipid abnormalities in children,[4] which can lead to earlier presentation of non-communicable diseases in children than seen in previous generations.[5] In the majority of studies, sugar sweetened beverages (SSBs) are the primary source of dietary sugar intake among children and adolescents that has been studied.[9] One study found that SSB consumption in the first year of life was associated with a 13% increase in risk of being overweight at 8 years of age.[10] Recently, a study found higher intakes of SSBs and 100% fruit juices to be associated with increased risk of cardiometabolic risk factors in preschool-aged children.[11] Contrary to these findings, there are studies that have found no significant associations between SSB intake and body weight or body mass index (BMI) Z-scores in preschool-aged and school children.[10,12] Given these mixed findings and the primary focus on SSBs, we embarked on our research study using detailed dietary assessments to more broadly examine sources of sugar intake to understand associations between dietary sugar intake and anthropometric measures in preschool-aged children. Our study objectives were two-fold. Firstly, to examine the daily intakes of total sugar, free sugar and added sugar, and the key food sources (by category) of free and added sugar among a sample of preschool-aged children. Secondly, to examine cross-sectional associations between intakes of total, free and added sugar with anthropometric measures, including body weight, BMI Z-scores, body weight, waist circumference and percent body fat among a sample of preschool-aged children in the Guelph Family Health Study (GFHS) pilot studies. We hypothesized that free and added sugar intake in preschool-aged children would be positively associated with all anthropometric measures.

Methods

Study Design and Participant Recruitment

The Guelph Family Health Study (GFHS) is a family-based lifestyle intervention study, initiated in 2014 at the University of Guelph (REB#:17-07-003). The current study includes cross-sectional data gathered from preschool-aged children from the GFHS pilot studies at baseline from 2014 to 2016.[13] Families with at least one child aged 18 months to 5 years, who were not planning to move within the next year were recruited from the Guelph-Wellington areas through the Family Health team, Community Health Centre and Ontario Early Years Centres.[13] A total of n=117 (83 families) participants were enrolled in the pilots. Participants were excluded from analyses if food records were incomplete (n=4) or if breastfeeding replaced a meal and/or exceeded 50 mins or >625mL of breastmilk per day (n=4). Thus,

our final analytic study sample included 109 preschool-aged children (55 females; 54 males) from 77 families.

Study Measures

Intake and Sources of Sugar

Total, free and added sugar intakes were assessed from the analysis of 3-day food records (2 weekdays and 1 weekend day). Parents were given paper food record forms, on which they recorded their child(ren)'s food and drink consumption, including amount and occasion of consumption, brand names of products, and recipes for mixed foods. Food record data were entered into ESHA Food Processor software for analysis of 3-day average nutrient intakes (Version 11.6.441, Salem, OR, 2015). Total sugar intake was analyzed by ESHA Food Processor; however, added sugar and free sugar intakes were determined through manual calculations and review of product and SMART LABEL websites. We adapted the algorithm of Louie and colleagues,[14] which included a standardized, objective and stepwise approach to calculate content of added sugar (including honey and syrups) and free sugar (including foods with added sugar and 100% fruit juice and concentrates).[14] This calculation has been used in other studies that investigated free sugar intake in preschoolers.[15,16] These manual calculations were performed by two data analysts to assure data quality. There are limitations in the research literature such as inconsistent definitions of free and added sugar[12] and limited food composition databases that calculate added and free sugar amounts.[15] Total, free, and added sugar intakes were normalized to grams (g) per 1000 kcal/day for ease of comparison in the regression analysis. To identify free and added sugar sources, we adapted the categorization system used by Bernstein and colleagues.[17] Approximately 17 broad free and added sugar food groups were used to classify the sources consumed by our study population.[17] The food records were reviewed to classify combined or stand-alone food items into free and added sugar food categories.

Anthropometrics

Anthropometric outcome variables included waist circumference (WC), height, body weight, percent fat mass and BMI Z-scores. Anthropometric measures were completed by trained research staff. Participants were instructed to remove any footwear and outer garments before measurements were taken. WC (cm) was measured at the top of the iliac crest of participants' bare abdomen, using a non-elastic tape measure (Gulick II™, Country Technology Inc., Gay Mills, Wisconsin). Height (cm) was measured using a child stadiometer. Height and WC were measured in duplicate; if the values were within 0.5 cm, then a mean value was calculated. Otherwise, a third measurement was taken and the mean of the two closest values was calculated. Body weight (kg) was measured using an electronic weighing scale. BMI Z-scores were calculated using the R package zscorer.[18,19] Percent fat mass was assessed using supine tetrapolar bioelectrical impedance analysis (BIA). Participants were instructed to avoid food/drink and vigorous physical activity for 30 minutes prior to the BIA assessment. Percent fat mass was calculated using Kushner and colleagues' total body water formula and Fomon and colleagues' hydration constants.[20,21]

Data Analysis

Data were analyzed using SAS® University Edition version 9.4 (SAS Institute Inc., Cary, NC). Descriptive statistics were used to summarize children's sugar intake and to compare children's sugar

intake in our sample to the recommendations of the World Health Organization and American Heart Association. Linear regression models using generalized estimating equations (GEE's) were fitted to estimate associations between sugar intake and anthropometric measures. GEE's were used to account for any dependence between sibling participants,[22] and to attain 95% confidence intervals for categories of sugar sources. The variables age and sex were identified as potential confounders and controlled for in the models that explored associations between sugar intake and children's body weight, fat mass, and waist circumference.

Results

Demographic characteristics

Among our sample of 109 children, the mean age was 3.67 ± 1.24 years and 84% of the participants were Caucasian. Approximately 61% of parents reported their annual household income >$80,000 and 41% had completed postgraduate training or degrees (Table 1).

Sugar intake amounts and percent of total energy

Sugar intakes (mean (g) ± SD) were 86 ± 26 (21.5 teaspoons) for total sugars, 31 ± 15 (7.75 teaspoons) for free sugars and 26 ± 13 (6.5 teaspoons) for added sugars. Relative to percent of total energy, 80% of children had free sugar intakes that exceeded the 5% lower limit recommendation set by the World Health Organization (WHO)[6] and followed by Health Canada[23] (Supplementary materials: Table 1) and 32% of children had free sugar intakes that exceeded the upper 10% recommendation (Figure 1).[6] Furthermore, 20.2% of children had added sugar intake that exceeded the 10% limit as set by the American Heart Association (AHA) Scientific Statement[24] (Figure 2).

Food sources of free and added sugar intakes

We noted that 100%; 77% and 72% of the children in our study sample were consuming foods with free and added sugar from bakery products; sugars and sweets and cereals and grain products respectively (Table 2). For free sugar intake, the top three food sources included bakery products (9.1 g; 95% CI 8.0, 10.2), sugars and sweets (7.5 g; 95% CI 6.3, 8.7), similar contributions by cereals and grain products (4.2 g; 95% CI 3.2 to 5.1) and beverages (10.5 g; 95% CI 8.0, 12.9). For added sugars, the top three food sources included bakery products (9.1 g; 95% CI 8.0, 10.2), sugars and sweets (7.5 g; 95% CI 6.3, 8.6), cereals and grains (4.2 g; 95% CI 3.2, 5.1) (Table 3).

Cross-sectional associations between sugar intakes and anthropometric measures

We found a weak, inverse, statistically significant association between free sugar intake and waist circumference (β= -0.02; 95% CI= -0.04, -0.0009 p-value=0.04) (Table 4). No other significant associations were found between intakes of free, added or total sugar and other anthropometric measures (Table 4).

Interpretation

Our study investigated daily intakes of total, free and added sugar along with key food sources among preschool-aged children in the GFHS pilot studies. In addition, we examined cross-sectional

associations between total, free and added sugar and anthropometric measures. To our knowledge, this is the first Canadian study to examine cross-sectional associations between dietary sugar intake and anthropometric measures among preschool-aged children.

Children's intake of total sugars (86 g/day) in our sample was below the 2015 Canadian average of 101 g/day or 24 teaspoons for children 2-8 years.[25] This age range might be too large for comparison as intake of total sugars may change markedly between toddlers, preschoolers and children. The average added sugar intake of 6.5 teaspoons/day in our sample exceeds the AHA Scientific Statement, which recommends <6 teaspoons / day for children >2 years and limiting or avoiding added sugar below 2 years.[24] In 2005, Kranz and colleagues analyzed added sugar consumption for 2 to 5 year old American children through the Continuing Survey of Food Intake.[26] In this study, the majority of participants consumed <25% of energy from added sugar, similar to our study sample.[26] Among this US sample, the top food sources were fruit drinks, high fat desserts and soft drinks,[26] whereas in our sample bakery products were the top food source. Data from population-based surveys in Canada and the US suggest that intake of SSB has decreased over the past 10 years, which may explain the differences in top food sources of sugar intake in our study versus earlier studies with preschoolers.[27,28]

A total of 80% of preschool-aged children in our study had a free sugar intake that exceeded the 5% recommendation and 32%, that exceeded the 10% recommendation set by the WHO.[6] These results are similar to research by Devenish and colleagues who analyzed free sugar intake among 2-year-old children in Australia.[16] In this study, 71.1% of children exceeded the 5% of total energy recommendation and 38% exceeded the less than 10% recommendation.[16] The main free sugar sources found in their sample were fruit juice, biscuits, cakes, desserts and confectionery, which were similar to the main free sugar sources we found in our study.[16]

Results linking sugar intake with weight gain and obesity in children are conflicting as seen in systematic reviews.[6] For instance, The Dortmund Nutritional and Anthropometric Longitudinally Designed (DONALD) Study of 216 participants (0.5 to 7 years)[3] found that a high added sugar intake in the first 2 years of life was associated with an increased BMI by age 7 years.[3] By contrast, using NHANES data (1971-1975; 1988-1994) from children aged 1-18 years, no association was found between total and added sugar with BMI.[29] This study suggested that total energy intake, rather than a specific nutrient, had a greater impact on children's BMI.[29]

There is a paucity of literature on sugar intake and anthropometric measures in preschool-aged children. While overall the research examining dietary sugar intake has been mixed in children, evidence shows SSB intake is associated with cardiometabolic risk factors that include waist circumference and BMI Z-scores in preschool-aged children.[30,31] This is likely due to the increased energy density in the overall dietary pattern with SSBs intake. Our findings indicated a statistically significant negative association between free sugar intake and waist circumference (that is not clinically relevant due to the small regression coefficient estimate) and do not suggest any other associations of sugar with anthropometric measures.

Study Limitations

Some limitations should be considered when interpreting our results including that our study sample consisted of 84% Caucasians and over 61% of participants had an annual household income over $80,000; thus, our results may not be generalizable to children from diverse ethnic or low socio-

economic populations. Parent-reported food records were used to collect dietary data which may be underreporting children's sugar intake data due to social desirability bias or errors in the reporting of children's intake. In Canada, it is not required that companies identify the proportion of added and naturally occurring sugars on nutrition labels. This meant that for some products, such as in infant formula, we were unable to differentiate the free and added sugars in the product. Our added sugar definition was adapted from Louie and colleagues[14] and includes honey and syrups. While this definition is aligned with other research in this field[32] it has been debated[33] as it is not consistent with current WHO and Health Canada definitions (Supplementary materials: Table 1).[6]

Conclusion

The study findings support current recommendations that preschool-aged children should limit free and added sugar intake to establish healthy dietary patterns early in life. While our study does not provide evidence linking sugar intakes and anthropometric measures, most children exceeded the WHO free sugar recommendations. This study can inform healthcare professionals and policy makers about the current consumption patterns of sugars in young children as there is currently limited research available for this age group. Our data regarding key food and beverage sources of sugar intake among preschool-aged children can be used to guide dietary and policy advice for preschool-aged children. Given the limited research examining sugar intake among young children and the impact on cardiometabolic risk factors in early years, further investigation of dietary sugar intake (amount, sources) and longitudinal associations with anthropometric measures are warranted in preschool-aged children.

Data Sharing Statement

The GFHS welcomes external collaborators. Interested investigators can contact GFHS investigators to explore this option, which preserves participant confidentiality and meets the requirements of our Research Ethics Board, to protect human subjects. Due to Research Ethics Board restrictions and participant confidentiality, we do not make participant data publicly available.

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Author contributions: AM conducted and interpreted the data analysis and wrote the manuscript. DWLM and JH are the Co-Directors of the GFHS and supervised this project. GD was the statistical advisor and ACB and AMD were co-advisors for this project. These authors critically evaluated the results of this project. AA assisted with data acquisition and JY, JLH, KJ, AC and AS assisted with data cleaning and data review. All authors reviewed and revised this manuscript.

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Tables and Figures:

Table 1: Characteristics of parents and children participating in Guelph Family Health Study pilot studies at baseline.

Characteristic	**N (%)**
Household Income (Canadian)	
Did not answer	3 (3.9)
<$39,000	5 (6.5)
$40,000-49,999	6 (7.8)
$50,000-59,999	5 (6.5)
$60,000-69,999	5 (6.5)
$70,000-79,999	6 (7.8)
$80,000-89,999	10 (13.0)
>$90,000	37 (48.0)
Parent Education	
Postgraduate training or degree	32 (41.5)
University graduate	30 (39.0)
College graduate	7 (9.1)
Some university, some college or technical school	8 (10.4)
Child Ethnicity	
Caucasian	92 (84.4)
Other	17 (15.5)
Child Age in years, Mean ± SD	3.67 ± 1.24
Child Sex Male Female	 54 (49.5) 55 (50.5)

Children Participants (n=109) and Families/Parent (n=77)

Figure 1: Percent of preschool-aged children in the GFHS pilot studies (n= 109) who consume free sugars in the amounts of 0 to <5%, ≥5% to <10%, ≥10% to <25%, ≥25% of total energy

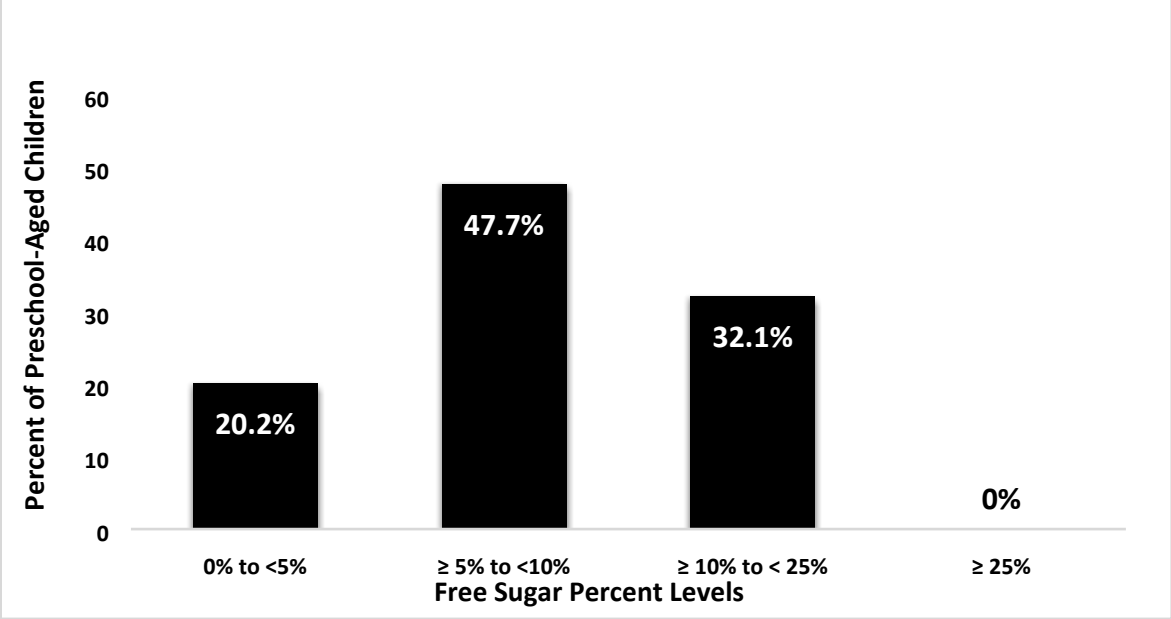

Figure 2: Percent of preschool-aged children in the GFHS pilot studies (n= 109) who consume added sugars in the amounts of 0 to <5%, ≥5% to <10%, ≥10% to <25%, ≥25% of total energy

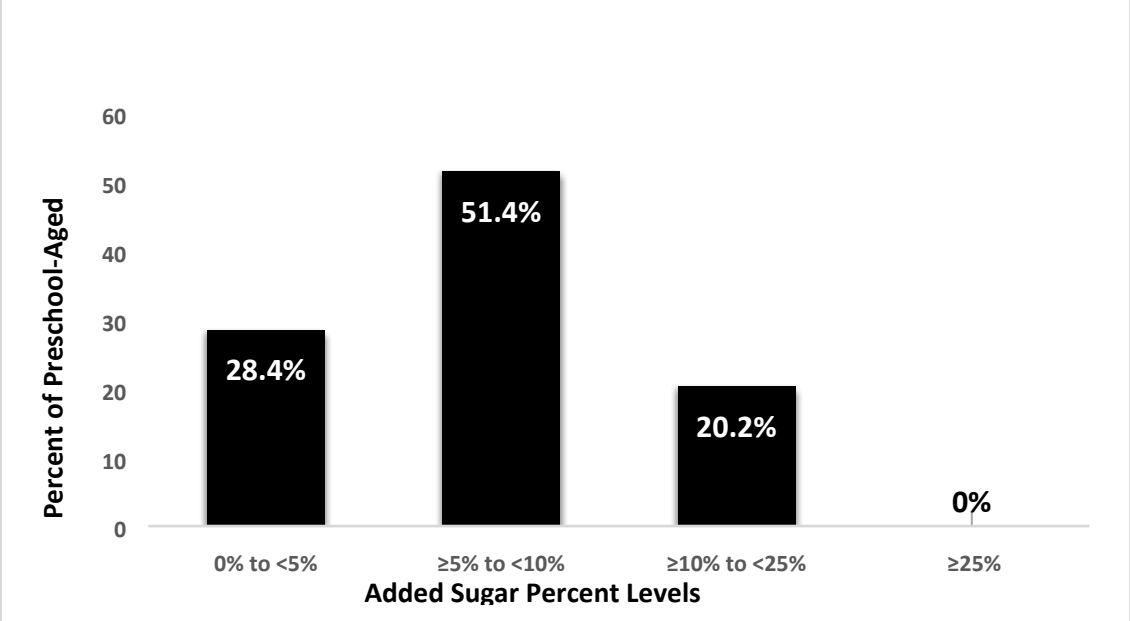

Table 2: Food source categories contributing to free and added sugar intakes in preschool-aged children (n=109) in the GFHS pilot studies.

Food source category[1]	Type of sugar	Percent of Free and Added Sugar intake[2]	n	Percent of children consuming the category[3]
Bakery Products	Free Sugar	29.6	109	100
	Added Sugar	34.9	109	100
Sugars and Sweets	Free Sugar	18.8	84	77
	Added Sugar	22.1	84	77
Cereals and Grain Products	Free Sugar	9.4	77	71.6
	Added Sugar	11.1	77	71.6
Beverages	Free Sugar	23	77	70.6
	Added Sugar	10.5	51	46.8
Dairy Products and Substitutes	Free Sugar	6.4	63	57.8
	Added Sugar	7.5	63	57.8
Snacks	Free Sugar	1.4	48	44
	Added Sugar	1.7	48	44
Sauces, Dips and Condiments	Free Sugar	2.1	44	41.3
	Added Sugar	2.5	44	41.3
Desserts	Free Sugar	4.1	29	26.6
	Added Sugar	4.7	28	25.7
Mixed Dishes, Sides and Entrees	Free Sugar	1.2	21	19.3
	Added Sugar	1.3	20	18.4
Meats, Eggs and Substitutes	Free Sugar	0.3	17	15.6
	Added Sugar	0.3	17	15.6
Fruits	Free Sugar	1.5	12	11
	Added Sugar	1.7	12	11
Other Foods and Beverages	Free Sugar	1.1	10	9.2
	Added Sugar	1.3	10	9.2
Nuts and Seeds	Free Sugar	0.1	7	6.4
	Added Sugar	0.1	7	6.4
Fats, Oils and Vinegars	Free Sugar	0.1	5	4.6
	Added Sugar	0.2	5	4.6
Soups	Free Sugar	0.3	5	4.6
	Added Sugar	0.3	5	4.6

Vegetables	Free Sugar	0	0	0
	Added Sugar	0	0	0
Fish and Seafood	Free Sugar	0	0	0
	Added Sugar	0	0	0

[1]17 categories were adapted from article by Bernstein and colleagues (2016)[17]

[2]*Percent of Free and Added Sugar intake:* Calculation for Free and Added Sugar: was completed by calculating the average of added/free sugar (grams) for 3-days for each participant in the specific category divided by total added/free sugar (grams) times 100.

[3]*Percent of children consuming the category*: This is a calculation of the percent of participants that were included in each category. Total n =109 preschool-aged children.

Table 3: Key food source categories of contribution to free and added sugar intake in preschool-aged children in the GFHS pilot studies (a subset of Table 2) with n, mean and confidence intervals for these categories.

Food source category	Type of sugar	n	Mean intake (g)	95% CI (g)
Bakery Products	Free Sugar	109	9.1	8.0 - 10.2
	Added Sugar	109	9.1	8.0 - 10.2
Sugars and Sweets	Free Sugar	84	7.5	6.3 - 8.7
	Added Sugar	84	7.5	6.3 - 8.6
Cereals and Grain Products	Free Sugar	77	4.2	3.2 - 5.1
	Added Sugar	77	4.2	3.2 - 5.1
Beverages	Free Sugar	77	10.5	8.0 - 12.9
	Added Sugar	51	6.5	4.7 - 8.3
Dairy Products and Substitutes	Free Sugar	63	3.4	2.8 - 4.0
	Added Sugar	63	3.4	2.8 - 4.0
Snacks	Free Sugar	48	1.0	0.6 - 1.4
	Added Sugar	48	1.0	0.6 - 1.4
Sauces, Dips and Condiments	Free Sugar	44	1.6	1.2 - 1.9
	Added Sugar	44	1.6	1.2 - 1.9
Desserts	Free Sugar	29	4.7	3.6 - 5.9
	Added Sugar	28	4.8	3.6 -6.0

Key food sources were defined based on those categories that were consumed by at least 25% of the preschool-aged children in the GFHS pilot studies

Table 4: Cross-sectional associations between added, free and total sugar intakes and anthropometric measures including body weight, BMI Z-scores, waist circumference and percent fat mass (n=109).

	Body Weight[1]		**BMI Z-scores**	
	β (95% CI)	**p-value**	**β (95% CI)**	**p-value**
Added Sugar	-0.01 (-0.03, 0.007)	0.25	-0.005 (-0.01, 0.002)	0.06
Free Sugar	-0.011 (-0.01, 0.002)	0.08	-0.004 (-0.008, 0.0006)	0.09
Total Sugar	-0.004 (-0.01, 0.006)	0.45	-0.001 (-0.005, 0.002)	0.07
	Waist Circumference[1]		**Fat Mass**[1]	
	β (95% CI)	**p-value**	**β (95% CI)**	**p-value**
Added Sugar	-0.02 (-0.05, 0.008)	0.16	-0.001 (-0.03, 0.03)	0.95
Free Sugar	-0.02 (-0.04, -0.0009)	0.04	-0.003 (-0.03, 0.02)	0.82
Total Sugar	-0.009 (-0.02, 0.007)	0.28	0.0009 (-0.02, 0.02)	0.92

[1]Data has been presented controlling for age and sex for body weight, waist circumference and percent fat mass.

Supplementary Materials:

Table 1: National and global recommendations for free and added sugar intakes for children

Organization	Free Sugar or Added Sugar Recommendations for Children	Age Group
World Health Organization, 2015[6]	"WHO recommends reducing the intake of free sugars to less than 10% of their total energy intake (strong recommendation). WHO suggests a further reduction to below 5% would provide additional health benefits (conditional recommendation)."	Throughout the lifespan (in both adults and children)
Health Canada, 2019[23]	"Free sugars: Less than 10% of total energy"	2 years or older
American Heart Association-Scientific update, 2017[24]	"Recommend that children consume ≤25 g (100 cal or ≈6 teaspoons) of added sugars per day for children and to avoid added sugars for children <2 years of age."	Children from < 2 years until 18 years