Snack and Beverage Sources of Free Sugar in Canadian Preschool-aged Children

by

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ABSTRACT

SNACK AND BEVERAGE SOURCES OF FREE SUGAR IN CANADIAN PRESCHOOL-AGED CHILDREN

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This thesis investigated free sugar (FS) intake from snacks and beverages among young Canadian children and compared intake with World Health Organization recommendations that FS intake be limited to <5% of total energy (TE). In 267 non-breastfeeding children from 210 families, FS contributed 10.6 ± 6.9% TE (mean ± SD). In our sample, 30% of children consumed ≥5% TE from snack FS and 17% consumed ≥5% TE from beverage FS. Snacks and beverages accounted for 49 ± 30.9% of FS energy. Top snack sources of FS (% children, children's %TE from FS) were bakery products (55%, 2.4%), candy and sweet condiments (21%, 3.0%), and sugar-containing beverages (SCB) (20%, 4.1%). Top SCB sources of FS (49%, 5.3%) were 100% fruit juice (22%, 4.6%) and flavoured milk (11%, 3.1%). Efforts should be made to reduce FS intake from these sources, particularly bakery products, candy and sweet condiments, and SCBs.

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LIST OF SYMBOLS, ABBREVIATIONS OR NOMENCLATURE

AAP: American Academy of Pediatrics

AS: Added sugar

ASA24: Automated Self-Administered 24-hour

CCHS: Canadian Community Health Survey

CNF: Canadian Nutrient File

DPB: Diastolic blood pressure

ECLS-B: Early Childhood Longitudinal Study-Birth Cohort

FFQ: Food Frequency Questionnaire

FITS: Feeding Infants and Toddlers Study

FNDDS: Food and Nutrient Database for Dietary Studies

FPED: Food Patterns Equivalents Database

FS: Free Sugar

HDL-C: High density lipoprotein cholesterol

LDL-C: Low density lipoprotein cholesterol

MHNS: Mexican Health and Nutrition Survey

NCNPAS: National Children's Nutrition and Physical Activity Survey

NHANES: National Health and Nutrition Examination Study

SBP: Systolic blood pressure

SCB: Sugar-containing beverage

SES: Socioeconomic status

SSB: Sugar-sweetened beverage

TE: Total energy

TG: Triglycerides

TS: Total sugar

WHO: World Health Organization

LIST OF APPENDICES

Chapter 1 Introduction and Literature Review: Sugary Snack and Beverage Consumption Among Preschool-aged Children

1.1 Introduction

Excess intakes of added sugar (AS) and free sugar (FS) have known associations with increased risk of dental caries and cardiometabolic disease (1,2). Health authorities such as the World Health Organization (WHO) recommend the reduction of AS and FS in the diet (2). However, preschool-aged children continue to over-consume AS and FS globally and feasible strategies are needed to help reduce FS intake in this population (3–5). Snacks may be an ideal target for health intervention as they contribute a large and increasing proportion of energy in young children and increased snacking frequency has been associated with increased AS intake among preschool-aged children (6–8). A clear understanding of snack and beverage dietary intake patterns in preschool-aged children will help to inform specific recommendations for this population.

The purpose of this review is to provide an overview of the role of snacks and beverages in AS and FS intake in preschool-aged children. In the first section, definitions and intake recommendations for total sugar (TS), AS, FS, snacks, and beverages are reviewed and summarized. In the second section, cardiometabolic association and intake data are summarized for snacks followed by beverages. Finally, variables impacting snack, beverage, and sugar intake, are investigated. Only studies investigating samples which included preschool-aged children 2-5 years old were included.

1.2 TS, AS and FS: definitions and recommendations

TS are defined as all sugars in foods and beverages, whether naturally present in intact fruits, vegetables, and milk, or in the form of AS or FS (9). AS are sugars added during processing and preparation and can generally be thought of as sugars added for the purpose of sweetening (9). FS are defined as all monosaccharides and disaccharides added to foods by the manufacturer, cook or consumer, plus sugars naturally present in honey, syrups and fruit juices (2,10). AS and FS are components of TS that should be differentiated because AS and FS consumption often represent excess calories without accompanying nutritional benefits. An example of this can be found by comparing the nutrient values of three apple-containing food and beverage items in **Table 1.1**. Known associations between excess AS and FS intake with increased dental caries and increased cardiometabolic risk are the basis of dietary sugar recommendations that exist globally (**Table 1.2**) (2,9).

Table 1.1: Sugar values and nutrient summary for a medium apple processed to unsweetened apple juice, then fruit punch [1]

Item	Sugar Values	Nutrient summary
Medium apple	TS = 19g - AS = 0g - FS = 0g	Nutrient dense, contains nutrients including fibre
Minute Maid 100% Apple Juice (177 mL)	TS = 19g - AS = 0g - FS = 19g	Less nutrient dense than an apple, fibre removed
Minute Maid Fruit Punch (177 mL)	TS = 17.7g - AS = 16.2g - FS = 17.7g	Nutrient-poor, fibre removed, sugars added

[1] Sugar values for the medium apple was sourced from the Canadian Nutrient File (CNF) (11). Sugar values for Minute Maid products were sourced from the US Minute Maid product website (12).

Table 1.2: Select AS and FS intake recommendations for children

Organization and Reference	AS and FS Recommendation
WHO (2)	- Reduce intake of FS throughout the life course to reduce risk of dental caries and weight gain - Reduce intake of FS to <10% of total energy intake (TE) in both adults and children to reduce the risk of dental caries and <5% TE for a further reduction of risk
Health Canada (13)	- <10% of TE from FS, no specific recommendations for children
Heart and Stroke Foundation of Canada (10)	- The Heart and Stroke Foundation recommends that an individual's total intake of FS not exceed 10% of total daily calorie (energy) intake, and ideally less than 5%.
American Heart Association (9)	- ≤25 g AS (100 kcal or ~6 teaspoons) in children - Avoid AS in children <2 years

1.3 Snacks and beverages: definitions and recommendations

Several definitions of snacks exist in the literature (14), however, this review supports the common definition of foods and beverages consumed between meal occasions (i.e., outside of breakfast, brunch, lunch, dinner, supper). There are no clear definitions of sugary snacks, however, in this review they are defined as foods and beverages consumed between meal occasions that can contribute to excess FS. This aligns with Health Canada's definition of sugary drinks: beverages that can contribute to excess FS (13). This encompasses the overlapping terms sugar-sweetened beverages (SSB) and sugar-containing beverages (SCB). SSBs include beverages with AS while SCBs include beverages with both AS and 100% fruit juice. Several recommendations exist to reduce intakes of FS from snacks and beverages (**Table 1.3**). Analysis of these recommendations found that most organizations take a total avoidance approach using language such as "should not be consumed regularly", "avoid", "stay away from", and "limit". Some organizations allow for a

certain amount of 100% fruit juice. However, most organizations recommend limiting and replacing all SCBs including 100% fruit juice with alternatives such as water or plain milk.

Table 1.3: Sugar snacking and beverage recommendations

Organization and Reference	Sugary Snack or Beverage Recommendations
The European Society for Paediatric Gastroenterology, Hepatology and Nutrition Committee on Nutrition (15)	"Sugar should preferably be consumed as part of a main meal and in a natural form as human milk, milk, unsweetened dairy products, and fresh fruits, rather than as SSBs, fruit juices, smoothies, and/or sweetened milk products. FS in liquid form should be replaced by water or unsweetened milk drinks"
Canada's Food Guide (13)	"Sugary drinks and confectionaries should not be consumed regularly" "Prepare meals and snacks using ingredients that have little to no added sodium, sugars or saturated fat"
American Academy of Pediatrics (AAP) (16)	"100% fruit juice consumption should be limited to 4 ounces (118ml) per day in toddlers 1 through 3 years of age, and 6 ounces (177 ml)/day for children 4 through 6 years of age"
Indian Academy of Paediatrics (17)	"recommends intake of regional and seasonal whole fruits over fruit juices in children and adolescents, and advises no fruit juices/drinks to infants and young children (age <2 years), whereas for children aged 2-5 years and >5-18 years, their intake should be limited to 125 mL/day and 250 mL/day, respectively"
World Health Organization (18)	"limiting the consumption of foods and drinks containing high amounts of sugars, such as sugary snacks"

	"eating fresh fruit and raw vegetables as snacks instead of sugary snacks"
Heart and Stroke Foundation of Canada (19)	" Snack sensibly. Stock up on roasted nuts, lower-fat, lower-sodium cheese and crackers, veggies and dip, and plain yogurt with fresh fruit. Reduce the amount of baked goods, sweet desserts, candies, and chocolates you eat." "Avoid sugary drinks." "Avoid soft drinks and sports drinks. They are high in sugar and have no nutritional value (which is why they are called "empty calories")." "Avoid fruit juice, even when it is 100% fruit juice. Although fruit juice has some of the benefits of the fruit (vitamins, minerals), it has more sugar than the fruit and less fibre. Fruit juice should not be consumed as alternative to fruits. Canadians should eat their fruits, not drink them." "Stay away from fancy hot drinks with FS. Order a latte instead of a mocha coffee. Add nutmeg and cinnamon toppings for extra flavor rather than adding sugar."
Diabetes Canada (20)	"Limit intake of SSBs and drink water in their place."

1.4 Sugary snacks and cardiometabolic risk

Health Canada recommends the reduction of consumption of AS and FS through several methods such as preparation of snacks using ingredients that have little to no AS. Although intakes of AS and FS have been linked to increased cardiometabolic risk (1), research investigating the

relationship between sugary snack intake and particularly non-beverage sugary snack intake and cardiometabolic risk is limited (2).

In a cross-sectional study in 18,988 adults in the National Health and Nutrition Examination Survey (NHANES), the relationship between snacking clusters and select cardiometabolic risk factors was examined using in-person 24-hour dietary recalls (21). Snacks were defined by participant-identified snacking occasions. Participants were assigned to one of 12 snacking clusters according to which one contributed the greatest to their total snacking energy intake. Compared to non-snackers, the snacking clusters of Cakes/Cookies/Pastries, Sweets, Milk Desserts, and Soft Drink were all significantly associated with increased consumption of total AS. Furthermore, the snacking clusters of Sweets and Milk Desserts were significantly associated with higher energy intake compared to non-snackers and the Soft Drink snacking cluster was significantly associated with lower diet quality compared to non-snackers. Despite associations with higher AS intake, the snacking clusters of Cakes/Cookies/Pastries, Sweets, Milk Desserts, and Soft Drinks were not significantly associated with increased cardiometabolic risk as measured by diastolic blood pressure (DBP), systolic blood pressure (SBP), high density lipoprotein cholesterol (HDL-C), and low density lipoprotein cholesterol (LDL-C) (21). These findings suggest that in adults, sweet snacking is generally associated with increased AS intake. However, specific sweet snacking categories have complex relationships with TE. It should be noted that these data are being compared with data from non-snackers. Since most children snack and snacking can be part of a wholesome diet, future research should investigate the associations between snacking clusters and intake of total AS, diet quality, and cardiometabolic risk (without comparison to non-snackers) in young children. No research investigating the relationship between sugary snacks and cardiometabolic risk was identified in children.

1.5 Sugary snack trends

Snacking is common among preschool-aged children and contributes a substantial amount of children's energy intake; studies have found that >25% of Canadian preschool children's TE comes from snacks and in the United States (US), it is 28% (22–25). Recent data demonstrate that snacking is becoming more frequent and is contributing an increasing proportion of energy (26). For example, Dunford and Popkin (26) found that in a nationally representative sample of US preschool-aged children (2-5 years), the number of daily snacks consumed, percentage of children who snacked, and energy consumed per snacking occasion all increased from 1977 to 2014. Most young Canadian children have been found to consume snacks multiple times a day. The 2015 Canadian Community Health Survey (CCHS) conducted by Health Canada found that in a nationally representative sample of Canadians, consumption of at least one snack in the past 24 hours was most prevalent in children aged 2-5 years (96.4%) (24). This study found that 18%, 64%, and 19% of children 2-5 years old consumed snacks once, 2-3 times, and ≥4 times in the past 24 hours, respectively. Other studies have shown that sugary snacks are introduced early in life. For example, the US Feeding Infants and Toddlers (FITS) 2008 study found that cookies were fed to 8.7% of infants 6-8 months and 17.5% of children 2 years of age (27). Furthermore, candy or SSBs were consumed as a snack by approximately 14% of children 1-<2 years of age and nearly 20% of children 2 years of age. In Canada, FS from snacks has not been assessed in preschoolers although a national Canadian study found that in children >1 year old, "sugars, syrups, preserves, confectionary and dessert", "regular soft drinks", "baked products", "juice (w/o AS)", "frozen desserts", and "fruit drinks" were the top six contributors to FS (5). Given the tendency of young children to be "grazers" and recent increases in snacking frequency, it is clear that snacking is playing an increasingly important role in the overall diet quality of young children.

Categories of snacks being consumed may also be changing over time. Dunford and Popkin (26) found that consumption of SSB as a snack among children and adolescents decreased from 1977 to 2014. This study used data from eight surveys representative of the US population to investigate snacking trends in 49,952 children ≤18 years from 1977 to 2014. Data were from the 1977–1978 Nationwide Food Consumption Survey; the 1989–1991 Continuing Survey of Food Intake by Individuals (CSFII), the 1994–1996 CSFII and the 1997–1998 CSFII. Four NHANES were used: NHANES 2003–2004, 2005–2006, 2011–2012 and 2013–2014. In children 2-5 years old, calorie intake from SSB as a snack decreased from 1977 to 2012. This trend was reflected in the overall sample ≤18 years where consumption of SSB as a snack increased from 1977 to 2006 and decreased from 2006 to 2014 resulting in overall lower intake of SSB as a snack. Upon stratification by race, SSB intake increased only in non-Hispanic Black individuals. Furthermore, calorie intake from Desserts and Sweets as snacks slightly increased in children 2-5 years although there was no difference found in the entire sample. Lower intake of SSBs as a snack may be an effect of altered public beliefs; however, sociodemographic differences suggest that resources should be allocated both towards general population interventions and targeted to vulnerable populations. Limitations including differences in dietary collection methods among the surveys that the study included should be considered.

1.6 Snack categories

Previous studies have investigated food and beverage sources of AS and FS, as well as the amount of sugar in the food supply (4,5,28). Studies suggest that bakery products and SSB are categories that contribute excess added and FS intake (4). However, only a few studies investigated

how specific snacking categories contribute to AS and FS energy intakes in preschool-aged children.

Two studies reporting the proportion of children consuming various snack categories were identified. As part of FITS 2008, the cross-sectional snacking of (n=1461) preschool-aged children 2-4 years old was investigated (27). Among children 2-3 and 3-4 years old, percent consumers of snack categories were as follows: fruit (46.3%, 42.9%), cow's milk (38.4%, 40.7%), cookies (36.8%, 33.1%), 100% fruit juice (25.7%, 19.1%), sweetened beverages (19.9%, 17.7%), candy (19.8%, 23.9%), yogurt (12.8%, 12.2%), and frozen desserts (8.0%, 12.2%). Daily per capita consumption of snack categories in decreasing order for the same age groups was as follows: Cow's milk (95.8 g, 93.4 g), 100% fruit juice (45.4 g, 41.2 g), and SSBs (42.7 g, 35.2 g). Kay et al. (29) analyzed 1733 children 0-4 years old from FITS, 2016. Among children 1-<2 years and 2-4 years, 24% and 22.1% consumed 100% fruit juice and 13.2% and 16.6% consumed fruit flavored drinks as a snack, respectively. Consumption of other SSBs during snacking occasions were not reported due to low prevalence of consumption. Together, these studies suggest that among US preschool-aged children, cookies, fruit juice, SSBs, candy, and yogurt are commonly consumed sugary snacks.

Among US children (n=3,429) 2-5 years from 2005-2012 NHANES, the top sources of snack AS energy were sweetened beverages (i.e., soda and fruit drinks) (25%), sweet bakery products (20%), other desserts (15%), candy (14%), flavored milk (6%), and yogurt (4%), jams, syrups toppings (3%), ready-to-eat cereals (2%), coffee and tea (1%) (23). GFHS pilot data (n=52) found that SSBs were consumed on average 0.2 times per day, and sugary treats (such as Bear Paws™, yogurt, and granola bars) were consumed 0.7 times per day (22). Girls consumed significantly more sugary treats than boys (0.8 versus 0.5 times per day).

1.7 Snacks, AS, FS and energy contribution

Assessing how sugary snacks contribute to energy is important to understand snacking in the context of energy recommendations. For example, the WHO recommends that FS intake be limited to less than 5% or 10% of TE (Table 2). Consumption of sugary snacks may increase TE as well as raise excess AS and FS consumption over recommended levels. This section summarizes research investigating how sugary snacks contribute to TE, AS energy and FS energy in preschool-aged children (**Table 1.4**).

Snacks were consistently found to contribute more than a quarter of TE among preschool-aged children. Cross-sectional analysis of 2005-2012 NHANES (n=3429), CCHS 2015 (n=1,181,823) and pilot data from the GFHS (n=52) revealed that in preschool-aged children (2-5 years), snacks accounted for 28%, 27%, and 33.2% of TE, respectively (22–24). Large contribution of snacks to TE is mirrored by snack contribution to AS. Analysis of 2005-2012 NHANES found that snacks contributed 39% (22 g) of AS in children 2-5 years old (23). Another cross-sectional analysis of US preschool-aged children enrolled in FITS 2008 (n = 1461) found that snacks accounted for 35.6% and 38.5% of total AS in 2-3 year (n = 736) and 3-4 year (n = 725) old children, respectively (27).

Nutrient density of snacks is also relevant to consider. Shriver et al. (23) found that snacks had an average nutrient density of 4.9 grams (19.6 kcal) of AS per 100 calories. This energy density variable is useful to assess the AS content of the snacks the children are consuming.

In conclusion, previous studies suggest that snacks contributed over one quarter of TE in US and Canadian samples and over one third of AS energy in US samples. Through analysis of energy density, Shriver et al. (23) found that approximately 1 in 5 snack calories was from AS. It can be

concluded from these data that snacks are a major source of TE and that they significantly contribute to FS energy and AS energy in preschool-aged children (23,27). Research investigating specific snack categories suggest that bakery products, SCB, and candy are categories of sweet snacks that are consumed by the highest proportion of children, particularly in the US. Research investigating how snack categories contribute to AS or FS intake was not identified in this population and sugar snacking data relevant to Canadian preschool-aged children is lacking.

Table 1.4: Narrative summary of studies investigating snack intake among preschool-aged children

Country, Study, Sampling Year(s), Reference	n	Age (years)	Dietary Assessment Method	Relevant Results
Canada GFHS 2014-2015 (22)	52	1.5-5	3-day food records (2 days, 1 weekend day) by proxy, ESHA Food Processor *Snack categories* Sugary treats, salty snacks, SSBs (All beverages with AS)	**Frequency of snack consumption** -SSBs: 0.2 times per day -Sugary treats: 0.7 times per day -Bear Paws, yogurt, and granola bars were frequently consumed sugary snacks. **Contribution to TE** -Snacks: 33.2% -TS from snacks: 12.4%
US NHANES 2005 and 2012 (23)	3,429	2-5	24-h recall, AMPM by proxy, in-person interview, Food Patterns Equivalents Database (FPED), Food and Nutrient Database for Dietary Studies (FNDDS). *Snack categories:* What We Eat In America Categories	**Contribution to TE** **-Snacks:** 28% **Contribution of snacks to AS:** 39% **Contribution to snack AS** -Soda and fruit drinks: 25% -Sweet bakery products: 20% -Other desserts: 15% -Candy: 14% -Flavored milk: 6% -Yogurt: 4%
US FITS 2008 (27)	1,461	2-4	24-h recall, multiple pass by proxy, telephone interview, FPED, FNDDS *SSB:* Carbonated and non-carbonated sweetened beverages *Snack categories:* FITS Food groups	**Percent consumers (2-3 years, 3-4 years)** -Cookies (36.8%, 33.1%) -100% fruit juice (25.7%, 19.1%) -SSBs (19.9%, 17.7%) -Candy (19.8%, 23.9%) -Yogurt (12.8%, 12.2%) -Frozen desserts (8.0%, 12.2%) **Contribution of snacks to AS** -2-3 y: 35.6% -3-4 y: 38.5%
US FITS 2016 (29)	1,733	1-4	24-h recall, multiple pass by proxy, telephone interview, FPED, FNDDS *Snack categories:* FITS Food groups adapted to better align with NHANES	**Percent consumers (1-2 years, 2-4 years)** -100% fruit juice: 24%, 22.1% -Fruit flavored drinks: 13.2%, 16.6%

1.8 Sugary drinks and cardiometabolic risk

Four studies have investigated the impact of sugary beverages on cardiometabolic risk in preschool-aged children (30–33).

The first study investigated the cross-sectional impact of SCB, SSB, and 100% fruit juice on cardiometabolic risk outcomes using repeated measures in 1778 children 2-6 years of age recruited in TARGet Kids! (Hamilton, Canada) between 2008 and 2017 (30). Dietary data were assessed using a detailed Nutrition and Health Questionnaire, which queried parents on how many 250 mL cups of each drink their child consumes in a typical day. SCBs were the sum of responses from 100% fruit juice, sweetened drinks, soda/pop. SSBs were the sum of sweetened drinks and soda/pop. A cardiometabolic risk score was calculated using SBP, waist circumference, triglycerides (TG), glucose, and HDL-C. Each additional cup of SCB intake was accompanied with a non-significant increase in the cardiometabolic risk score by 0.05 SD units after adjustment for socioeconomic status (SES) and child and parent characteristics, but not when the model was adjusted for BMI z-scores. However, analysis of individual risk factors found that each additional cup of SCB consumption was associated with a significant 0.02 mmol/L reduction of HDL-C and a significant Log (0.02 mmol/L) increase in triglycerides after adjustment. Furthermore, each additional cup of 100% fruit juice was significantly associated with a 0.02 mmol/L decrease in HDL-C. This study found that consumption of sugary beverages was associated with a small increase in cardiometabolic risk in young children.

A second study investigated the longitudinal associations of SCB intake at the age of 1 year with cardiometabolic health at median age of 5.9 years in 2045 Dutch children (31). The primary caregiver responded to a semi-quantitative food frequency questionnaire (FFQ) asking for the

infant's habitual diet over the last month, i.e., from 12 months to 13 months old. Habitual SCB intake was assessed using this FFQ and participants were separated into tertiles based on SCB intake. At the 6-month timepoint, cardiometabolic health outcomes were measured and a cardiometabolic risk score of insulin, C-peptide, HDL-C, total cholesterol, LDL-C, TG, SBP, DBP, mean arterial pressure and abdominal fat mass was calculated. In the total population, the highest tertile of SCB intake was significantly associated with a 0.13 SD higher cardiometabolic risk factor score as compared to the lowest tertile after adjustment for sociodemographic and lifestyle factors. Boys in the highest tertile of SCB intake had a significantly higher cardiometabolic risk factor score (0.18 SD) compared to boys in the lowest tertile of SCB intake. In this study, no associations were found between SCB intake and individual risk factors after adjustment.

A third study investigated the longitudinal impact of SSB intake on obesity in (n=1257) children in the Dutch GECKO Drenthe birth cohort (33). Dietary intake was assessed at 5/6 years with a FFQ and SSBs were defined to include soda, fruit drinks, instant lemonade made with fruit syrup, sugar-sweetened tea, and sugar-sweetened yogurt drinks. Anthropometrics were measured at 5/6 years and 10/11 years. Logistic regression revealed that the odds of overweight at 10/11 years in the highest versus lowest quartile of SSB consumers at 5/6 years was 3.12 (95% CI, 1.60–6.07).

A fourth study investigated the longitudinal impact of SSB intake on obesity in (n=227) Mexican preschoolers from the Early Life Exposure in Mexico to Environmental Toxicants birth cohorts (32). SSB intake was defined as the sum of daily intake of sodas, fruit drinks, and flavoured water with sugar; and was measured every six months. Anthropometrics were measured at age 8-14 years. In this study, preschoolers who were in the 3rd tertile of cumulative SSB intake (high

intake) compared to the 1st tertile had a 2.99 (95% CI, 1.27, 7.00) times increased adjusted odds of obesity and 2.70 (95% CI, 1.03, 7.03) times increased adjusted odds of abdominal obesity at 8-14 years.

These studies indicate that associations between SSBs and SCBs with weight gain, risk of type 2 diabetes, and cardiometabolic disease risk found in adults may also be present in young children (30–34). Continued monitoring and reduction of sugary beverage intake in preschool-aged children is therefore important to improve health in this population and is reviewed in the following sections.

1.9 Sugary drink trends in Canada and US – Comparative studies

The proportion of Canadian and US children consuming SCBs has decreased over the past decade (6,7). The changes found in two national cohorts (NHANES and CCHS) are summarized in **Table 1.5**.

In US preschoolers, the proportion of children consuming various sweet beverage categories has decreased (6). Cross-sectional analysis of 4,384 US preschool-aged children 2-5 years using NHANES data collected from 2003 to 2014 found that 68.9% of children consumed a sugary beverage on a given day in the 2003-2004 survey, whereas 46.5% of children consumed a sugary beverage in the 2013-2014 survey (6). Furthermore, the proportion of children consuming 100% fruit juice decreased from 55.6% to 45.4%, soda decreased from 31.4% to 14.9%, and fruit drinks decreased from 44.0% to 24.1%. Garriguet et al. (7) completed a comparable study using 24-hour dietary data collected from the CCHS in 2004 and 2015. From 2004 to 2015, the proportion of children 1-8 years who consumed 100% fruit juice decreased from 54.0% to 46.1%, regular soft drinks decreased from 14.1% – 6.3%, and fruit drinks decreased from 36.8% to 14.4%. For

contribution to TE, fruit juice decreased from 4.8% to 3.8%, soft drinks decreased from 1.0% to 0.4%, and fruit drinks decreased from 3.3 to 1.1%. In terms of mean quantity consumed per consumer (g), 100% fruit juice decreased from 327g to 266g, regular soft drinks decreased from 302g to 229g, and fruit drinks decreased from 332g to 277g. Finally, fewer children may be consuming extremely large amounts of SSBs. Analysis of NHANES 24-hour dietary data from 2003 to 2016 found that heavy (≥500 kcal/day) SSB intake (non-dairy and non-dairy alternative beverage with >0 g AS) decreased from 4.7% to 0.4% in US preschoolers 2-5 years (35).

These data demonstrate that sweet drink intake has decreased in young US and Canadian children from around 2003 to 2015. However, sweet drinks still contribute significant excess added and FS in these populations. The following section will summarize studies investigating how beverages contribute to FS intake.

Table 1.5: Trends in beverage intake among young Canadian and US children

Study, Country, Reference	n	Dietary Assessment Method	Age (years)	Results
NHANES 2003-2014, US (6)	4,384	Proxy, 24-hour dietary recalls, AMPM	2-5	**Percent consumers (2003 versus 2014)** *Change* -Sugary beverages: 86.9% to 46.5% -100% fruit juice: 55.6% to 45.4% -Diet drinks: 5.3% to 3.5% -Soda: 31.4% to 14.9% -Fruit drinks: 44.0% to 24.1% *No change* -Sports drinks: 3.7% to 3.9% -Low calorie SSBs: 3.0% to 5.3%.
CCHS 2004 and 2015, Canada, (7)	5,650[1] (2004) 2,550[1] (2015)	Proxy or parent-assisted, 24-hour dietary recall, in person or telephone, AMPM	1-8	**Percent consumers (2004 versus 2015)** -100% fruit juice: 54.0% to 46.1% -Regular soft drinks: 14.1% to 6.3% -Fruit drinks: 36.8% to 14.4% **Per capita contribution to TE** -100% fruit juice: 4.8% to 3.8% -Regular soft drinks: 1.0% to 0.4% -Fruit drinks: 3.3 to 1.1%. **Per capita contribution (g)** -100% fruit juice: 327g to 266g -Regular soft drinks: 302g to 229g -Fruit drinks: 332g to 277g

[1]Sample size of age groups was not reported by Garriguet et al. (7) and was obtained from Stats Canada correspondence (36).

1.10 SSBs, SCBs, and fruit juice

SSBs and fruit juice consumption is common among preschool-aged children and children may be consuming SSB and 100% fruit juice in excess of recommendations. Researchers have identified the use of three general approaches to investigate the consumption of sweet beverages: 1) Describing the proportion of the sample consuming beverage categories; 2) Volume of consumption (per capita, per consumer and comparing volume to recommendations); and 3) Energy contribution of beverage categories (to TE and added/FS energy). This section summarizes

articles investigating sweet beverage intake. In particular, research focused on SSB, SCB and fruit juice intake is summarized in **Appendices A and B**.

SSBs and SCBs. Children have been found to overconsume SSBs and SCBs. It should be noted that studies have used various definitions of SSBs and SCBs, sometimes excluding fruit juice and flavoured milk (29,37,38).

Although SSB intake is decreasing in Canadian and US preschool-aged children, overall intake remains of concern (6,7). US studies using 24-hour recalls have found that 31% to 46% of preschool-aged children (1.5 – 5 years) consume SSBs per day (29,39). Concerningly, in 2005, almost one in three US children (mean 4.5 years) drank SSBs every day and 72.9% drank SSB ≥1 time in the past week (40). A cross-sectional analysis of 24-h diet recalls from 1733 children (2-4 years) enrolled in FITS 2016 found that the proportion consuming, mean consumption per capita and per consumer values for SSBs was high (45.5%, 135.9g, and 298.7g, respectively); SSBs were composed of fruit drinks (34.5%, 90.7g, 263.1g), soft drinks (8.8%, 19.6g, 228.8g), and tea and coffee (unreported), while flavoured milk was analyzed separately from the SSB category (15.2%, 38.4g, 252.4g) (29). Another analysis of FITS 2016 found that in (n=600) children 2-4 years old, 6.9% of children consumed sweetened teas and 1.8% consumed sports drinks (41).

Wang et al. (42) completed a cross sectional analysis of 3,345 non-breastfed children, <5 years from three NHANES cycles (2009-2014) and found that SCBs contributed 6.7% of TE. Since this value was calculated from all macronutrients and not just sugar, a deeper analysis of AS was completed. In this analysis, SSBs were not explicitly defined, however, AS from SSBs were indirectly calculated by calculating AS from all beverages. AS from SSBs contributed 3.8% TE and this proportion increased with age as follows: 0–<1-years (0.3%), 1–<2-years (3.4%), 3-<4

years (4.6%), and 4-<5 years (5.1%). Given that AS from SSBs contributes 3.8%TE among 0-5y and 5.1%TE among 4-<5y US children, contribution of FS from SCBs (includes fruit juices) likely exceeds the WHO FS <5%TE recommendation in this sample. In the same study, fruit drinks were the third leading source of AS among food and beverages, contributing a mean of 12.0% of AS intake overall and remained stable among children 2-5 years old. Another analysis of NHANES using 651 US children between the ages of 1-2 years from cycles 2011-2016 found that fruit drinks were the top source of AS (19.6% of AS) and sweetened drinks (which included soft drinks, sports and energy drinks, nutritional beverages, smoothies, grain drinks, and coffee and tea) contributed 7.5% of AS (3). These data suggest that among US preschoolers, FS from beverages likely exceeds WHO recommendations and fruit drinks were the top beverage source of AS intake among US preschoolers.

While fruit drinks appear to be of particular concern in the US, the types of SSBs consumed are country and sample specific. Among 1,191 Australian children 2-3 years old, enrolled in the 2007 National Children's Nutrition and Physical Activity Survey (NCNPAS), SSBs including carbonated products, energy drinks, juices with AS, cordial (defined as flavoured drink concentrate), sports drinks, milkshakes/smoothies, and flavoured milk were found to contribute a mean of 4.2% and 3.8% of TE in boys and girls, respectively (43). Sweetened juice contributed the largest proportion (39.9%) of SSB intake, which was equivalent to a per capita mean intake of 145 mL (39.9%, 145 ml). This was followed by flavoured milk (22.1%, 38.8 ml), cordial (19.9%, 27.7 ml), carbonated soft drinks (15.0%, 56.5ml), milk shakes/smoothies (3.8%, 12.9 ml), and sports drinks (0.3%, 1.2 ml) (43). In Mexican preschool-aged children 1-4 years old from the Mexican Health and Nutrition Survey (MHNS) 2006, the percent consumers, amount per consumer (mL), calories per consumer (kcal) and percent contribution of sweet beverage

subcategories to TE listed in order of most consumed to least consumed were as follows: regular soft drinks (68.0%, 59.5 mL, 26.9 kcal, 2.4%), sweetened beverages (i.e., sweetened fruit water sugar added orange juice, sweetened flavored waters (65.2%, 110.9 mL, 58.4 kcal, 5.1%), atole (traditional Mexican cornmeal drink) (10.9%, 80.4 mL, 86.3 kcal, 8.6%), sweetened coffees and teas (37.5%, 72.7%, 14.6 kcal, 1.6%), flavoured whole milks (5.4%, 205.7 mL, 201.2 kcal, 0.8%), and diet soft drinks & unsweetened flavor (3.7%, 67.4 mL, 0.16 kcal, 0.01%) (37). These data indicate that compared to US children, Mexican children are consuming a greater amount of SCBs, specifically soda (29,37). Green et al. (44) found that in (n=495) Indonesian children (6-35 months), the preceding day, 40.0%, 33.3%, 10.1%, 3.4%, and 0.4% of children consumed any SSB (beverage with AS), sweetened milks, sweetened teas, packaged juice, and soda, respectively. Furthermore, 56.4% 49.7%, 21.6%, 10.5%, and 1.2% of children consumed the same categories the preceding week. Overall, consumption of SSBs among preschoolers is high and the categories that contribute most to AS/FS intake varies by country.

Fruit juice. Younger US preschool-aged children may be more commonly consuming 100% fruit juice than older preschool-aged children, although both are exceeding recommendations. In 2017, the AAP recommended that fruit juice be limited to less than 4 ounces/118 mL in children 1-3 years old and less than 6 ounces/177 mL in children 4-6 years (16). Studies comparing children's juice intake with AAP and WHO recommendations are presented in Appendix B. For comparison with AAP recommendations, 1 g of fruit juice was assumed to be equivalent to 1 mL in this review. A cross-sectional analysis of children in FITS, 2016 found that among 2–4-year-old children (n=1733), 46.7% consumed 100% fruit juice, and the mean consumption per capita and per consumer was 113.2g/113.2mL and 242.2g/242.2 mL, respectively (29). This indicates that on average, these children exceeded AAP fruit juice recommendations on a per consumer

basis by not a per capita basis. Roess et al. (39) completed an analysis of (n=413) children 1.5-2 years old in FITS, 2016 and found that 55% consumed 100% fruit juice. In children 18 months-20.9 months (n=251), 40% consumed >4 ounces and 29% consumed >6 ounces of 100% fruit juice. In children 21-23.9 months (n=162), these values were 46% and 32%, respectively. The Early Childhood Longitudinal Study-Birth Cohort (ECLS-B) 2005 assessment found that in 8900 US preschool-aged children (44.0 – 65.3 month old), for the week prior, most children drank juice ≥1 time/day, almost 1 in 5 children drank juice 3 times/day and only 8% drank no juice in the past week (40). Since then, fruit juice intake has decreased. But among US preschool-aged children from NHANES cycles between 2009-2014, FS from 100% fruit juice still contributed significant amounts of TE (3.8%), which increased from 0-5 years: 0-<1-years (1.7%), 1-<2 years (4.7%), 2-<3 years (4.0%), 3-<4 years (4.1%), and 4-<5 years (3.8%) (42). Given that the WHO recommends that less than 5% of TE come from FS, this contribution from fruit juice is of concern. Large contribution of fruit juice to energy may be a result of its perceived health benefits compared to other SCBs.

In (n=3,552) Mexican children 1-4 years from the MHNS-06, the proportion of children who consumed fruit juice was nearly half that of US children (29,37,39). The proportion of children who were consumers, amount per consumer (mL), calories per consumer (kcal) and percent contribution to TE of fruit juice was 25.3%, 54.5 mL, 24.6 kcal, and 2.15%, respectively. These data show that fewer Mexican children consume fruit juice and fruit juice contributes a lower proportion of TE compared to US children.

In summary, previous studies indicate that many sugary drinks contribute excess sugars and calories, but little to no nutrients. SSBs and SCBs have known associations with cardiometabolic risk in adolescents and adults; and research suggests that this association is present in preschool-

aged children as well. Sugars consumed in the form of beverages may have a reduced impact on satiety and health authorities recommend the reduction of sugary drink intake to improve dental and cardiometabolic health outcomes (Table 1.3). Furthermore, dietary habits of preschoolers have been found to track into older childhood. For example, level of preschool SSB intake was associated with the level of SSB intake at 8-14 years (32). Sugary beverage intake is decreasing among North American children (Table 1.5); however, high consumption is still of concern (Table 1.5, Appendices A and B). The summarized studies indicate that in Canadian and US preschool-aged children, SSB and fruit juice intake is decreasing with time. However, sweet beverage intake remains high and fruit juice and fruit drinks are of particular concern since they are consumed by many children, consumed in large quantities and contribute a large amount to TE. Studies suggest that important beverage sources of AS vary by country among preschoolers: US and Canada (fruit drinks), Australia (Sweetened juice), Mexico (soda), Indonesia (sweetened milk). Variables that impact differences in sweet snack and beverage intake and their relationship with health are summarized in the next section.

1.11 Determinants of snack, SSB and fruit juice intake

A thorough review investigating factors that impact children's eating behaviours including parent and family, community, demographic, SES, food characteristics, and child characteristics was completed by Scaglioni et al. (45). Thus, these same factors may impact sweet snack and beverage intake. Studies investigating the determinants of sweet snack and beverage intake in preschoolers are reviewed below.

One study investigating 26 US preschoolers found that providing children with a larger sized beverage during a snacking occasion increased beverage and/or food intake and serving

100% fruit juice led to greater overall snack energy intake (46). In a cross over study, US preschoolers (n=45) were not found to regulate their intake when faced with a 5-day increased food challenge (i.e., their daily energy intake increased) (47). Furthermore, children with higher weight status had greater increases in daily energy intake from larger portions. Among 50 low-income US preschoolers, children were found to consume larger serving sizes when offered less healthy versus healthier snack foods; for example, canned versus fresh fruits (48). Despite the palatability of sweet snacks and beverages, replacing energy dense snacks with fruits and vegetables has been found to be a feasible method of reducing TE and improving diet quality in preschool-aged children from the United Kingdom (49). Furthermore, providing children with a variety of fruits and vegetables as a snack has been found to increase intake of fruits and vegetables among 61 US preschoolers from Pennsylvania (50). Thus, strategies including replacement, controlling access to and portion size of sweet snacks, and providing a variety of fruits and vegetables as snacks may help to reduce FS intake from snacks.

Maternal characteristics have also been studied in relation to child snack intake. In Indonesian children (n=594) 0-35 months, children of less educated mothers were 2-4 times more likely to consume a commercial snack food compared to children of mothers with a post-secondary level of education (44). The most common reason that mothers reported providing commercial snack products or SSB were that the child requests it (34%) followed by it makes the child happy (32%). Furthermore, frequency of consumption of commercial snack foods increased from 6 to 35 months of age. In a study of 136 Dutch mothers with children (2-7 years), mothers recorded each instance of providing their child with a snack along with their considerations for providing that snack over 13 days. Fruits, cookies, and candy were the most frequently provided snacks (51). Healthfulness of the snack and child preference were the most common maternal considerations

when providing the snack. Higher maternal education was associated with considerations such as diet variation, whereas mothers with lower education were more likely to use health-conscious considerations as justification for providing less healthy snacks. Use of child preference as a consideration did not vary based on maternal education. In this same study, mothers of children 6-7 years gave more candy and vegetables as a snack compared to mothers of children 2-3 years. Studies investigating the father's role in child snack intake are lacking. These studies suggest that snack portion size, child age, maternal education, and child preference may be associated with child sweet snack intake.

Several determinants including SSB portion size, TV viewing, snack consumption, child SSB liking, home availability of SSBs, parental SSB consumption and attending out of homecare have been positively associated with SSB intake among young children, while parental (positive) monitoring and high SES has been associated with lower SSB intake (52). Among 2322 Dutch preschoolers, most SSBs were found to be consumed in the home emphasizing the importance of the family environment to child SSB intake (33). Preferred beverages may also be country or region specific. For instance, cordial is a popular SSB consumed in Australia and atole is a popular Mexican cornmeal drink. Ethnicity has been found in some studies to impact sweet beverage intake and in the US, Mexican American and Non-Hispanic white preschool-aged children have been found to consume more soda than non-Hispanic black preschool-aged children, while fruit drink intake was higher in non-Hispanic Black preschool-aged children (53). Furthermore, Mendez et al. (53) found that high household income was associated with lower SSB intake in non-Hispanic white, but not non-Hispanic black or Mexican-American preschool-aged children. Given that non-Hispanic black toddlers have been found to consume more AS than non-Hispanic White, non-Hispanic Asian, and Hispanic toddlers, these data indicate that targeting fruit drink intake and

further investigating the interactions between SES and SSB intake may be particularly helpful for non-Hispanic black toddlers (3).

In preschoolers, males have also been found to have higher intake of SSBs, carbonated SSBs, juices and sweetened beverages when compared to females (37,43). Increased SSBs have also been repeatedly found to be associated with increased age (37,42,43). For example, contribution of AS from SSBs and 100% fruit juice calories to TE increased with age among US children 0-5 years (42). In Australian preschool-aged children, parent education was negatively associated with level of SSB consumption (43). Contrary to results in high income countries, in Mexico, higher SES has been associated with higher SSB intake (37,52). This is likely a result of accessibility since Mexican preschool-aged children from urban compared to rural areas consumed more regular soft drinks, sweetened beverages, whole milk, and unsweetened fruit juice, but less sweetened coffee and tea, and atole (37) Data may have changed since.

1.12 Conclusion

The present review has assessed how snacks and beverages contribute to excess AS and FS intake in preschool-aged children. Existing studies are inconsistent in the data reported with studies investigating frequency, percent consumers, amount consumed (energy, volume), contribution to TE, and contribution to AS causing difficulties in comparison across studies. However, this review provides evidence that sugary snacks and beverages contribute a large proportion of AS and FS intake among children. Furthermore, several determinants including age, sex, ethnicity, parent education, and parent income may impact sweet snack and beverage intake. Thus, it is logical to target snacks and beverages to help this age group meet recommendations, although it is unknown how specific snack and beverage categories contribute to FS energy or if intake varies by age or

sex. Overall, research investigating how snack and beverage categories contribute to FS consumption is needed in preschool-aged children to help inform health interventions.

Chapter 2 Rationale, Objectives, and Experimental Design

2.1 Rationale

While healthful snacks and beverages can be a part of a wholesome diet, sugar-dense snacks and beverages may contribute to poor diet quality by displacing nutrient-dense foods and contributing excess calories. Research from the Guelph Family Health Study (GFHS) found that snacks contributed 1/3 of children's daily energy intake and TS contributed 37.2% of snacking energy (22,25). The GFHS found that the top sources of FS were “beverages”, “bakery products”, “sugars and sweets” and “cereals and grain products” (4). A study of Canadians ≥1 years from the 2015 CCHS found that the top four sources of FS were “sugars, syrups, preserves, confectionary, desserts”, “soft drinks”, “baked products”, and “100% fruit juice” (5). However, these top sources of FS may not reflect those of young children. Furthermore, FS intake was not assessed by meal occasion and thus, research identifying sugar intake during snacking occasions and by various snacking categories can provide insight into specific dietary intervention messages to reduce FS energy intake. Overall, the contribution of snacks to FS intake has not been investigated in young Canadian children. Given the importance and frequency of snacking and the need to address Canadian preschool-aged children consuming FS above Health Canada recommendations, research investigating the contribution of snacks to FS intake in this age group is warranted.

2.2 Objectives

The overall objective was to determine the contribution of energy intake from FS from snacks and beverages in preschool-aged children. The specific objectives were to determine:

1. the mean contribution of FS from snacks (food snacks and beverage snacks) and beverages, expressed as a percentage of daily TE and daily FS energy intake.
2. the contribution of FS intake from snack and beverage categories.
3. if snack and beverage intake vary by age and/or sex.
4. the percentage of children exceeding the WHO FS recommendations through snack or beverage FS intakes.

2.3 Experimental design

The Guelph Family Health Study is a lifestyle family-based intervention study that consists of two pilot studies and one full study cohort. This secondary analysis used cross-sectional baseline data from children enrolled in the full study cohort, which was initiated in 2017. Families with at least one child between the ages of 1.5 and 5 years and who were not planning to move in the next year were recruited from Guelph-Wellington areas via the Family Health Team, Community Health Centre, Ontario Early Years Centres, community events, and social media. At baseline, parents reported sociodemographic data including age, sex, household income, parent education, and ethnicity for their child(ren). Child dietary data were collected between 2017 to 2020 using the online Automated Self-Administered 24-hour (ASA24) Dietary Assessment Tool 2016 - Canadian version (National Cancer Institute, Bethesda, MD) (54). Parents were instructed to report all the foods and beverages consumed by their child(ren) in 24 hours, amount consumed, eating occasion, and time of eating occasion. ASA24 automatically calculated AS data.

FS, snack, and beverage data were analyzed by trained researchers. FS intake was assessed from 24-hour dietary recalls using a novel and semi-automated stepwise approach. Snacks were defined as foods and/or beverages (except water) consumed between parent-identified meals

(breakfast, brunch, lunch, dinner, and supper). Beverages were defined as all drinks consumed within the 24-hour recall. Snacks and beverage items were further categorized using a system adapted from Bernstein et al. (28) and FS from these sources was determined.

Chapter 3 Experimental Chapter: Snack and beverage sources and intakes of FS in Canadian preschool- and toddler-aged children – a cross-sectional study

3.1 Introduction

The WHO recommends that FS intake be limited to <10% of TE to reduce the risk of unhealthy weight gain and <5% of TE to reduce the risk of dental caries. FS is defined as monosaccharides and disaccharides added to foods and beverages by the manufacturer, cook or consumer, and sugars naturally present in honey, syrups, fruit juices and fruit juice concentrates (2). Intakes of preschool- and toddler-aged children have been found to exceed recommended levels of FS (3–5,55,56), which is of particular concern because of short term consequences such as dental caries and the fact that dietary habits formed in young children have been found to track into adulthood (2,57).

Canada's new Dietary Guidelines have adopted the WHO recommendation that FS intake be limited to <10% TE. They also encourage the overall reduction of FS through several strategies including the preparation of nutritious snacks with little to no AS and the selection of water as the beverage of choice (13), despite the contribution of snacks and beverages to FS intake being poorly understood. This is concerning because in Canadian and US children, snacking is becoming more prevalent and snacks contribute >25% TE (22–24,26,58). Studies in Canada and US reveal promising data that sweet beverage consumption is decreasing in children; however, intake still remains high (6,7). Continuous monitoring is necessary given evidence that FS from beverages have a particularly adverse impact on cardiovascular risk (2,59).

While it is known that many young children exceed recommendations for FS, few studies have explored specific food or beverage sources of FS (4,5,55). Understanding the top sources of

FS can help inform approaches to reduce sugar intake among young children. This study investigated how snacks, beverages, and their categories (e.g., bakery products, frozen desserts, candy and sweet condiments, flavored milk, 100% fruit juice) contribute to FS intake among young Canadian children. The objectives of the present study were to investigate the proportion of children whose intakes exceed recommended FS limits through snacks and beverages and to identify leading snack and beverage sources of FS.

3.2 Methods

Study design

This study is a cross-sectional secondary analysis of baseline data obtained from children participating in the Guelph Family Health Study-Full Study cohort. The University of Guelph Research Ethics Board approved the study, and parents provided written informed consent (REB#17-07-003).

Setting and participants

The Guelph Family Health Study is a family-based behavior change intervention study (NCT02939261). Between 2017-2020, families with at least one child between the ages of 1.5 and 5 y and who were not planning to move in the next year were recruited from Guelph-Wellington areas via the Family Health Team, Community Health Centre, Ontario Early Years Centres, community events, and social media platforms.

Dietary assessment

A single 24-hour dietary assessment was completed for each child by one of their parents using the online ASA24 Dietary Assessment Tool 2016 - Canadian version (National Cancer Institute, Bethesda, MD) (54). Parent-reported dietary data for preschool children using ASA24 has been previously validated (60). The ASA24 included a detailed description of all foods and beverages consumed with brand names, time and eating occasion. Dietary supplement data were not included in this analysis. Energy and nutrient intakes were screened for mathematical outliers and implausible dietary intakes.

TS and AS intakes were determined by ASA24. FS intake was defined as AS plus sugar from 100% fruit juice (includes not from concentrate and fruit juice concentrate diluted to single strength); and determined using a standardized and semi-automated stepwise approach as described in **Appendix C.**

Snacks, beverages, and their categories

Snacks were defined as foods (i.e., food snacks) and beverages excluding water (i.e., beverage snacks) consumed between parent-identified meals. Beverages were defined as all beverages (including water) consumed at any meal or snack during the 24-hour recall. Items were classified into snack and beverage categories by two data analysts to ensure quality of data entry. Snack and beverage items were classified into 15 categories and several subcategories using a classification system adapted from Bernstein et al. (28) (**Appendix D**). FS intakes were determined from these sources.

Statistical analyses

Statistical analyses were completed using SAS® University Edition version 9.4 (SAS Institute, Inc., Cary, NC) with $p<0.05$ considered significant. The percent contribution (mean ± SD) of snacks, beverages, and their FS to TE and total FS energy was calculated using summary statistics. The proportion of children whose intakes exceeded WHO FS recommendations (<10% TE and <5% TE) from snacks or beverage alone was determined.

To identify snack and beverage sources of FS, the proportion of children consuming each snack and beverage category (**Appendix E)** and each category's FS contribution to TE were determined. The frequency and percent of children consuming each snack and beverage category (regardless of serving size) over 24-hours were reported. For each participant, %TE from FS per snack and beverage category was determined by summing FS energy for the snack or beverage category, dividing the sum by the participant's TE, and multiplying the resulting quotient by 100%. Then, participants' %TE from FS (mean, 95% CI) was calculated for snack and beverage categories consumed by at least 30 participants (to ensure adequate data for a meaningful summary). Associations between child age (<3 years versus ≥3 years) or sex and FS variables were assessed using linear models with generalized estimating equations (GEEs) to account for correlated data amongst siblings.

Sub-analysis. The percent contribution of beverage categories to beverage FS energy in children <3 years versus ≥ 3 years was assessed. For each beverage category, the sum of FS energy from the beverage category was divided by the sum of FS energy from all beverage categories and multiplied by 100%.

3.3 Results

Sample Characteristics

A total of 322 children were enrolled in the Guelph Family Health Study full study cohort. Exclusion criteria included incomplete (n=28) or unreliable (n=12, mathematical outlier and implausible intake) ASA-24 records. Breast- or formula- fed (n=15) children were also excluded since breastmilk intake could not be accurately quantified and FS present in formula is not the focus of this study. Thus, the final cross-sectional analysis used baseline data from 267 (n=129 boys, n=138 girls) children from 210 families. **Appendix F** presents a participant flow chart.

In the final analytical sample, over half (52%) of families had a household annual income of ≥$100,000 and the majority (79%) had at least one parent with a university degree or higher **(Table 3.1)**. Most families (73%) had one child included in the analysis. The majority of the children (77%) were Caucasian with an average age of 3.6 ± 1.2 y (mean ± SD).

Table 3.1: Demographic characteristics of families and participants

Family Characteristics (n=210)	**N (%)**
Household Income (Canadian Dollars)	
<$60,000	33 (16)
$60,000 – $99,999	56 (27)
≥$100,000	110 (52)
Did not answer	11 (5)
Highest level of education obtained by at least one parent	
Some university, some college or technical School, high school graduate	13 (6)
College graduate	31 (15)
University graduate	63 (30)
Postgraduate training or degree	103 (49)
Child(ren) included in this analysis	
1 child	154 (73)
2 or 3 children	56 (27)
Participant Characteristics (n=267)	**N (%)**
Child Ethnicity	
Caucasian	205 (77)
Other	55 (21)
Did not answer	7 (3)
Child Age in years, Mean ± SD	3.6 ± 1.2
Child Sex	**N (%), Mean age (years) ± SD**
Male	129 (48), 3.6 ± 1.3
Female	138 (52), 3.5 ± 1.2

Snacks and beverages: FS energy

Among all children, FS contributed 10.6 ± 6.9% of TE (**Table 3.2)**. Furthermore, FS from snacks and beverages contributed approximately 5.7% of TE, which exceeded WHO recommendations. Snacks contributed more than one-third of total FS energy, and snacks and beverages combined contributed nearly half of all total FS energy.

Table 3.2: Percent of children's TE contributed by FS, snacks, and beverages [1]

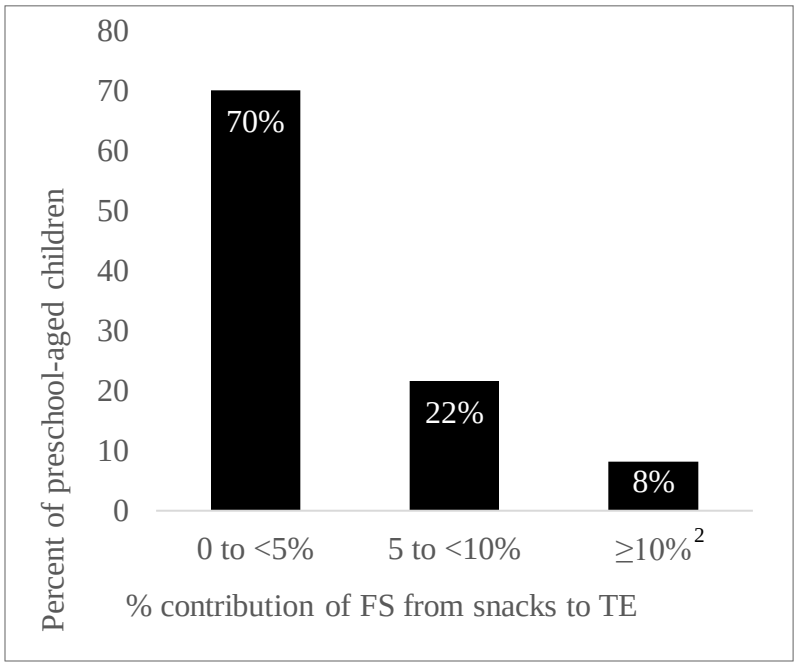
	% TE (mean ± SD)	% total FS energy (mean ± SD)
Total FS	10.6 ± 6.9	-
Snacks	26.6 ± 13.6	-
FS from snacks	3.9 ± 4.0	36.5 ± 28.1
FS from food snacks	3.1 ± 3.4	29.9 ± 26.7
FS from beverage snacks	0.8 ± 2.2	6.6 ± 16.4
Beverages	12.4 ± 10.9	-
FS from beverages	2.6 ± 4.2	19.3 ± 26.0

[1]Sample included (n=267) non-breastfed Canadian children 1.5-5 years from the Guelph Family Healthy Study. Snacks and beverages are not exclusive. Beverage snacks are beverages (excluding water) consumed during snacking occasions (i.e., between meals), whereas beverages include water and are consumed at any time within the 24-hour recall. FS, Free Sugar; TE, Total Energy

Snacks and snack categories: FS energy

Compared to WHO FS recommendation limits, 30% and 8% of children consumed ≥ 5% TE and ≥10% TE from snack FS, respectively (**Figure 3.1)**. Almost all (97%) children consumed snacks and most (91%) consumed ≥2 snack items over 24-hours (**Table 3.3**). Among children who consumed snacks, snack FS contributed 4.0% TE. Although food snacks (96%) were consumed by more children than beverage snacks (45%) and food snacks contributed more FS than beverage snacks, the single snack category that contributed the most %TE from FS was SCBs followed by candy and sweet condiments, then bakery products. These categories were also consumed by large proportions of children: 20% for SCBs, 21% for candy and sweet condiments, and 55% for bakery products. The proportions of children consuming snacks containing no to low FS were 72% for fruits, 27% for plain milk, 17% for cheese, 16% for vegetables and legumes, and 4% for plain yogurt.

Figure 3.1: Percent of children consuming 0 to <5, 5 to <10 or ≥10% of TE from snack FS [1]



[1] Sample included (n=267) Canadian children 1.5-5y.
[2] ≥10% ranges from 10% to 23% of TE.

Table 3.3: Snack intake by snack categories and their contribution to FS energy intake among children [1]

Snack category	Children (percent)			Children's %TE from FS Mean (95% CI)
	≥1	1	≥2	
ALL SNACKS	260 (97)	17 (6)	243 (91)	4.0 (3.5 – 4.5)
BEVERAGE SNACKS	121 (45)	81 (30)	40 (15)	1.8 (1.3 – 2.3)
Sugar-Containing Beverages	53 (20)	41 (15)	12 (4)	4.1 (3.2 – 5.0)
Plain Milk	73 (27)	49 (18)	24 (9)	0
FOOD SNACKS	257 (96)	24 (9)	233 (87)	3.2 (2.8 – 3.6)
Candy and Sweet Condiments	56 (21)	50 (19)	6 (2)	3.0 (2.2 – 3.8)
Bakery Products	148 (55)	108 (40)	40 (15)	2.4 (2.1 – 2.7)
Dairy Products and Alternates	94 (35)	69 (26)	25 (9)	1.1 (0.7 – 1.6)
Savory Snacks	111 (42)	93 (35)	18 (7)	0.3 (0.2 – 0.5)
Fruits	191 (72)	86 (32)	105 (39)	0.5 (0.3 – 0.8)
Vegetables and Legumes (except fried potatoes)	44 (16)	30 (11)	14 (5)	0.01 (-0.01 – 0.04)
Cereals and Grain Products	29 (11)	24 (9)	5(2)	-
Nuts and Seeds	42 (16)	35 (13)	7 (3)	0.1 (0.1 – 0.2)
Mixed Dishes, Sides and Entrees	16 (6)	13 (5)	3 (1)	-
Frozen Desserts	12 (4)	11 (4)	1 (0.4)	-
Meats, Eggs and Substitutes	11 (4)	11 (4)	0 (0)	-

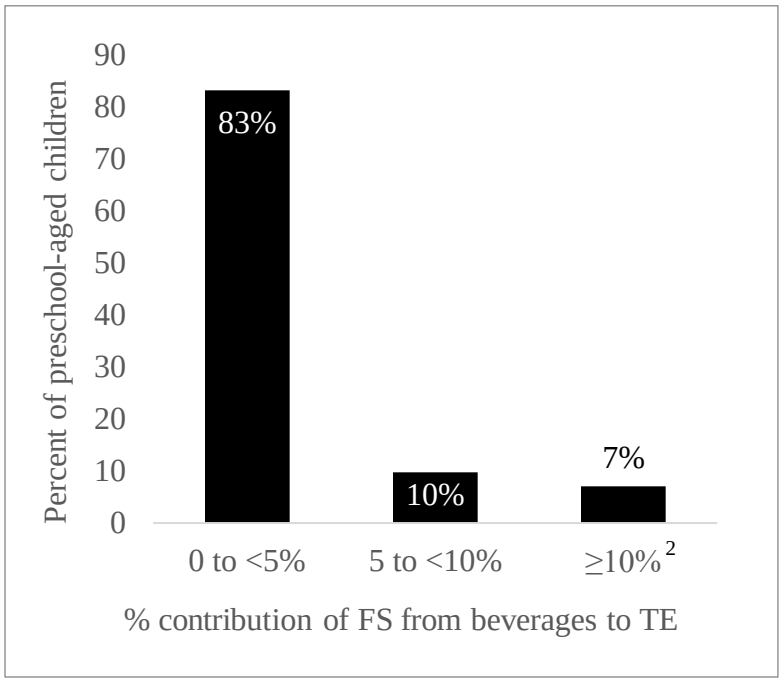
[1] This table summarizes the number and percent of children 1.5-5 years who consumed different snack categories, relative to the total number of children (n=267). Percent was calculated to identify the proportion of children who consumed snack categories at least once (≥1) over 24-h, then calculated for the more discrete categories of one time (1) or two or more times (≥2). Not all

children were reported to consume a snack (n=7). Mean children's %TE from FS was calculated for categories that were consumed by ≥30 children. For these calculations, only data from children who consumed each respective category were used (i.e., data from children who did not consume the snack category over 24-h were not included in the mean). For categories consumed by <30 children, mean %TE from FS was not calculated and was instead denoted with a dash. Sugar-containing beverages included beverages with sugars added during processing + 100% fruit juice. An expanded version of this table including food and beverage items included in each snack category can be found in Appendix E. FS, Free Sugar; TE, Total Energy

Beverages and beverage categories: FS energy

Compared to WHO FS recommendation limits, 17% and 7% of children consumed ≥ 5% TE and ≥10% TE from beverage FS, respectively (**Figure 3.2)**. Almost all (98.5%) children consumed beverages ≥2 times over 24-hours (**Table 3.4)**. SCBs, consumed by nearly half (49%) of children, included 100% fruit juice, flavored milk, smoothies, sweetened plant-based beverages, fruit drinks, flavored yogurt beverages, sweetened hot beverages, regular soft drinks, and sports drinks. More children consumed SCBs once (30%) compared to multiple times (19%) over 24 hours. FS from SCBs contributed a mean of 5.3% TE among consumers, which exceeds the WHO limit of 5% TE. The SCB that was consumed by the highest proportion of children and contributed the greatest %TE from FS among consumers was 100% fruit juice followed by flavored milk. Smoothies, plant-based beverages, fruit drinks, yogurt beverages, and hot beverages were each consumed by fewer than 8% of children. Regular soft drinks and sports drinks were rarely consumed. Diet soft drinks, energy drinks, and vegetable drinks were not reported in any ASA24-records. Water and plain milk were the beverage categories consumed by the largest proportion of children (92% and 68%, respectively) and were more commonly consumed several times than once over 24-hours.

Figure 3.2: Percent of children consuming 0 to <5, 5 to <10 or ≥10% of TE from beverage FS [1]



[1] Sample included (n=267) Canadian children 1.5-5 years.
[2] ≥10% ranges from 10% to 26% of TE.

Table 3.4: Beverage intake by beverage categories and their contribution to FS energy intake among children [1]

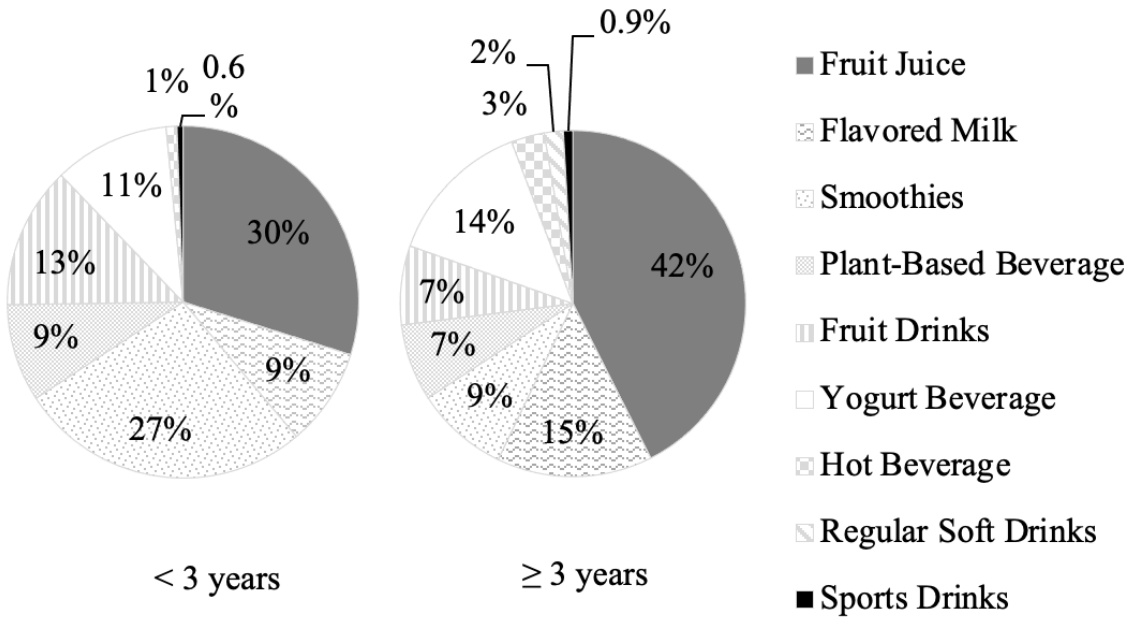
Beverage Category	Children (Percent)			Children's %TE from FS Mean (95% CI)
	≥1	1	≥2	
All Beverages	265 (99)	2 (0.7)	263 (98.5)	2.6 (2.1 – 3.1)
Sugar-Containing Beverages	129 (48)	79 (30)	50 (19)	5.3 (4.5 – 6.1)
100% Fruit Juice	58 (22)	48 (18)	10 (4)	4.6 (3.6 – 5.7)
Flavored Milk	29 (11)	25 (9)	4 (1)	3.1 (2.3 – 4.0)
Water	245 (92)	31 (12)	214 (80)	0
Plain Milk	180 (67)	66 (25)	114 (43)	0
Smoothies	23 (9)	21 (8)	2 (1)	-
Plant-Based Beverages	21 (8)	15 (6)	6 (2)	-
Fruit Drinks	16 (6)	16 (6)	0	-
Yogurt Beverages	15 (6)	12 (5)	3 (1)	-
Hot Beverages	7 (3)	5 (2)	2 (1)	-
Regular Soft Drink	2 (1)	2 (1)	0	-
Sports Drinks	2 (1)	2 (1)	0	-
Diet Soft Drink	0	0	0	-
Energy Drinks	0	0	0	-
Vegetable Drinks	0	0	0	-

[1] This table summarizes the number and percent of children 1.5-5 years who consumed different beverage categories, relative to the total number of children (n=267). Percent was calculated to identify the proportion of children who consumed beverage categories at least once (≥1) over 24-h, then calculated for the more discrete categories of one time (1) or two or more times (≥2). Not all children were reported to consume a snack (n=7). Not all children were reported to consume a beverage (n=2). Mean children's %TE from FS was calculated for categories that were consumed by ≥30 children. For these calculations, only data from children who consumed each respective category were used (i.e., data from children who did not consume the beverage category over 24-h were not included in the mean). For categories consumed by <30 children, mean %TE from FS was not calculated and was instead denoted with a dash. Sugar-containing beverages include beverages with sugars added during processing + 100% fruit juice. In this sample, this includes flavored milk, smoothies, sweetened plant-based beverages, fruit drinks, yogurt beverages, sweetened hot beverages, and 100% fruit juice. FS, Free Sugar; TE, Total Energy

Sex and age

Contribution of FS, snacks, and beverages to TE and total FS energy did not significantly differ based on age or sex ($p>0.10$, data not shown) with one exception. Age (<3 years versus ≥3 years) was associated with a decreased proportion of calories from beverages (15.1 ± 14.0% versus 10.7 ± 8.0%, $p <0.01$), but a greater proportion of beverage calories from FS (16.7 ± 25.6% versus 26.1 ± 29.5%, $p<0.01$) (data not shown). **Figure 5** presents the distribution of beverage FS calories for children <3 years versus ≥3 years. In these age groups, 43% and 50% consumed a SCB, respectively. The top beverage source of FS in both age groups was 100% fruit juice.

Figure 3.3: Distribution of beverage FS calories by types of drinks in children <3 years versus ≥ 3 years [1]



1 Data for preschool-aged children <3 years (n=44) and ≥ 3 years (n=85) are presented. The distribution was analyzed separately since linear models with generalized estimating equations found that children ≥3 years (max 6 years old) consumed a greater proportion of beverage calories from FS compared to <3 years ($p <0.01$).

Discussion

We found that snacks and beverages combined contributed nearly half of all FS energy, 30% of children exceeded 5% TE through snack FS, 17% of children exceeded 5% TE through beverage FS; and SCB, bakery products, and candy and sweet condiments were the top snack and beverage sources of FS energy. Our study provides evidence that FS energy intake is exceeding WHO recommendations and that interventions could target snacks and beverages to reduce FS intake in Canadian preschoolers and toddlers.

Snacking is increasing in young children and the present study found that snacks contributed over one-quarter (26.6%) of TE, similar to preschoolers from Canadian (27%) and US (28%) national datasets (9,12,13). FS energy as a proportion of TE was lower in our study (10.6%) than a recent analysis of children 1-8 y from CCHS-2015 (13.8%) (4) but still exceeded WHO FS recommendations (1). The findings that SCBs, bakery products, and candy and sweet condiments were the top snack sources of FS is consistent with previous studies (4,5) and provides new information that these sources are commonly consumed during snacking occasions. SCBs are of particular concern due to their association with cardiometabolic risk (1,16). Despite reductions in SCB intake among young Canadian children (15), our findings that SCBs (particularly 100% fruit juice and flavored milk) were consumed by nearly half of the children and contributed FS greater than 5% TE reinforces that SCBs are still a concern among preschoolers and toddlers.

Possible strategies to reduce FS from snacks and beverages include replacing with alternates, reducing frequency of consumption, and reducing portion size. Replacing top snack and beverage sources of FS with fruits and vegetables during snacking occasions can limit FS intake and improve diet quality in young children as demonstrated by Reale et al. (19). In our study, fruits and plain

milk are snack and beverage categories that contain no to low FS and were consumed by a large proportion of children. Substituting sweetened items such as flavored yogurt with plain yogurt plus unsweetened fruits, and flavored milk with plain milk, can reduce FS intake while retaining the nutrients these items offer. Reducing portion size and frequency of consumption of sweet snacks and beverages may also reduce FS intake. A previous study in (n=26) US preschoolers found that providing children with a larger size of beverage at a snack increased beverage and/or food intake and serving 100% fruit juice led to greater overall snack energy intake (20). Given that SCBs were mostly consumed once a day among consumers in our study, portion size of beverages may be a larger contributor of excess FS intake than frequency of consumption.

We noted that age was not associated with the contribution of beverage FS to TE, which supports previous findings that the contribution of SCBs to TE remains stable from 1 to 5 y (21). This stability may be explained by our finding that age was associated with less TE from beverages, but the beverages that were consumed contained more FS per beverage calorie. Thus, previously observed age-related increases in SCB intake from childhood to adolescence may begin in school-aged children upon exposure to the school environment (14,15). In the present study, children ≥3 years compared to <3 years consumed beverages with more FS per calorie. Thus, prompting further analyses in these two age categories. Since intake of FS from beverages did not vary by sex and intake of FS from snacks did not vary by age or sex, further sub analyses of these respective variables were not investigated.

Some limitations should be considered when interpreting our study results. Most participants came from middle-income households, had educated parents, and were Caucasian. Given that household income, parental education and ethnicity have been associated with diet quality and sweet snack and beverage intake, our findings may not be generalizable to children of diverse

backgrounds (9,22,23). Finally, using ASA24-Canada-2016 to calculate FS resulted in the use of data from multiple databases (i.e., FPED, CNF-2015, FNDDS) with sometimes inconsistent added sugar and TS values thus, leading to an overestimation of FS amounts. In particular, "muffins with fruits/and or nuts" and "lemonade" are items where FS sometimes exceeded TS, suggesting an overestimation of FS in these items. Despite these potential overestimations, the contribution of FS to TE was lower in our study compared to children from the CCHS-2015 (10.6% TE in 1.5 – 5 y versus 13.8% TE in 1-8 y children), which analyzed FS using a different methodology (4).

Strengths of this study include its focus on how snack and beverage categories contribute to FS intake among young Canadian children. Furthermore, this study allowed direct comparison of snacks, beverages, and their categories to WHO FS recommendations. Our findings suggest that targeting the snack categories bakery products and candy and sweet condiments as well as the beverages 100% fruit juice and flavored milk may help reduce FS intake in young children.

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and had primary responsibility for final content. All authors read and approved the final manuscript.

Conflicts of Interest: The authors declare no conflict of interest.

Chapter 4 General Discussion and Future Directions

4.1 General Discussion

Studies have shown that preschool-aged children are exceeding WHO intake recommendations for FS and therefore, strategies to reduce FS intake are needed. Guidelines encourage reduction of FS intake from snacks and beverages, but the contribution of energy intake from FS present in snacks and beverages among Canadian preschool-aged children remains unexplored. The present study has investigated how snacks, beverages and their categories contribute to FS intake among Canadian preschool-aged children. This study shows that snacks and beverages are significant sources of FS among preschool-aged children from primarily middle income families (61) with relatively high parent education. Previous research on the associations between household income and parent education on sweet beverage intake, FS intake, and diet quality suggests that snack and beverage FS will become an increased concern among children with lower socioeconomic status (5,53,62). Candy and sweet condiments, bakery products, and SCBs including 100% fruit juices and flavoured milks were the top snack and beverage sources of FS in the current study. Thus, strategies targeting these specific snack and beverage categories may help to reduce FS intake among preschool-aged children.

4.2 Limitations

This secondary analysis of the Guelph Family Health Study baseline cohort has some limitations. The objective of the study was to determine the contribution of energy intake from FS in snacks and beverages in preschool-aged children. Our study demonstrates that snacks and beverages contribute 49.2% of daily FS energy but does not account for the remaining 50.8% of

FS energy. While FS consumed during meal occasions is also an important area of interest, it was not the focus of this study.

The strength of our study is that it reports FS intake from snacks and beverages and compares findings with recommendations in preschoolers overall. However, it was not designed to distinguish if high FS energy from a category is a result of quantity of consumption (frequency and portion size), innate FS content of items in that category, or a combination. Our results capture frequency and mean FS energy data, but portion size was not directly investigated.

Our study was not designed to identify differences based on various sociodemographic variables. Household income, parent education and ethnicity have been previously associated with diet quality and sweet beverage intake but was not the focus of this analysis (53,62). Furthermore, limited sample size of children from lower household income, parent education, and non-Caucasian ethnicity may limit the power of such an analysis.

The present study found that SCBs, bakery products, and candy and sweet condiments are top snack and beverage sources of FS. Our method to calculate FS from AS and fruit juice values had limitations. ASA24-Canada-2016 uses a US database (FPED) to calculate AS values and a mix of Canadian (CNF-2015) and US (FNDDS) databases to calculate TS values. In our own analysis of the diets of preschool-aged children, 29 items (0.5% of items, which included 11 snacks and 3 beverages) contributed FS that were between 20-100 kcal greater than their TS value (due to differences in databases). This included muffins with fruits/and or nuts (n=10/11 snacks) and lemonade (3/3 beverages), which suggests that FS energy of bakery products and fruit drinks may be overestimated. These items were not adjusted because they made up only a small proportion of items. Despite these overestimations, contribution of FS to TE was lower in our study compared

to children from the CCHS-2015 (10.6% TE in 1.5-5 years versus 13.8% TE in 1-8 years children), which analyzed FS using another methodology (5).

The diet of preschoolers is highly dependent on their family environment whereas older children are exposed to other influences including the school environment (63). The present study focuses on young children, but research investigating influences outside the family environment are still necessary, such as food labelling and taxation of sugary beverages (64,65).

In summary, our study focused on FS intake consumed from snack and beverage categories in a sample of Canadian preschool-aged children. However, the sample demographic and dietary assessment method should be considered when extrapolating findings. Other variables that may impact FS intake such as non- snack and beverage sources of FS, snack portion size, demographic and socioeconomic variables, and extra-familial influences were outside the scope of this study.

4.3 Strengths

FS intake of young Canadian children is high and strategies to reduce intake is needed in this population. Our study is the first to investigate how snack and beverage categories contribute to FS intake among Canadian preschool-aged children. Furthermore, FS intake was reported as a percent of TE, which allows for direct comparison to WHO and Health Canada FS intake recommendations. Understanding that specific snack and beverage categories are important sources of FS intake in young Canadian children is the first step in creating targeted interventions to reduce FS intake among this population.

4.4 Future Directions

The results from this study demonstrate that snacks and beverages and specifically SCBs (100% fruit juices, flavoured milks), confectionary and sweet condiments, and bakery products are top sources of FS among preschool-aged children. Thus, it is of interest to determine if this pattern holds among all Canadian preschoolers and if it varies among children who consume higher levels of FS intake. Moreover, information regarding how children are consuming these snacks and beverages (portion size, source of item) as well as how these change with age are important to inform strategies to reduce FS intake.

To target children consuming the greatest amount of FS, studies should investigate the relationship between sweet snack and beverage categories and overall FS intake to identify vulnerable populations. In Canada, higher household income, higher education, living in an urban environment, and age have been associated with increased FS intake (5). In the US, Mexican American (MA) and Non-Hispanic white (NHW) preschool-aged children have been found to consume more soda than non-Hispanic black preschool-aged children, while fruit drink intake was higher in non-Hispanic black (NHB) preschool-aged children (53). High household income was associated with lower SSB intake in NHW, but not NHB or MA preschool-aged children (53) suggesting that strategies are needed to reduce SSB intake in US children, and particularly in NHB children. Future research should assess if snack and beverage interventions should be targeted based on socioeconomic and race/ethnicity in Canadian preschool-aged children.

How and from where children receive sugary snacks and beverages is also important. Previous studies have found that increased portion size results in increased energy intake and increased portion size of 100% fruit juice during snacking occasions results in increased snack energy intake among preschoolers (46,47). Future research investigating socioeconomic variables

(household income and parent education) and consumption variables (portion size, source of item) will inform interventions and policies to reduce FS among young children.

4.5 Concluding Remarks

This study uniquely addresses a gap in our knowledge about sugar intake from snacks and beverages in Canadian preschool-aged children. The current study provides evidence that snacks and beverages represent important opportunities to reduce FS intake. Furthermore, it suggests that targeting specific snacks and beverage categories may help to reduce FS in young children. Overall, preschoolers should be provided with nutritious snacks and beverages to reduce FS intake and improve diet quality.

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Chapter 6 Appendices

Appendix A – Narrative summary of studies investigating SSB intake among preschool-aged children

Country, Study, Sampling Year, Citation	Study Design, Dietary Assessment Method and Nutrient Database	Sample Size, Age (years) and Characteristics	Sugary Beverage Intake Variable			Relevant Results Summary	Conclusions
			1 Consumer (%)	2 Volume/ Portion	3 Energy		
US ECLS-B 2005 (40)	Cross-sectional analysis. By proxy via FFQ for the week prior. Sugar analysis not completed.	n=8900 ~4.5 years Non-breastfed	•	•		**1 Percent consumers** SSB - (≥1) time/day: 30.1% - (≥3) times per day: 6.2% - ≥1 time in the past week: 72.7% - None in past week: 27.3%	**NA**
US FITS 2016 (39)	Cross-sectional analysis. 24-hour dietary recall, primary caregiver over the phone. FPED for AS analysis. SSB = fruit drinks, soft drinks and tea and coffee	n=413 1.5-2 years Breastfed included	•	•		**1 Percent consumers** SSB: 31%	**NA**
US FITS 2016 (29,41†)		n=? 2-4 years Breastfed included †n=600 2-4 years Breastfed included	•	•		**1 Percent consumers** SSB: 45.5% -Fruit drinks: 34.5% -Regular Soft drinks: 8.8% Sweetened teas: 6.9%† Sports drinks: 1.8%† Flavoured milk: 15.2% **2 Per capita volume consumption** SSB: 135.9g/4.6 fl oz -Fruit drinks: 90.7g/3.1 fl oz -Soft drinks: 19.6g/0.7 fl oz Flavoured milk: 38.4g/1.3 fl oz **2 Per consumer volume consumption** SSB: 298.7g/10.1 fl oz	**NA**

						-Flavoured milk: 252.4 g/8.5 fl oz -Fruit drinks: 263.1g/8.9 fl oz -Soft drinks: 228.8g/7.7 fl oz	
US NHANES 2011-2016 (three cycles) (3)	Cross-sectional analysis. Proxy, 24-hour recall, AMPM. FPED for AS analysis.	651 1-2 years Breastfed included		•	•	**3 Contribution to TE (%kcal)** -AS Energy: 7.6% **3 Contribution to AS energy (%kcal)** -Fruit drinks: 19.6% -Sweetened drinks (except fruit drinks): 7.5%	Fruit drinks were the top source of AS and sweetened beverages were the third most important contributor to AS
US NHANES 2009-2014 (four cycles) (42)	Cross-sectional analysis. Proxy, 24-hour recall, AMPM. FPED for AS analysis.	n=3,345 0-5 years non-breastfed		•	•	**3 Contribution to TE (%kcal)** -AS Energy: 10.1% -SCB: 6.7% **3 Contribution to AS energy (%kcal)** **-SSB:** 3.8% -0-<1 years: 0.3% -1-<2 years: 3.4% -2-<3 years: 4.3% -3-<4 years: 4.6% -4-<5 years: 5.1% **-Fruit juice drinks/fruit-flavoured drinks:** 12.0% -1-<2 years: 12.1% -2-<3 years: 13.4% -3-<4 years: 11.8% -4-<5 years: 12.8%	Contribution of AS from SSBs and FS from 100% fruit juice calories to total energy increased with age among US children 0-5 years.
Mexico MHNS-2006 (37)	Cross-sectional 2006: semi-quantitative FFQ, past week. Sugar analysis not completed.	n=3553 1-4 years Breastfed included	•			**Percent consumers** -Regular soft drinks: 68.0% -Sweetened Beverages i.e., sweetened fruit water, sugar-added orange juice, sweetened and flavoured water: 65.2% -Sweetened coffee and tea: 37.5% -Diet soft drinks & unsweetened flavor: 3.7%	Consumers of sweetened beverages consumed the largest amount per consumer (110.9 mL) among a Mexican preschool-aged cohort.
Indonesia 2018	Cross-sectional	n=495 0.5-3 years	•			**Percent Consumers** -SSB: 40%	**NA**

(44)	Questionnaire of preceding day querying consumption of commercial snack foods. Sugar analysis not completed. SSB = Beverage with AS	Breastfed included				-Sweetened milks: 33.3%	
Australia NCNPAS 2007 (43)	Cross-sectional Proxy, two multiple-pass 24-hour recalls and reporting of usual dietary habits. CSIRO for nutrient analysis. Sugar analysis not completed.	n=1191 2-3 years Breastfed included		•	•	**Contribution to total SSB intake by volume** -Sweetened juice: 39.9% -Flavoured milk: 22.1% -Cordial: 19.9% -Carbonated soft drink:15.0% -Milk shake/smoothie: 3.8% -Sports drink: 0.3% **Mean per-capita volume of SSB subcategories consumed** -Sweetened juice: 145ml -Flavoured milk: 38.8 ml -Cordial: 27.7ml -Carbonated soft drink: 56.5ml -Milk shake/smoothie: 12.9ml -Sports drink: 1.2ml **Mean contribution to total energy** -SSBs in boys: 4.2% -SSBs in girls: 3.8%	**NA**

Appendix B – Narrative summary of studies investigating fruit juice intake among preschool-aged children [1]

Country, Study, Sampling Year, Citation	Study Design, Dietary Assessment Method and Nutrient Database	Sample Size, Age (years) and Characteristics	Fruit Juice Intake Variable			Relevant Fruit Juice Results and Comparison with Recommendations	Conclusion (AAP or WHO)
			1 Consumer (%)	2 Volume/ Portion	3 Energy		
US ECLS-B 2005 (40)	Cross-sectional analysis. By proxy via FFQ for the week prior. Sugar analysis not completed.	n=8900 ~4.5 years Non-breastfed	•	•		**1 Percent consumers** - (≥1) time/day: 67.4% - (≥3) times per day: 18.4% - ≥1 time in the past week: 91.7% - None in past week: 8.3%	**NA**
US FITS 2016 (39)	Cross-sectional analysis. 24-hours dietary recall, primary caregiver over the phone. FPED for AS analysis.	n=413 1.5-2 years Breastfed included	•	•		**1 Percent consumers** - (≥1) time/day: 55% **2 Volume/Portion** - 18-20.9 months (n=251): 40% consumed >4 ounces (>118mL) and 29% consumed >6 ounces (>177 mL) - 21-23.9 months (n=162): 46% consumed >4 ounces (>118mL) and 32% consumed >6 ounces (>177 mL)	**AAP:** 55% of US children 1.5-2 years consumed 100% fruit juice. Around 1/3 of children exceeded AAP fruit juice recommendations.
US FITS 2016 (41)		n=600 2-4 years Breastfed included	•	•		**1 Percent consumers:** 46.7% **2 Per capita consumption** -100% fruit juice: 113.2g **2 Per consumer consumption** -100% fruit juice: 242.2g	**AAP:** 46.7% of US children 2-4 years consumed 100% fruit juice and on average exceeded AAP fruit juice recommendations on a per consumer basis but not a per capita basis.
US	Cross-sectional analysis.	n=3,345 0-5 years		•	•	**3 Contribution to TE (% kcal)** **-100% fruit juice:** 3.8%	**WHO:** 100% fruit juice alone

NHANES 2009-2014 (four cycles) (42)	Proxy, 24-hour recall, AMPM. FPED for AS analysis.	non-breastfed				-0-<1 years: 1.7% -1-<2 years: 4.7% -2-<3 years: 4.0% -3-<4 years:4.1% -4-<5 years: 3.8%	contributed nearly enough FS to exceed the WHO FS recommendation of <5% TE in US children 1-4 years
Mexico MHNS-2006 (37)	Cross-sectional 2006: semi-quantitative FFQ, past week. Sugar analysis not completed.	n=3552 1-4 years Breastfed included	•			**1 Percent consumers:** 25.3%	**NA**

[1] For comparison with AAP recommendations, 1 g of fruit juice was assumed to be equivalent to 1 mL

Appendix C – Stepwise determination of FS from ASA24-Canada-2016 data

1	**AS (tsp. eq.) was converted to kcal**
	a. AS (tsp. eq.) from foods and beverages was determined by ASA24. b. AS (tsp. eq.) was converted to kcal using the following equation: [1]AS (kcal) = AS (tsp. eq.) x (4.2 g/1 tsp. eq). x (4 kcal/1 g).
2	**'Sugar from Fruit Juice' was calculated for foods and beverages**
	a. Food and beverage items containing 100% fruit juice were identified using the ASA-24 F_JUICE variable. Items were categorized as 100% fruit juice or Mixed Items [2]. b. For 100% fruit juice (with no AS), FS is equal to TS and so the ASA24 TS data were used. c. For Mixed Items, the type of 100% fruit juice in the food or beverage item was identified. If it could not be reasonably identified, apple juice was used since it is the most common fruit juice. a. Sugar from Fruit Juice was calculated for each food and beverage item using the following equation: Sugar from Fruit Juice = Fruit juice (cups.eq.) x Grams Sugar Per Cup Fruit Juice[3]. b. For each food and beverage item, sugar from fruit juice was converted from grams to kcal using the following equation: Sugar from fruit juice (kcal) = Sugar from fruit juice (g) x 4 kcal / 1g
3	**FS (kcal) was calculated**
	a. FS was calculated for each food and beverage item by summing 'AS' (Step 1) and 'Sugar from Fruit Juice' (Step 2).

[1]ASA24 calculates AS using the USDA's FPED definition of AS. This includes all sugars added during processing and sugars from undiluted fruit juice concentrates (Bowman et al., 2014). The WHO defines FS as monosaccharides and disaccharides added to foods and beverages by the manufacturer, cook or consumer, and sugars naturally present in honey, syrups, fruit juices and fruit juice concentrates (WHO, 2015). ASA24 AS were calculated based on the FPED definition of AS where one teaspoon equivalent of AS was reported to be equivalent to 4.2 grams.
[2] ASA24 items (Food_Description) from the full study baseline children cohort that contain fruit juice were categorized into 1) 100% Fruit Juice or 2) Mixed Items. 1) 100% Fruit Juice includes 100% fruit juice & Fruit juice concentrate diluted to single strength with no AS. Items in this category included "Fruit juice blend, 100% juice, with added Vitamin C", "Orange juice, chilled, includes from concentrate", "Pomegranate juice, ready-to-drink", "Apple juice, canned or bottled, added vitamin C", "Fruit juice, NFS (Mixed fruit juices)", "Orange juice, frozen concentrate, with calcium and vit. D added, diluted", "Grape juice, canned or bottled,

unsweetened, with added vitamin C", and "Orange juice, frozen concentrate, unsweetened, diluted"). Coconut water is not counted as juice by ASA24-Canada-2016 but was treated as 100% fruit juice for this analysis. 2) Mixed Items included items that contain non-100% fruit juice sources of FS or 100% fruit juice plus other sources of FS. Items in this category include "Fruit smoothie drink, made with fruit or fruit juice only (no dairy products)", "Sauce, fruit (All fruits)", "Juice drink, fruit, ready-to-drink", "Fruit smoothie drink, NFS", "Fruit cocktail (peach, pear, apricot, pineapple, cherry, grape), canned, juice pack, solids and liquid", "Drink, fruit punch, vitamin C added, ready-to-drink", "Fruit flavored drink, low calorie, with high vitamin C", "Peach, canned halves or slices, juice pack, solids and liquid", "Lemon juice, raw", "Hummus, homemade", "Sauce, plum, ready-to-serve", "Macaroni or pasta salad", "Dessert, frozen, sherbet, orange", "Pad Thai with meat", "Macaroni or pasta salad with cheese", "Sweet and sour chicken", "Lemonade, frozen, diluted with water", "Fruit syrup (Strawberry, Blueberry)", "Light ice cream, creamsicle or dreamsicle (formerly ice milk)", "Sweets, jellies", "Macaroni or pasta salad W/ MAYONNAISE-TYPE SALAD DRESSING (INCLUDE MIRACLE WHIP)", "Sweets, fruit butters, apple".

[3]An in -house 'Grams Sugar Per Cup Fruit Juice' database was populated using ASA24 TS data for each fruit juice, e.g., "Apple juice, canned or bottled, added vitamin C" contains 24.05g / cup eq.

Appendix D – Categories and subcategories of snacks and beverages [1]

Food Group	Subcategory
Bakery Products	Baked Breakfast
	Baked Desserts
	Bread Products
	Cake
	Cereal/Granola Bars
	Cookies
	Pies, Tarts, Cobblers, Crisps
Beverages	Sugar-Containing Beverages[2]
	Unsweetened Milk
	Flavored Milk
	Plant-based beverages
	Fruit Juice
	Fruit Drinks
	Yogurt Beverage
	Smoothies
	Water
	Hot Beverages
	Regular Soft Drinks
	Diet Soft Drinks
	Sports Drinks
	Vegetable Drinks
	Energy Drinks
Cereals and Grain Products	Hot Breakfast Cereal
	Other Cereals and Grains
	Ready-to-eat breakfast cereal
Dairy Products and Alternates	Cheese
	Flavored yogurt
	Plain yogurt
	Cream cheese
Frozen Desserts	
Fats, Oils and Vinegars	Butter, margarine, oils
	Mayonnaise
Fruit	Raw fruit
	Fruit puree
	Dried fruit
	Fruit leather
	Canned fruit
	Frozen fruit
Meats, Eggs and Substitutes	Deli meats
	Eggs
	Meat and poultry
	Beans

Mixed Dishes, Sides and Entrees	Taco
	Soup
	Pizza
	French fries/hash browns
	Seafood salad
	Dumplings
	Pot pie
	Spaghetti
Nuts and Seeds	Butters, pastes and creams
	Nuts and seeds
	Nuts and seeds, Not For Snacking
Oral Nutrition Supplement	
Sauces, Dips and Condiments	Condiments
	Dips
	Sauces
Savory Snacks	Chips, corn and rice snacks
	Crackers
	Ethnic snacks
	Popcorn
	Pretzels
Confectionary and Sweet Condiments	Confectionary
	Sweet condiments
Vegetables and Legumes (except fried potatoes)	Raw vegetables
	Cooked vegetables and legumes
	Pickled vegetables
	Salad

[1] Categories were adapted from Bernstein et al., 2016. Sugar-containing beverages included beverages with sugars added during processing + 100% fruit juice.

Appendix E – Snack intake by major and minor snack categories and their contribution to FS energy intake among children [1]

Snack category	Children (percent)			Children's %TE from FS Mean (95% CI)
	≥1	1	≥2	
ALL SNACKS	260 (97)	17 (6)	243 (91)	4.0 (3.5 – 4.5)
BEVERAGE SNACKS	121 (45)	81 (30)	40 (15)	1.8 (1.3 – 2.3)
Sugar-Containing Beverages[2]	53 (20)	41 (15)	12 (4)	4.1 (3.2 – 5.0)
Fruit Juice	20 (7)	18 (7)	2 (1)	-
Smoothies	10 (4)	10 (4)	0	-
Plain Milk	73 (27)	49 (18)	24 (9)	0
FOOD SNACKS	257 (96)	24 (9)	233 (87)	3.2 (2.8 – 3.6)
Candy and Sweet Condiments	56 (21)	50 (19)	6 (2)	3.0 (2.2 – 3.8)
Confectionary	41 (15)	36 (13)	5 (2)	2.8 (2.2 – 3.3)
Sweet Condiments	16 (6)	15 (6)	1 (0.4)	-
Bakery Products	148 (55)	108 (40)	40 (15)	2.4 (2.1 – 2.7)
Baked Desserts	15 (6)	15 (6)	0	-
Bread Products	57 (21)	50 (19)	7 (3)	1.9 (1.3 – 2.5)
Cake	7 (3)	7(3)	0	-
Cereal/Granola Bars	42 (16)	41 (15)	1 (0.4)	2.4 (2.1 – 2.8)
Cookies	55 (21)	53 (20)	2 (0.7)	1.8 (1.3 – 2.3)
Dairy Products and Alternates	94 (35)	69 (26)	25 (9)	1.1 (0.7 – 1.6)
Cheese	46 (17)	39 (15)	7 (3)	0
Flavored Yogurt	40 (15)	37 (14)	3 (1)	2.7 (1.9 – 3.5)
Plain Yogurt	10 (4)	10 (4)	0	0
Savory Snacks	111 (42)	93 (35)	18 (7)	0.3 (0.2 – 0.5)
Chips, Corn and Rice Snacks	33 (12)	32 (12)	1 (0.4)	0
Crackers	64 (24)	58 (22)	6 (2)	0.4 (0.3 – 0.5)
Popcorn	16 (6)	16 (6)	0 (0)	-
Fruits	191 (72)	86 (32)	105 (39)	0.5 (0.3 – 0.8)
Raw Fruit	172 (64)	96 (36)	76 (28)	0
Fruit Puree	28 (10)	27 (10)	1 (0.4)	-
Dried Fruit	16 (6)	14 (5)	2 (1)	-
Fruit Leather	11 (4)	11 (4)	0 (0)	-

Vegetables and Legumes (except fried potatoes)	44 (16)	30 (11)	14 (5)	0.01 (-0.01 – 0.04)
Raw vegetables	35 (13)	21 (8)	14 (5)	0
Cereals and Grain Products	29 (11)	24 (9)	5(2)	-
Nuts and Seeds	42 (16)	35 (13)	7 (3)	0.1 (0.1 – 0.2)
Nuts and Seeds including trail mix	24 (9)	22 (8)	2 (0.7)	-
Butters, Pastes and Creams	19 (7)	18 (7)	1 (0.4)	-
Mixed Dishes, Sides and Entrees	16 (6)	13 (5)	3 (1)	-
Frozen Desserts	12 (4)	11 (4)	1 (0.4)	-
Meats, Eggs and Substitutes	11 (4)	11 (4)	0 (0)	-

[1] This table summarizes the number and percent of children 1.5-5 years who consumed different snack categories, relative to the total number of children (n=267). Percent was calculated to identify the proportion of children who consumed snack categories at least once (≥1) over 24-h, then calculated for the more discrete categories of one time (1) or two or more times (≥2). Not all children were reported to consume a snack (n=7). Not all children were reported to consume a snack (n=7). Mean children's %TE from FS was calculated for categories that were consumed by ≥30 children. For these calculations, only data from children who consumed each respective category were used (i.e., data from children who did not consume the snack category over 24-h were not included in the mean). For categories consumed by <30 children, mean %TE from FS was not calculated and was instead denoted with a dash. Categories consumed by <10 children were removed including (Bakery Products: baked breakfasts (n=6), pies, tarts, cobblers, and crisps (n=1)), (Beverages: flavored milk (n=9), plant-based beverages (n=9), fruit drinks (n=4), yogurt beverages (n=5), hot beverages (n=4), sports drinks (n=2)), (Dairy Products and Alternates: cream cheese (n=6)), (Fruits: canned fruit (n=1), frozen fruit (n=6)), (Meats, Eggs, and Substitutes: Deli Meats (n=3), Eggs (n=2), Meat and Poultry (n=6)), (Nuts and Seeds: Nuts and seeds, not for snacking (n=5), (Savory Snacks: ethnic snacks (n=1), pretzels (n=9), (Mixed Dishes, Sides and Entrees: Taco (n=1), soup (n=3), pizza (n=1), french fries/hash browns (n=7), sandwich (n=2), seafood salad (n=3), dumplings (n=1), pot pie (n=1), spaghetti (n=1)), (Vegetables: cooked vegetables and legumes (n=9), pickled vegetables (n=1), and salad (n=1)).
[2] Sugar-containing beverages included beverages with sugars added during processing + 100% fruit juice. FS, Free Sugar; TE, Total Energy

Appendix F – Participant flow chart