BEVERAGE INTAKE OF CHILDREN AND YOUTH WITH OBESITY

INVESTIGATING THE BEVERAGE PATTERNS OF CHILDREN AND YOUTH WITH OBESITY AT THE TIME OF ENROLLMENT INTO CANADIAN PEDIATRIC WEIGHT MANAGEMENT PROGRAMS

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Lay Abstract

Beverage intake can influence diet and health outcomes in population-based studies. However, patterns of beverage consumption are not well-described among youth with obesity. This study examined beverage intake and relationships with sociodemographic information, behaviours and health outcomes among youth (2-17 years) at time of entry into Canadian pediatric weight management programs (n=1425). In contrast to current recommendations, 80% of youth consumed ≥1 serving/week of sugar-sweetened beverages and 66% consumed <2 servings/day of milk. Additionally, five distinct patterns of beverage intake were identified using dietary pattern analysis. Social factors (age, sex, socioeconomic status) and behaviours (screen time, eating habits) were related to the risk of failing to meet recommendations and to beverage patterns. Identifying sociodemographic characteristics and behaviours of youth with obesity who fail to meet beverage intakes thresholds and adhere to certain patterns of consumption may provide insight for clinicians to guide youth to improved health in weight management settings.

Abstract

Introduction: Beverages influence diet quality, however, beverage intake among youth with obesity is not well-described in literature. Dietary pattern analysis can identify how beverages cluster together and enable exploration of population characteristics.

Objectives: 1) Assess the frequency of children and youth with obesity who fail thresholds of: no sugar-sweet beverages (SSB), <1 serving/week of SSB, ≥2 servings/day of milk and factors influencing the likelihood of failing to meet these cut-offs. 2) Derive patterns of beverage intake and examine related social and behavioural factors and health outcomes at entry into Canadian pediatric weight management programs.

Methods: Beverage intake of youth (2–17 years) enrolled in the CANPWR study (n=1425) was reported at baseline visits from 2013-2017. Beverage thresholds identified weekly SSB consumers and approximated Canadian recommendations. The relationship of sociodemographic (income, guardian education, race, household status) and behaviours (eating habits, physical activity, screen time) to the likelihood of failing cut-offs was explored using multivariable logistic regression. Beverage patterns were derived using Principal Component Analysis. Related sociodemographic, behavioural and health outcomes (lipid profile, fasting glucose, HbA1c, liver enzymes) were evaluated with multiple linear regression.

Results: Nearly 80% of youth consumed ≥1 serving/week of SSB. This was more common in males, lower educated families and was related to eating habits and higher screen time. Two-thirds failed to drink ≥2 servings milk/day and were more likely female, demonstrated favourable eating habits and lower screen time. Five beverage patterns were identified: 1) SSB, 2) 1% Milk, 3) 2% Milk, 4) Alternatives, 5) Sports Drinks/Flavoured Milks. Patterns were related to social and lifestyle determinants; the only related health outcome was HDL.

Conclusion: Many children and youth with obesity consumed SSB weekly. Fewer drank milk twice daily. Beverage intake was predicted by sex, socioeconomic status and other behaviours, however most beverage patterns were unrelated to health outcomes.

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Abbreviations

CVD: cardiovascular disease

T2D: Type 2 diabetes

NAFLD: Non-alcoholic fatty liver disease

HDL: High-density lipoprotein cholesterol.

LDL: High-density lipoprotein cholesterol.

TG: Triglycerides

TC: Total Cholesterol

Non-HDL: Non-high-density lipoprotein cholesterol.

AST: Aspartate transaminase

ALT: Alanine transaminase

SSB: Sugar-sweetened beverage(s)

ASB: Artificially sweetened beverages

CHMS: Canadian Health Measures Survey

CCHS: Canadian Community Health Measures Survey

CANPWR: Canadian Pediatric Weight Management Registry Study

Svg/day: servings per day

Svg/wk: servings per week

Hrs/day: hours per day

Hrs/wk: Hours per week

PCA: Principal component analysis

Declaration of Academic Achievement

Together with other CANPWR project sites and personnel, I assisted with the collection of baseline and follow-up data, data entry, participated in communication between research team members at the multiple sites in quarterly meetings and with the local team in bi-weekly meetings. Rutaba Khatan compiled baseline pilot and main study cohort data for my analysis, which I completed independently under the guidance of Dr. Katherine Morrison and input from Dr. Russell de Souza, Dr. Lehana Thabane and Rajibul Mian.

Chapter 1. Literature Review

Obesity in Children

At the simplest level, obesity can be defined as excess adiposity resulting from a positive energy imbalance sustained over time (Lau et al. 2006). Among children (<10 years old) and adolescents (10-19 years old) (Canadian Paediatric Society, 2003), obesity is classified as an age and sex-specific BMI z-score of ≥2 SD using the World Health Organization (WHO) growth charts (Onis et al. 2007) or a BMI ≥95th percentile according to the Center for Disease Control for age/sex-specific growth charts (Kuczmarski et al. 2002). While obesity prevalence among Canadian youth across all ages, sex and ethnicities has appeared to decrease by approximately 3% from 2004-2013, there remains approximately 13% of Canadian children and adolescents overall with obesity (Rodd and Sharma, 2016). Similarly, a recent analysis of medical records across Ontario from the Electronic Medical Records Administrative Data Linked Database demonstrated an annual decrease of 0.02 units in BMI z-score and a significant decrease in the odds of severe obesity (BMI z-score >3.0 according to WHO growth charts) from 2006 to 2015 among children and youth aged 5-18 years after adjusting for sociodemographic factors. Following this small decline in BMI z-scores, 3.0% of children and youth had severe obesity during 2014-2015 (Carsley et al. 2019). Although the prevalence of severe obesity in Canada, outside of Ontario is not well known, it has continued to rise in other developed countries such as the United States (Skinner et al. 2016).

Consequences of Obesity in Children

Youth with obesity are considered a high-risk population for cardiovascular disease (CVD) given the increased prevalence of multiple cardiovascular risk factors (hyperlipidemia, hypertension, dysglycemia) which can lead to the progression of atherosclerosis (Berenson et al. 1998).

Compared to healthy weight children and adolescents, youth with obesity are more likely to have significantly elevated total cholesterol (TC), triglycerides (TG), low-density cholesterol (LDL) (Friedemann et al. 2012) and lowered concentrations of high-density cholesterol (HDL) (Messiah et al. 2014). Often, these abnormalities in the lipid profile of youth with obesity occur concomitantly and combined dyslipidemia is commonly characterized by lowered HDL with elevated TG, non-HDL and/or low-density cholesterol (LDL) (Kavey et al. 2015).

In addition to an impaired lipid profile, dysglycemia is also a major health concern in children and youth with obesity. Dysglycemia often presents itself as elevated fasting plasma glucose or HbA1c %, and/or by abnormally high plasma glucose two hours after a standardized glucose challenge (Saleh et al. 2018). Obesity-related metabolic abnormalities include insulin resistance (Friedemann et al. 2012; Sinha et al. 2002) and impaired insulin production due to beta cell dysfunction in the pancreas (Sinha et al. 2002; Tresaco et al. 2003). These are important predictors of prediabetes (Ajala et al. 2017) and Type 2 Diabetes (T2D) and can occur in childhood or later in adulthood (Hannon et al. 2005; Srinivasan et al. 2002). Additionally, the manifestation of these risk factors into CVD later in life (Barr et al. 2007) is due in part to an inflammatory state induced by insulin resistance and hyperglycemia (de Ferranti et al. 2019; West et al. 2009). Thus, monitoring metabolic health in children and youth with obesity is critical short and long-term.

Non-alcoholic fatty liver disease (NAFLD) is also associated with insulin resistance (Alisi et al. 2009; Nobili et al. 2006), elevated TG and TC (Alp et al. 2013; Nobli et al. 2006). NAFLD is highly prevalent among individuals with obesity (Alp et al. 2013; Nier et al. 2018) and is cited to affect nearly 35% of children and youth enrolled in weight management clinics (Anderson et al. 2015a). This disease is characterized by fat accumulation in the liver and elevated liver enzymes including aspartate aminotransferase (AST) and alanine aminotransferase (ALT) (Delvin et al. 2014) and can range in severity from mild steatosis to cirrhosis (Nobli et al. 2006).

In addition to the multiple physical implications of pediatric obesity, this population is also more likely to experience mental health issues. Among the associated psychological health impacts of obesity in youth, these individuals are at an increased risk of depression (Morrison et al. 2015), lowered self-esteem (Strauss 2000) and bullying (Puhl and King 2013). In a cross-sectional analysis of children and youth aged 8-17 years enrolled in a Canadian pediatric weight management program, body fat percent predicted lower health-related quality of life and an increased risk of depression independently of age, sex, socioeconomic status (SES). (Morrison et al. 2015). Additionally, youth who report lower self-esteem tend to participate in higher risk behaviours, (Strauss et al. 2000) or develop mental health disorders such as binge eating disorder which can hinder progression to improved health outcomes in weight management settings (Wildes et al. 2010)

In summary, the significant health consequences of childhood obesity including dysglycemia, hypertension and dyslipidemia (Nadeau et al. 2011; Sahoo et al. 2015) can manifest later in life as one of various non-communicable diseases such as CVD (Nadeau et al. 2011; Raitakari et al. 2003; Sahoo et al. 2015), type 2 diabetes (T2D) or NAFLD (Nobili et al. 2006), and result in an increased risk of premature mortality in adulthood (Engeland et al. 2003; Flegal et al 2005). Furthermore, obesity in childhood often persists into adulthood (Juonala et al. 2011; Morrison et al, 2008), with an estimated 24-90% of youth with obesity remaining obese as adults (Singh et al. 2008). Thus, obesity in childhood is a condition associated with significant morbidity and mortality, highlighting the need to identify efficacious approaches to treatment.

Contributing Factors of Obesity

Many inter-related factors contribute to the development and progression of obesity and may be appropriate targets for such treatment approaches. Some factors including genetic pre-disposition (Frayling et al. 2007; Herbert et al. 2006), environmental exposures beginning in-utero (e.g. maternal obesity) (Segovia, et al. 2014) and the built surroundings that can promote unhealthy lifestyles (e.g., availability of unhealthy foods) are non-modifiable. However, behavioural factors may be modifiable (Sahoo et al. 2015; Xu and Xue 2016) such as sedentary lifestyles and diet which can both contribute to obesity (Lobstein et al. 2004) in high-income countries and increasingly more in low-income countries (Ford et al. 2017). Thus, modifiable behaviours are a primary focus in the clinical management in pediatric weight management (Canadian Task Force on Preventative Care 2015).

Behavioural and Lifestyle Factors

Among many behaviours that can contribute to increased weight status, eating behaviours are a critical part of overall diet (Berge et al. 2017; Trofholz et al. 2019; Wijtzes et al. 2015) and can influence diet quality and play an important role in pediatric obesity management (Lau et al. 2007; Styne et al. 2017; Weihrauch-Blüher et al. 2018). Mealtime tendencies such as frequency of breakfast consumption and structured family dinners are associated with consumption of more nutritious foods and are related to lower prevalence of obesity among children and youth (Watts et al. 2016). Mealtime structure (i.e. family meals) is an important component of the home food environment and is related to the accessibility of healthful foods in the home and family eating habits (Couch et al. 2014; Demissie et al. 2015). Meals eaten as a family and prepared at home are associated with increased fruit and vegetable intake as well as higher scores on validated dietary quality indices (Trofholz et al. 2017). Increased availability of fruit and vegetable consumption at home has been shown to be an independent predictor of better diet quality among children and youth independent of SES (Ranjit et al. 2015; Schrempft et al. 2015). Furthermore, a relative lack of mealtime structure and consumption of fast foods is higher among youth with obesity. As such, Canadian children and youth enrolled in the Canadian Health Measures Survey (CHMS) cycle 2.2 who were classified as obese, reported consumption of an average of 80 calories more from fast food per day compared to those with healthy weight status (Black and Billette 2015). Therefore, eating habits such as eating out/ordering in are an important focus of the youth diet.

Among other behaviours, low physical activity levels and high screen time have been consistently cited as contributing factors of obesity (Kumar and Kelly 2017; Sahoo et al. 2015; Xu and Xue 2016). Currently, self-reported physical activity of both youth with healthy BMI and youth with obesity often falls below the recommended 60 mins of moderate to vigorous physical activity per day (Tremblay et al. 2016). From 2014 to 2015, it was estimated that only 35% of children and adolescents aged 5 to 17-years achieved the recommended 1-hour per day of moderate to vigorous physical activity (Barnes et al. 2018). This is concerning, as objective measures of physical activity have demonstrated that individuals with obesity accumulate significantly less moderate to vigorous physical activity than their healthy weight, age and sex matched counterparts (Cooper et al. 2015; Elmesmari et al. 2018). Although 30 minutes of moderate to vigorous physical activity per day has been shown to significantly reduce the risk of obesity by nearly 50% independently of age, sex and sedentary time among children and adolescents (Katzmarzyk et al. 2015), inadequate exercise among all children and youth is evident, especially among youth with obesity.

These sedentary lifestyles of youth highlight an important factor to address in pediatric weight management (Elmesmari et al. 2018), especially given that time spent using electronic devices has continued to increase since the early 2000's (Saunders, et al. 2014). Currently, an estimated 50% of Canadian children and youth ages 6-17 years report screen time use of two or more hours per day (Statistics Canada (a)). Of further concern, time spent on the computer, watching TV or using other electronics has also been associated with an increased tendency to snack and consume beverages with high sugar content, ultimately increasing total energy intake (Jashinky et al. 2017) and the risk of obesity (Avery et al. 2017; Börnhorst, et al. 2015; Kelishadi et al. 2017; Lipsky et al. 2017). The relationship between poor diet and screen time may be a result of distracted eating and higher consumption of snack foods (Trofholz et al. 2017) or exposure to unhealthy food advertising (e.g. TV commercials) (Kelly et al. 2019; Taylor et al. 2005). These ads often appeal to children and youth and can influence this population to consume more fast foods and SSB, especially given that youth have reported feeling susceptible to food advertising (Gesualdo and Yanovitzky 2019).

Social Determinants of Obesity

While behaviours such as screen time and poor physical activity levels can directly contribute to obesity, certain populations of youth and children are at a higher risk of obesity based on sociodemographic characteristics (You and Choo 2016; Guerrero et al 2016). The prevalence of obesity and related co-morbidities such as CVD risk factors (Winkleby et al. 1999) and diabetes (Goran et al. 2003) vary across age, sex (Carsley et al. 2019), race, SES (Ford et al. 2016; Guerrero and Chung 2016; Khanolkar, et al. 2013; Lord et al. 2015) and family structure (Gibson et al. 2007).

Population-based studies examining obesity prevalence among children of different race in high-income countries demonstrate that youth of black race have a significantly greater odds of obesity [OR=1.7; 95% CI: 1.1, 2.6] compared to white children independently of age, sex and SES (Zilanawala et al. 2015). Furthermore, SES is another sociodemographic factor and can be measured using household parental education or income. Studies assessing relationships between SES and weight status in youth have shown a higher prevalence of obesity among children with parents who are lower educated (You and Choo 2016) and from lower income households (Goisis et al. 2016). In a study assessing BMI and eating habits of children aged 1-5 years from low-income households, youth whose parents reported difficulty buying food due to affordability were 30% and 60% more likely to consume less than three servings of fruits and vegetables per day and more than one serving per day of fruit juice or sugar-sweetened beverage (SSB) after adjustment for gender, physical measures, maternal BMI, education of guardian, ethnicity, and neighbourhood income (Fuller et al. 2017).

Less understood, family structure is another socio-cultural factor that is associated with youth obesity prevalence and lifestyle behaviours in children and youth. Family structure has been described in previous studies by the number of occupants within a household (Gibson et al. 2007), the number of residences a child lives in or the marital status of the parents (Chen et al. 2010; Baek et al. 2014). It has been demonstrated that youth belonging to single-parent households are at a higher risk of obesity compared to those of two-parent households (Gibson et al. 2007), independent of covariates including ethnicity and SES (Chen et al. 2010; Schmeer 2012). While there is no clear explanation of the relationship between household status and obesity in children, it has been hypothesized that parenting behaviours may be different in single parent households, eg. less strict rules surrounding food intake at home (Ambrosini et al. 2009) and higher likelihood of eating meals in front of the TV (Avery et al. 2017). Therefore, while the specific association with obesity remains unclear, family structure may provide insight into eating behaviours of families and certain children and adolescents at a greater risk of obesity.

To summarize, assessing sociodemographic factors is critical to determine how obesity prevalence and related lifestyle factors such food accessibility vary among sex, age, race, SES and family structure. Identifying these social determinants can help to better understand which individuals are at an increased risk of obesity and may face barriers to achieving improved health outcomes.

Beverages as a Target of Weight Management in Youth

In addition to the home food environment and screen time, beverage intake may also be representative of overall diet quality. SSB intake has been associated with lowered diet quality measured using validated dietary scoring methods (e.g. Healthy Eating Index) (Leung et al. 2018a) and is also known to increase total energy intake independently of sex, ethnicity, SES and the presence of overweight or obesity (Leung et al. 2018b).

As part of weight management programs, behaviour-focused interventions involve dietary counselling. This dietary plan should include the creation of plans and goals for dietary change together with the child and guardian (Canadian Task Force on Preventative Care 2015). The aim of these plans should emphasize foods high in protein and aim to reduce consumption of fatty or processed foods and sugary beverages (Lau et al. 2007; Styne 2017). Specifically, eating whole fruit instead of fruit juice (Canadian Task Force on Preventative Care 2015; Wojcicki and Heyman 2012) and eliminating soft drinks, energy drinks, fruit drinks, sports drinks and sweetened hot beverages is emphasized in an effort to reduce sugar and energy intake (Styne et al. 2017; Health Canada, 2007). Thus, beverage consumption is an important modifiable behaviour that can be targeted to improve dietary quality in weight management settings.

Sugar-Sweetened Beverages

SSB are considered a contributor to obesity, and the rise in obesity prevalence up to the early 2000's has been paralleled by increased sugared beverage consumption in youth in multiple countries (Bray and Popkin 2014). SSB include any beverage with sugars added by the producer or consumer. Examples include soft drinks, energy drinks, fruit-flavoured beverages, flavoured milks and sweetened coffees or teas. These beverages provide little nutrient value beyond calories and are not satiety-promoting. Often, their consumption is not compensated for by a decrease in food intake, which can consequently lead to a hyper-caloric diet (Popkin. and Hawkes 2016) and may explain the relationship between increased adiposity and SSB consumption in children and youth (Zheng et al. 2015). Children and adolescents with obesity have been cited to consume a greater number of calories from sugar-sweetened beverages compared to children of healthy weight (Millar et al. 2014). Furthermore, patterns of sugared drink intake have been identified among youth (Beck et al. 2014). For example, consumption of more than one energy drink per week has been associated with increased intake of sweetened fruit drinks (Larson et al. 2014) while fruit juice, soda, and sports drinks are also known to be consumed in combination (Williams et al. 2017).

Although reports of beverage purchases in Canada suggest declining intakes of fruit juice, soft drink and fruit-flavoured beverages by 10-27% among all ages, large increases in other SSB have been demonstrated, including energy drinks which increased a staggering 638%, flavoured milks by >20% and sports drinks by nearly 5% from 2001 to 2015 (Jones et al. 2017). A recent report of evidence from the 2015 Canadian Community Health Survey (CCHS) showed that

Canadian children and adolescents aged 2-18 consume on average 9% of total daily energy intake from sugars in beverages. Further, while sugar intake from soft drinks decreased by nearly half (15.9% to 7%) since the 2004 CCHS cycle, soft drinks remain a top contributor to daily sugar intake among Canadian youth. Together, all sugary beverages combined (soft drinks, sweetened milks, juice, fruit drinks, ED and milk alternatives and sweetened tea and coffee) remained the highest contributors to daily sugar from 2004 to 2015 compared to any other food source such as fruits, syrups and confectionary in children and youth (Langlois et al. 2018). Similar findings in other developed countries such as the US have been observed for which reported energy intake from added sugars was nearly 16% of total energy intake, with >40% of this energy from SSB sources (Afeiche et al. 2018).

In interventions targeting reduction of SSB to improve weight status, results have been somewhat mixed but improvements in measures of adiposity have been cited. A systematic review of educational and/or environmental school-based programs and delivery of beverages to homes in predominantly healthy weight children demonstrated generally positive results on weight status in children and adolescents. Of the eight intervention studies assessed, two led to reduced BMI and three school-based education programs lowered the risk of obesity at follow-up. However, reductions in adiposity and SSB intake were often not sustained or evaluated after 12 months (Avery et al. 2015). Included in this review, one study examined a 2-year intervention in adolescents with overweight or obesity who were SSB drinkers. These individuals were provided water and diet beverages for the duration of the study. Reported SSB intake significantly declined by nearly 1.5 servings per day at 1- and 2-year follow-up from 1.7 servings consumed daily at baseline. Significant decreases in BMI in the intervention group compared to the control group were noted at 1-year (−0.57 units; $p<0.05$) but not at 2-years (Ebbleing et al.

2012). Thus, evidence from cross-sectional studies point to a positive relationship between weight status and SSB consumption while a decrease in adiposity when SSB are reduced is also evident in limited interventions targeting SSB in youth.

Energy Drinks and Sports Drinks

Among SSB, energy drinks and sports drinks are unique from other SSB due to their nutritional profile. Energy drinks contain high amounts of caffeine (Pound et al. 2017) which is associated with adverse health impacts including difficulties with sleep, headaches and other health outcomes (Pound et al. 2017; Visram et al. 2016). Consequently, the Canadian Pediatric Society has released a position statement which discourage energy drink use among children and emphasize the need for physicians to communicate these risks educate youth and families (Pound et al. 2017). Although a link between BMI and energy drinks consumption was not found in young adults (Trapp et al. 2014), few studies have assessed the influence of energy drinks on weight status exclusively of other beverages in children and youth. Consequently, in a review exploring the relationship between SSB and CVD risk by Hoare et al. (2017), future recommendations included elucidating the link (if any) between energy drink consumption and CVD risks such as obesity.

Sports drinks are another misused beverage by children and youth. These drinks contain high sugar and sodium and are meant to replenish electrolytes after prolonged vigorous exercise and excessive sweating. Despite their intended use, many adolescents consume these beverages for taste (Broughton et al. 2016), as sports drinks contain in excess of 40g of sugar per 8 oz. serving (Field et al. 2014). For this reason, these beverages are and are often grouped together with all other SSB in large dietary analysis. In a study by Field et al. (2014) the link between sports drinks exclusively and weight status was examined in children 9-11 years. It was found that those who reported drinking sports drinks daily at baseline exhibited an increase in BMI of 0.3 kg/m^2 at 3-year follow up independent of age, time between study visits, baseline BMI, physical activity and time spent watching TV (Field et al. 2014). However, few studies have investigated the link between sports drinks and weight gain exclusively. Although additional research is needed to confirm the link between sports drinks and weight status, the American Academy of Pediatrics recommends that these beverages should be consumed solely by adult elite athletes given their high sugar content (Schneider and Benjamin 2011).

Fruit Juice

Although the previous edition of Canada's food guide recommended ½ cup of 100% pure fruit juice as a serving of fruits and vegetables (Health Canada 2007), the current Canada Food Guidelines recommend limiting sugary drinks and replacing these with water as the main beverage source (Health Canada, 2019). The high energy content and absence of fiber compared to whole fruit has also led to recommendations against this type of beverage in pediatric weight management settings (Styne et al. 2017). Furthermore, the WHO considers the mono and di-saccharides from fruit juice and fruit juice concentrates as contributors to total daily energy intake from sugars, grouping these sugars with sucrose added to foods and beverages like soft drinks (World Health Organization, 2015). In line with WHO recommendations, fruit juice intake has significantly declined amongst adolescents in developed countries such as the United States since the early 2000's (Bleich et al. 2018; Herrick et al. 2017). In Canada, direct measures of fruit juice trends over time in Canada are not well described, however a large cross-sectional survey of sweet beverage intake in adolescents (n= 10,188) conducted in 2010 reported that 48.0% consumed fruit juice the day prior to assessment (Vanderlee et al. 2014).

Among a recent review of fruit juice intake and measures of weight status in youth, fruit juice consumption was significantly linked to weight status in two cross-sectional studies, however when adjusted for total energy intake, fruit juice was not a significant correlate of adiposity in 11 other cross-sectional, prospective or retrospective studies (Crowe-White et al. 2016). In another meta-analysis of longitudinal relationships between weight status and daily fruit juice intake of 8 oz per day, Auerbauch et al. (2017) found clinically insignificant BMI z-score increases of 0.09 units among young children aged 1-6 years and an average BMI z-score unit increase of <0.001 among children and youth ages 7-18 over a period of one year after adjustment for daily energy intake. The relationship between fruit juice and weight status is difficult to conclude, as most studies are population-based, and cross-sectional studies present heterogeneity. Given this, randomized controlled trials and longitudinal studies are recommended in the future to better understand how fruit juice may influence weight status among children and youth (Auerbach et al. 2017; Crowe-White et al. 2016).

Artificially-Sweetened Beverages

In the wake of the high energy content of SSB, artificially-sweetened beverages (ASB) have been widely consumed in an effort to reduce caloric intake (Swithers, 2015), While calorie free, the heightened sweetness of ASB is thought to condition individuals to crave more sweet foods and potentially lead to dysregulated appetite (Pereira, 2014), ultimately leading to consumption of other high energy sweet foods (Frisch, 2016; Swithers, 2015). For example, based on dietary recalls collected from the 2011 to 2016 NHANES cycles, youth who consumed at least 4 oz. of ASB daily compared to those who consumed at least 4 oz of water per day had significantly higher total daily energy intake by nearly 200 calories independently of BMI. Interestingly, there was no difference in total energy intake between those who consumed ≥4 oz ASB per day and those who drank ≥4 oz SSB per day (Sylvetsky et al. 2019). Thus, evidence suggests that strategies to replace SSB with ASB may not result in declines in energy intake and the use of ASB in place of SSB is not an effective means to improve weight status and other cardiometabolic health outcomes if calories are consumed from other sources (Johnson et al. 2018).

In support of these findings, a recent review of 56 studies by Toews et al. (2019) of youth with normal and increased BMI discovered that those who consumed artificial sweeteners for at least seven consecutive days had an average 0.15 [95%CI: −0.17 to −0.12] lower BMI z-score vs those who consumed less or no artificial sweeteners. Interestingly, randomized controlled trials included in this review did not result in a significant reduction in average body weight among those who consumed artificial sweeteners compared to controls (i.e. those who consumed no or less artificial sweetener) (Toews et al. 2019). While there is limited evidence for improvement in BMI z-score with artificial sweetener use compared to SSB, multiple reviews conclude that future studies including randomized blinded controlled trials and detailed information of control groups are needed to elucidate the relationship between artificial sweeteners and health outcomes (Pereira 2014; Toews et al 2018; Young et al. 2019).

Milk

Low-fat, unflavoured milk and water are recommended for youth in place of juice and other sweetened beverages (Styne et al. 2017, Health Canada 2019). Milk intake is important, especially for young children, as it is a major source of nutrients, minerals (e.g. vitamin D, calcium) and protein important for growth (Fenton 2017). Milk is consumed more frequently by young children (Bleich et al 2018) vs older adolescents who tend to consume more SSB (Herrick et al. 2017). Given its protein and fat content, milk has a satiety-promoting effect, especially among higher fat milks. In a study in boys with overweight, milk consumption at breakfast compared to apple juice resulted in lower perceived hunger and reduced energy intake by 50 ± 19 calories at the midday meal (Mehrabani et al. 2016). Similarly, in a randomized crossover trial in children aged 10-12 years (n=48), reported appetite was significantly lower four hours after consuming a serving (240 ml) of full-fat milk compared to skim milk during breakfast (Kavesade et al. 2018).

Furthermore, milk has been described as having a protective effect against obesity in multiple cross-sectional analyses and reviews. In a systematic review of milk intake and obesity among young children and adolescents, a weak inverse association between adiposity (BMI, BMI percentile, BMI z -score) and milk intake was seen in adolescents, however this effect was not seen in younger children (Dror 2014). The protective effect of milk against obesity has also been cited for full fat milk in a cross-sectional study of 2745 young children age 1 – 6 years. Results demonstrated that those who consumed full-fat milk compared to 1% milk had a 0.72 [95% CI: 0.68, 0.76] lower z-BMI score, when controlled for age, sex, screen time, PA, volume of milk and SSB intake, maternal BMI and SES (Vanderhout et al. 2016).

In the previous version of Canada's food guide (2007), a minimum 2 servings of milk and alternatives per day were recommended for the youngest age group (2 years). In the more recent version of the document, released early in 2019, no specific number of milk servings has yet to be recommended, as milk and meat are now part of a larger group of protein sources (Health Canada, 2019). Furthermore, milk 'alternatives' have become increasingly popular in recent years. From 2011 to 2015, almond milk sales have increased by 250% (St. Pierre 2017) while cow's milk intake has declined. Few studies have examined the influence of milk alternatives on weight status among children and youth in contrast to previous findings demonstrating a protective effect of cow's milk against obesity (Dror et al. 2014; Vanderhout et al. 2016). With the exception of soy milks, protein quantity is diminished in these alternatives including rice and almond milks (Fenton 2017; Singhal et al. 2017). For example, in a 240ml serving of regular cow's milk and soy milk there is approximately 8g of protein, however in the alternatives such as almond milk there is less than 2g of protein (Vanga et al. 2018). The lower nutrient and protein content of these beverages compared to cow's milk poses concern, as the decreased nutritional content may have implications for child growth and body composition (Lappe et al. 2017). However, the relationship between milk alternatives and weight status has yet to be explored.

Flavoured Milks

Among other sweetened beverages, flavoured milk beverages have been consumed by youth for their palatability and may help youth to consume more nutrients and minerals from their diet (Fayet-Moore 2016). Flavoured milk is often advertised to athletes on social media. Chocolate milk companies often use words "refuel" to connect to active individuals (Lauricella and Koster 2016) and "Recover like a champion" (https://www.builtwithchocolatemilk.com). Although these types of beverages may offer beneficial effects for sports training and recovery in athletes (Amiri et al. 2018), future studies with stricter controls (e.g. diet) are needed to confirm these effects (Born et al. 2019).

While benefits for healthy athletes may exist, flavoured milk drinks contain a large amount of sugar, totalling 28g per one cup serving (ASA24 Dietary Assessment Tool, Version 2019, National Cancer Institute, Bethesda, MD). Given the predominantly sedentary lifestyles of children and youth today (Barnes et al. 2018), consumption of sweetened milk is unnecessary. Drinking one or more servings of flavoured milk per day, has been related to higher total body fat content (Noel et al. 2013) and increased total energy intake (Patel et al. 2018). Alternatively, in another cross-sectional study, it was found that weekly intake of flavoured milk is associated with a 12% lowered risk of obesity independently of relevant covariates (Beck et al. 2015). Given these inconsistent findings in recent literature, reviews by Fayet-Moore et al. (2016) and Patel et al. (2018) failed to establish a significant relationship between weight status and flavoured milk intake. In conclusion, despite containing calcium and protein and nutrients such as vitamin A, vitamin D among others, chocolate milk's sugar content is concerning for youth with obesity. Future randomized clinical trials are needed to help elucidate the relationship between flavoured milk and measures of adiposity in youth controlling for dietary intake (Patel et al. 2018).

Social and Behavioural Factors Related to Beverage Consumption

Similar to differences in the prevalence of obesity, sociodemographic factors vary with consumption of different beverages across age and sex and correlate with different behaviours such as eating habits, physical activity and screen time among youth. For example, among children and adolescents from 2011-2014 NHANES, older youth consumed significantly more energy from SSB than children <12 years old. Specifically, males ages 6–11 consumed 6.6% of total energy intake from SSB and adolescents aged 12–19 years consumed 9.3% of calories from SSB. Similarly, energy intake calculated from SBB for females accounted for 5.8% among girls aged 6–11 and 9.7% for youth aged 12–19 years (Rosinger et al. 2017). These results were similar to previous surveys in the US such as one by Evans et al. (2010) in which it was found that regular soda consumption decreased with age; 10% more grade 11 vs grade four students reported drinking soft drinks the previous day (Evans et al. 2010). However, when fruit juice consumption was assessed in the same study, 15% less individuals reported consuming fruit juice in grade 11 compared to those in fourth grade (Evans et al. 2010).

Multiple other population-based studies have examined trends of beverage and demonstrated that SSB intake is greater among males compared to females and older individuals (Cordrey et al. 2018; Han and Powell 2013). However, the frequency of adolescents consuming fruit juice daily has also been documented to be similar among males and females at about 15% (Winkvist et al. 2016) and higher among younger children (Bleich et al. 2018).

Furthermore, beverage consumption differs among various racial populations. For example, Asian children in the United States, consume fewer calories from SSB than white, black or Hispanic youth (Rosinger et al. 2017). This trend was paralleled by an analysis of sugar intake from beverages from population-based studies conducted across different European countries from 2009 to 2012. This study reported sugar intake from SSB contributed 43% of American children's daily sugar intake compared to 28% in Mexican children and only 7% among Chinese youth ages 4-13 years (Afeiche et al. 2018). Additionally, decreases in milk consumption since 2011 are most prominent among non-Hispanic white adolescents regardless of sex (Miller et al. 2017), thus trends in beverage intake appear to vary with ethnicity.

Among proxies of SES and the relationship with diet quality, higher SES (highest income or parental education level) is associated with diets high in low-fat milk, while lower SES is related to consuming diets high in soft drinks after controlling for age, sex, and BMI z-scores (Manyanga et al. 2017). In a study assessing diet reported by guardians of children aged 1-5 years in low-income households, Fuller et al (2017) found that youth whose parents reported difficulty buying food due to affordability were 30% and 60% more likely to consume one or more servings per day of fruit juice or SSB after adjustment for gender, physical measures, maternal BMI, education of guardian, ethnicity, and neighbourhood income. Thus, SES is an independent determinant of diet quality and is related to consumption of SSB in youth.

Beverage intakes are also linked to other behavioural or lifestyle factors including physical activity, screen time and eating habits. Lower physical activity (Ranjit et al. 2010; Rao et al. 2015) and screen time (Calaramro et al. 2012; Hicks et al 2019) have been documented to coincide with SSB intake in youth. Kenney et al. (2017) demonstrated that screen time totaling more than five hours per day nearly doubled the odds of consuming one or more servings per day of SSB across nearly 25,000 US high school students independent of age, sex, race and screen time. However, SSBs such as ED have been associated with active lifestyles, potentially due to stimulatory effect of these beverages for performance and the tendency of youth to consume ED and sports drink during or post-exercise. This trend was seen among 2793 American children and adolescents in grades 6-12 in which individuals who reported participating in a higher amount of moderate to vigorous physical activity consumed sports drinks weekly (Larson et al. 2014).

Differences in beverage intake with different behaviours including screen time are often influenced by sex. Screen time is consistently cited to be more pronounced in males, particularly the association between playing videogames and energy drink intake (Cordrey et al. 2018; Larson et al. 2014; Visram et al. 2017). Furthermore, fruit juice intake among girls and soft drink consumption among boys have been negatively associated with the frequency of eating meals prepared at home and consumption of milk independently of other variables such as total energy intake, SES and eating habits (Vagstrand et al. 2009).

Taken together, differences in beverage intake are observed among individuals based on different sociodemographic characteristics and with different favourable and unfavourable behaviours among youth (Ford et al. 2016). These inter-related social factors and behaviours are important to consider in the management of childhood obesity as they may help clinicians to identify certain barriers to be targeted in weight management counselling.

Relationship Between Beverage Intake and Metabolic Health Outcomes

Since beverage choices have been associated with the tendency to develop obesity among children and youth, consumption of beverages high in added sugars such as SSB have also been associated with obesity-related health outcomes, including dyslipidemias, impaired fasting glucose and elevated liver enzymes along with other comorbidities of obesity.

In 2011, the Expert Panel on Integrated Guidelines for Cardiovascular Health and Risk Reduction in Children and Adolescents recommended limiting SSB intake by youth in an effort to lower CVD risk (NIH, 2012) and more recently, the American Heart Association released a scientific statement in 2017 which summarized the relationship between CVD risk factors and added sugar intake from sources such as SSB (Vos et al. 2017). In this review by Vos et al. (2017), two cross-sectional studies of adolescents aged 12 to 19 years from the 1999-2004 NHANES cohort (n=6967 and n= 2157) reported positive associations between added sugars from SSB with TG levels and an inverse relationship with HDL-cholesterol levels compared to those who drank no SSB. While evidence for metabolic health implications with SSB intake were noted in this review, quality of the evidence was low given that studies were predominantly cross-sectional. Considering these limitations, Vos et al. (2017) emphasize the need for intervention studies, randomized controlled trials and longitudinal studies to better understand the impact of added sugars from SSB on cardiovascular health. Additionally, authors suggest that future research focus on the relationship between 100% juice and cardiovascular health, as the cardiovascular implications of fruit juice intake remains largely unexplored in youth (Vos et al. 2017).

SSB intake has also been related to measures of glycemia. In a meta-analysis of SSB consumption and type 2 diabetes risk in adults, a 13% [CI: 6%; 21%] increased risk of type 2 diabetes was identified in those who consumed SSB daily independent of covariates including adiposity (Imamura et al. (2015). Among youth, an analysis of beverage intake in more than 600 individuals aged 4–18 during 2009-2012 demonstrated that daily consumption of SSB was associated with a 6% higher sugar intake, 0.30 mmol/L higher blood glucose levels and 0.29 mmol/L higher TG levels vs non-consumers (0 servings per day). These relationships persisted after adjustment for various demographic variables, physical activity and takeaway food consumption (Seferidi et al. 2017). High-fructose corn syrup present in SSB has also gained attention in recent years for its metabolic implications including increased risk of diabetes (Imamura et al. 2015; Xi et al. 2014), elevated ALT (Chiu et al. 2014) and dyslipidemias (Vos et al. 2017) in primarily adult populations. However, the link between fructose and metabolic health outcomes has not been consistently described in the literature (Hannou et al. 2018). Often, total energy intake (Chiu et al. 2014; Chiavaroli et al. 2015) and adiposity (Lin et al. 2016) are stronger predictors of metabolic health and attenuate the effect of SSB. Additionally, the relationship between fructose consumption and metabolic health outcomes varies depending on the source of fructose. To elucidate these relationships, a recent review which assessed different sources of fructose intake and resulting differences in measures of glycemia (HbA1c, insulin, fasting glucose) in different study types (substitution, addition, subtraction and ad libitum studies) was conducted. It was found that the source of fructose played an important role on the relationship between fructose and metabolic health depending on the study type: fruit juice demonstrated a beneficial interaction on fasting glucose in substitution studies (i.e. iso-caloric foods or beverages without fructose), SSB had a negative interacting effect on fasting glucose in addition studies and sweetened milks were associated with increased insulin levels in substitution studies (Choo et al. 2018).

Furthermore, findings linking ASB with metabolic health outcomes are difficult to interpret given the current methodological shortcomings of predominantly cross-sectional studies (Brown et al. 2010; Pereira 2014). In the cross-sectional analysis by Seifreidi et al. (2015), ASB was related to greater energy and sugar intakes from solid foods and similar increases in fasting blood glucose concentration (0.24 mmol/L) compared to those who did not drink ASB. Implications of ASB and SSB appear to be similar in other studies, with no significant changes in TG levels after a 12-week RCT of 2 serving per day intervention of ASB or SSB in healthy overweight adults with or without hepatic steatosis (n=26) (Campos et al. 2017). In summary, beverage intake (primarily SSB) appears to influence metabolic health in addition to diet quality and weight status. This is concerning given that this population is already at an increased risk of adverse metabolic health outcomes.

The Use of Dietary Patterns to Assess Diet and Beverage Intake

While associations between specific beverage types are useful to determine their relationship with behavioural or health outcomes, individuals often consume multiple types of beverages on a regular basis. Therefore, identifying how beverages are consumed together is useful to assess beverage intake in nutritional epidemiology settings. To do so, methods of dietary pattern analysis can be used to reduce large amounts of dietary intake information to a few identifiable underlying patterns (Hu, 2002). Different methods of dietary pattern analysis such as cluster analysis or principal component analysis (PCA) have been used to characterize diet as a whole rather than specific nutrients or foods alone. Once patterns are identified using pattern analysis, the relationships between diet and sociodemographic factors and health outcomes can be explored (Cespedes and Hu 2015; Manyanga et al. 2017).

Briefly, cluster analysis is used to define mutually exclusive groups of individuals within a population who demonstrate similar observations (i.e. quantity beverage and food intake) (Hu 2002). The other method, PCA, linearly correlates items or variables (i.e. food and beverages) to derive patterns called “components” which explain the variance in observed outcomes. The resulting patterns are characterized by food and beverages that are most prominent within that pattern (i.e. is most strongly related to that component). These relationships can provide insight for researchers and health professionals on how different diets vary among certain populations and which lead to favourable or poorer health outcomes such as CVD (Rodríguez-Monforte et al. 2015).

Among dietary analysis in children and youth, few studies have focused exclusively on beverage intake exclusively in pediatric populations. Emmett et al. (2015) tracked dietary patterns among 13, 988 children from ages 3-9 years old in a birth cohort study population. Using PCA, dietary patterns were revaluated each year from FFQ responses and three similar patterns were derived at all follow-ups: Snacks, Junk/processed, Traditional and Healthy/Health-Conscious/Vegetarian. The Snacks pattern (component) was characterized by a high loading on carbonated beverages in addition to other convenience foods. This pattern explained 4.2% of the total 20% variance in food and beverage intake by PCA. Further analysis revealed that individuals with high component scores (i.e. greater adherence) for the Snacks pattern were more often male, had more than two siblings and mothers who attained a lower education level (Emmett et al. 2015).

In a cross-sectional analysis, Ambrosini et al (2009) identified two dietary patterns in adolescents aged 14 years (n=1631). These patterns included a Western diet characterized by high fat, cholesterol, and refined sugar intake from sources such as SSB and a "Healthy" pattern which loaded highly on juices and mineral water in addition to foods such as vegetables, fruits, fish, whole grains and other items. Together, these patterns explained 84% in dietary intake. Authors found a significant association between the Western pattern and watching TV and lower SES (indicated by income). Alternatively, the Healthy pattern was associated with sex (female), higher SES (higher maternal education), living in a two-parent household and lower TV use (Ambrosini et al. 2009).

Furthermore, the importance of beverages in dietary pattern analysis is important to consider. In a randomized intervention study, 173 adolescents with overweight were provided one liter of water skim milk, casein or whey mix per day for 12 weeks. PCA was used to derive dietary patterns which included: Convenience Food, Fast Food and Health-Conscious Food patterns. It was found that those who consumed skim milk, casein or whey mix drank significantly less SSB and had lower average component scores to the Convenience food pattern scores at 12 weeks on an ad libitum diet (Andersen et al. 2016). Thus, the derivation and characterization of dietary patterns in large populations allows for a greater understanding of which foods and beverages are consumed together and how related sociodemographic and behaviours predict adherence to different diets.

Previously Defined Beverages Patterns in Youth

Four studies have used dietary pattern analysis to specifically assess beverage intake only in youth populations. These have all used cluster analysis, which groups individuals together rather than identifying which beverages are correlated together. Once subjects are clustered into one exclusive group, the characteristics of these individuals can be explored (Hu et al. 2002).

In a study by Danyliw et al. (2012), beverage consumption data from single 24-hour recalls completed by 10,038 children aged 2-18 years of age as part of the Canadian Health Measures Survey Cycle (CHMS) 2.2 were assessed. Clusters were defined according to beverages commonly consumed by individuals, stratifying for age. Five clusters were characterized: "Fruit Drink", "Soft Drink", "Milk", "High-Fat Milk" And "Fruit Juice". The fruit drink cluster was comprised primarily of children aged 2-5 years, while the soft drink cluster was comprised of both children and adolescents aged 6-11 and 12-18 years respectively. Boys aged 6-11 years who were in the soft drink cluster had a higher risk of being overweight, independent of total energy intake, age, income, ethnicity, and food security (Danyliw et al. 2012).

In another cross-sectional analysis, LaRowe et al. (2007) utilized dietary recalls of children from the 2000-2001 NHANES study and identified five clusters of beverage intake. Children aged 2-5 years generally fell within a "Mix/Light Drinker", "High-Fat Milk", "Water", or "Fruit Juice" and the addition of a "Soda" among 6 to 11-year-old children. Diet quality assessed by the Healthy Eating Index Score was highest among 6-11-year old children within the high-fat milk cluster after controlling for BMI, age, sex, ethnicity, household income, physical activity and screen time. When differences in sociodemographic characteristics were compared in children aged 2-5 years, a greater proportion of males belonged to the fruit juice cluster vs the water cluster, a greater number of non-Hispanic African-American children belonging to the Mix/Light Drinker pattern vs the High-Fat Milk cluster and those in the water cluster were more likely to be from a higher income family. When differences between clusters among children aged 6-11years were observed, those in the Water cluster had significantly greater income than other clusters, and screen time was significantly higher for those in the Sweetened Drinks cluster vs the Mix/Light Drinker.

In addition to these two cross-sectional studies, one longitudinal study of beverage patterns in youth has been published. Marshall et al. (2017) assessed beverage intake patterns using cluster analysis longitudinally from questionnaire responses completed by youth between the ages of 13-14 years and again at age 17 (n=352). At baseline, five clusters were identified including “100% Juice”, “Milk”, “Water/Sugar-Free Beverages”, “Sugar-Sweetened Beverages” and “Neutral” (i.e. no high intake of any single beverage type). These clusters were once again identified at age 17 and no new patterns were derived, suggesting stability in beverage patterns across adolescence. Multiple sociodemographic characteristics were significantly different across clusters. Those within the Milk cluster were more likely male than female while females comprised a greater proportion of the fruit juice cluster. Among indicators of SES, those who belonged to the SSB cluster were more likely to have mothers who were lower educated. Furthermore, at follow-up (age 17), this group had significantly higher measures of BMI compared to those in the milk, water and SSB clusters. Alternatively, individuals in the 100% juice group had a lower average BMI compared to water/sugar free and milk groups at age 17 (Marshall et al. 2017). While beverage patterns appeared to track over time and were related to weight status, it should be noted that this study assessed beverage intake at two points and did not record any events or lifestyle factors between these two measurements, which could substantially contribute to differences in BMI, regardless of beverage intake patterns.

In summary, beverage pattern analysis provides a more complete understanding of beverage intake than assessing one type of beverage or nutrient from beverages sources. Limited previous research demonstrates that beverages do form into distinct patterns of consumption and are related to different sociodemographic factors and weight status. However, no patterns of beverage intake exist using PCA in populations of children and youth with obesity.

Current Approaches to Pediatric Weight Management

Given that obesity is a multifactorial disease, pediatric weight management programs that target multiple modifiable behaviours (e.g. physical activity, diet) are thought to be most effective according to evidence compiled by The Canadian Task Force on Preventive Health Care (2015). Weight management programs in Canada utilize a family-centered approach (Ball et al 2011), consistent with evidence that guardians are important mediators of dietary (Faught et al. 2016; Kairey, L., et al. 2018) and physical activity (Golan and Crow, 2004) related behavioural changes in children and youth. To assist with behavioural change, it is recommended that the clinical management of pediatric obesity include structured sessions with a multidisciplinary team including physicians, dieticians, psychologists, among others (Ball et al 2011).

Changes in weight status, cardiometabolic health, quality of life and fitness have been identified in pediatric weight management programs focused on modifiable behaviours including diet and exercise (Mead et al. 2017; Peirson et al. 2015). In a meta-analysis conducted by Peirson and colleagues (2015), a decrease in BMI z score of approximately 0.5 with behavioural intervention compared to control groups (no/minimal intervention) was identified after six months. However, continued reduction in BMI z-score was not sustained 1-year post-intervention, and no further significant changes in BMI z-score were found in the few studies (n=4) that continued follow-up after the 12-month time point. Although treatment programs varied greatly and few studies exceeded 6-months in length, current evidence demonstrates that targeting behavioural and lifestyle factors is the most effective approach to improve weight status measured by BMI and BMI z-score (Peirson et al. 2015) in children and youth. However, it is clear that improvements in these programs or identification of other approaches will be necessary for sustained declines in BMI or BMI z-score.

Summary

Beverage intake plays an important role in youth diets, can contribute to daily energy and nutritional intake, and reflect diet quality. Beverages, primarily SSB, are well-known to influence overall diet quality and have been associated with an increased risk of other unfavourable metabolic health outcomes. However, few studies have assessed patterns of beverage intake among youth and none have evaluated beverage consumption in children with obesity. Therefore, this study aims to evaluate beverage intake in children with obesity and to examine the behavioural and sociodemographic correlates of beverage consumption and the relationship to health outcomes.

Multidisciplinary behavioural change approaches are implemented in the clinical management of childhood obesity. Thus, a fuller understanding of beverage intake, including variability in beverages consumed, beverage patterns, socio-demographic correlates, and the relationship of beverage intake to other behaviours and health outcomes amongst youth with obesity at the time they commence pediatric weight management may assist health care professionals in further refining treatment programs.

Project Objectives

Primary:

1) Identify the frequency that youth and children with obesity who fail to meet, recommendations for sugar sweetened beverage and milk intake at the time of entry into a Canadian pediatric weight management program.

2) Evaluate the socio-demographic (age, sex, ethnicity, socioeconomic status, household status) and behavioural (eating habits, screen time, physical activity) factors related to failing to meet, pre-determined intakes of sugar-sweetened beverages and milk.

Secondary:

1) Identify patterns of beverage intake among youth with obesity and determine if there are related socio-demographic (age, sex, ethnicity, socioeconomic status, household status) and behavioural factors (eating habits, screen time, physical activity) among individuals at the time of entry to a pediatric weight management program.

2) Explore the relationship between beverage intake and metabolic health outcomes (lipid profile, measures of glycemia, liver enzymes) in children and youth with obesity.

Chapter 2: Methodology

Study Population

Data for this project included baseline information of children and youth who were enrolled in the Canadian Pediatric Weight Management Registry (CANPWR) Study pilot and main cohorts. The inclusion criteria for participants in CANPWR were broad and included any child or youth age 2 – 18 years who was entering one of 10 participating Canadian pediatric weight management programs. McMaster Children's Hospital has been the largest site in this study and is also the data coordinating site. For the analysis pertaining to this thesis, inclusion criteria comprised individuals in both the pilot and main studies who had a BMI z-score of ≥ 2.0 (classified as obesity according to respective WHO age/sex specific growth chart) (Onis et al. 2007). Only baseline data, collected at the time of entry into clinic prior to receiving counselling was evaluated.

Primary Objective #1

Identify the proportion of youth with obesity who fail to meet recommendations for sugar sweetened beverage and milk intake at the time of entry into a Canadian pediatric weight management program.

Outcomes

To assess consumption of SSB, fruit juice and milk, a semi-quantitative food frequency questionnaire (FFQ) was used. This FFQ was a modified version of the questions sampled from the Canadian Heath Measures Survey Cycle 2 (November 2012) (Tremblay, M., et al. 2007). The FFQ utilized is included in the appendix (Appendix Section 7). Consumption of 15 beverages was reported based on a 1-cup (250 mL) serving size and categorical responses were converted into servings per day as described in the Appendix Table A1, Section 1.

Sugar-Sweetened Beverages: In line with clinical guidelines suggesting no sugar-sweetened beverage intake among youth with obesity (Styne et al. 2017; Lau et al 2006), the frequency of children and adolescents who did not meet recommendations by consuming either, any SSB (>0 servings per day) and those who consumed one or more SSB per week was determined. Two definitions for SSB recommendations were chosen as the period of reference utilized in the questionnaire was the past month. Therefore, we defined failure to meet the cut-off as either zero intake of SSB or fruit juice or a slightly less stringent definition of less than one serving SSB or fruit juice per week. Thus, anyone who consumed more than one serving of SSB or fruit juice per week failed to meet the recommendation of no SSB intake. Further, based on some evidence that suggests fruit juice intake may have a different relationship with metabolic health than other SSB (Choo et al. 2018), these beverage types were analyzed separately and then together. That is, **SSB only** included fruit flavoured beverages, regular sodas, flavoured milks, sports drinks and energy drinks and **total SSB** included these and fruit juice.

Milk: To determine the number of youth with obesity who were regular milk drinkers, the frequency of youth who consumed more than one, or two daily servings per day of milk (skim, 1%, 2% or 3.25%) were reported. Given that 2007 Canada's Food Guidelines were being implemented at the time of the baseline data collection (2013-2017), these cut-offs were selected to determine the number of youth with obesity who consumed milk daily and/or fulfilled the minimum recommended milk and alternatives intake of two or more servings per day (Health Canada, 2007) from milk sources alone.

Statistical Analysis

Distributions of all variables included in the analyses were assessed for normality using the visual method of Q-Q plots. This method uses plots of quantiles of data on the y-axis and the quantiles of the normal distribution on the x-axis. Deviations of data points from the normal distribution (line of best fit) were assessed which indicated that data was not normally distributed. The Q-Q plot method has been suggested as a more effective means of investigating normality with large sample sizes (Ghasemi et al. 2013), as the Shapiro-Wilk test may be too conservative (Peat and Barton 2008). Beverage intake and any other non-parametric variables were reported as median and interquartile range (IQR) of the 25th and 75th percentiles. Data was not transformed if non-parametric given the large sample size (n>1000) and assumption of the central limit theorem (Altman et al. 2012). The frequency of youth who fail to meet SSB, fruit juice or milk intake recommendations was reported as a percent or "n" for continuous and categorical variables respectively.

Primary Objective 2:

Evaluate the socio-demographic (age, sex, ethnicity, socioeconomic status, household status) and behavioural (eating habits, screen time, physical activity) factors related to failing pre-determined intakes of sugar-sweetened beverages and milk.

Outcomes

As consuming any SSB was quite restrictive (and was somewhat difficult to evaluate with our questionnaire given the one-month interval), children and youth who consumed more than one serving of SSB or fruit juice per week were considered to have failed to meet the recommended intake of SSB. Those who consumed fewer than two daily servings of milk (skim, 1%, 2% or 3.25% combined) were considered to have failed the criteria for milk intake.

Potential Correlates Examined

Exposures of interest were recorded using self-reported questionnaires by guardian and/or child at baseline.

Sociodemographic**-** The sociodemographic factors that were included were self-reported ethnicity, annual household income, parental education and household status. Ethnicity (cultural and racial background) could include multiple different responses: “White”, “Chinese”, “South Asian”, “Black, Filipino”, “Latin American”, “Canadian First Nation”, “Southeast Asian”, “Arab”, “West Asian”, “Japanese”, “Korean”, or “Other”. Responses were grouped as “White” or “Other” for the analysis, given the predominantly white study population**.** Indices of socioeconomic status (SES) included annual total household income level and male/female guardian education. Household income was assessed using a scale from “<$49,000”, “$50,000-79,000”, “$80,000-99,000” or “$≥100,000” annually. Highest level of education completed by male and female primary caregiver was determined using a scale from “No High School”, “Some High school”, “High school diploma”. “University/College” or “Post-Graduate”. Income level was dichotomized into <$50,000 and ≥$50,000 annually. Household income of <$50,000 per year was selected as low-income cut-off based on Statistics Canada data which suggested this income below this threshold as low-income in rural and urban areas regardless of the number of household members (Statistics Canada (b)) in 2013-2017 when the data was collected. Guardian education level was also dichotomized as “High school or lower” and “College/University” respectively. Household status was reported as living in one primary residence or multiple residences.

Behavioural Factors- Beverage intake is related to several behavioural factors including physical activity and sedentary activities (Hicks et al 2019; Ranjit et al. 2010). Further, home eating behaviours may also influence beverage intake (Avery et al. 2017). Given this, we sought to evaluate these relationships in our study. Specifically, weekly moderate to vigorous physical activity was calculated by summing weekly hours spent engaging in moderate to vigorous physical activity (referred to as physical activity herein) during i) free time at school, ii) in unorganized activities outside of school and iii) organized activities outside of school. We derived daily screen use (hours/day) from the sum of total reported number of hours spent watching TV, playing video games and/or computer games or other leisure activities on electronic devices each day. Based on relationships between eating habits, the home food environment and diet quality of children and youth as described in chapter one, the following characteristics of the family food environment were considered: the frequency of eating in front of the TV, the frequency of eating meals as a family and the number of times eating out or ordering food in weekly. Responses ranged from “Never, less than 1/month” to “4-5 times per day” and participant behaviour responses were converted to continuous frequency per week as listed in Table A1, Appendix, Section 1.

Covariates

Height and weight, age and sex were collected from clinical charts. Height and weight measures were used to derive BMI z-scores according the WHO 2006 growth charts for children and youth (Onis et al. 2017). Age, sex and BMI z-score were included in all adjusted multivariate models.

Statistical Analysis

The purpose of this analysis was to determine which, if any, sociodemographic and behavioural factors influenced the likelihood of failing to meet SSB intake of once per week or failing to meet milk intake of twice per day. First, children and youth who did and did not meet the recommendations for SSB, fruit juice, total SSB (fruit juice and SSB) and milk intake as described above were identified. Univariate analysis including chi-square analyses and independent t-tests were used to compare the sociodemographic and behavioural factors described above in those who met or failed to meet the pre-defined beverage intakes. Variables that were significant in Chi-square analysis and independent t-tests analyses ($p<0.05$) were included in multivariate logistic regression models to explore their relationship with the likelihood of youth failing to meet the pre-determined beverage intakes. The multivariate models were also adjusted for age, sex and BMI z-score.

The variance explained by each model was assessed by the Cox & Snell and Nagelkerke R^2 values. All models were tested for collinearity to ensure that independent variables (sociodemographic and behavioural variables) were correlated <0.7 with one another as assessed using Pearson correlations. To further assess collinearity, variance inflation factor (VIF) <10 in multivariate models for all sociodemographic and behavioural independent variables were deemed acceptable (Peat et al. 2008). The odds ratio (OR) and 95% confidence intervals [95% CI] were reported for each significant variable in multivariate models.

Sensitivity Analyses: Multiple Imputation of Missing Values

Given that the study sample size decreased from n=1536 to n=1425 when participants without full beverage information were excluded (7.2% loss of information), a sensitivity analysis using multiple imputation was performed to evaluate differences in primary objective results (meeting or failing to meet recommended beverage intakes) with inclusion of missing data. Multiple imputation has been suggested as a robust method to account for missing data with five dataset imputations reported sufficient for this method of handling missing data (Pederson et al. 2017). All variables of interest (i.e. beverage intake, sociodemographic and behavioural variables) as well as auxiliary variables related to the imputed variables were included in the imputation process (i.e. those not directly used in analyses). These auxiliary variables included weight, height, BMI and moderate to vigorous physical activity in school and outside of school (unorganized and organized). Inclusion of auxiliary variables has been suggested as a more robust method of estimating missing values for missing cases to reduce bias (Collins et al. 2001). Pooled estimates (mean, SE) generated by multiple imputation were used to repeat logistic regression analyses in primary objective #2. Imputed and initial results were compared descriptively and any changes in observations were reported.

Secondary Objective 1

Identify patterns of beverage intake among youth with obesity and determine if there are related socio-demographic (age, sex, ethnicity, socioeconomic status, household status) and behavioural factors (eating habits, screen time, physical activity) among children and youth at the time of entry to a pediatric weight management program.

Outcomes

Components (used interchangeably with "patterns" herein) of beverage intake were derived using principal component analysis (PCA). This method correlates items to create linear relationships between variables of interest and derive components which explain the variance (%) in observed food or beverage intake. Suitability of PCA for a dataset is determined by the Kaiser-Meyer-Olkin (KMO) statistic which indicates sampling adequacy and suitability of the dataset for PCA. A KMO of ≥0.5 is generally sufficient for use of PCA. Multiple parameters are generated and used to determine which patterns are important to retain from those produced by PCA. The Eigenvalues ≥1.0 measure the variance explained and are displayed graphically on scree plots which graph the eigenvalues (y-axis) vs component number (x-axis) (Jannasch et al. 2018). Components with eigenvalues of 1.0 or greater are considered important to retain. Alternatively, component numbers which occur before a plateau in the scree plot arm can also be considered if there are many components with Eigenvalues >1.0. This plateau in the scree plot following a "break" in the scree plot line of best fit indicates that the addition of more components does not add greatly to the variance explained. Next, to characterize the patterns, factor loadings are assessed. Factor loadings are the correlation coefficients between items (i.e. beverages) and that component which characterize the patterns depending on which items that have high factor loadings (>0.3) (Hu, 2002). Orthogonal rotation is used to increase interpretability, that is to ensure that the linear components are uncorrelated, and items (beverages) have positive factor loadings >0.3 on one exclusive component where possible (Emmet et al. 2015; Fernández-Alvira et al. 2014). To determine components to retain, first the KMO statistic was interpreted and it was ensured that this value was equal to or greater than 0.50. Next, the variance explained of all components, their eigenvalues and the scree plot were assessed to determine which additional component did not significantly add to the variance explained. Finally, the factor loadings of each item for the components of interest were assessed to characterize patterns according to beverages with factor loadings 0.30 or greater.

Other outcomes generated by PCA are component scores. Component scores indicate adherence to each defined pattern and are generated for every participant (DeCoster 1998) by multiplying each item's factor loading by the respective participant response (i.e. servings for that beverage or food item) for a component. These products are summed for each component and individual (Emmett et al. 2015). A higher positive score indicates a greater degree of adherence to that pattern while a lower or negative score indicates low adherence or avoidance for that dietary pattern. All component scores are standardized to have a mean of 0 and SD of 1.0. To determine relationships between patterns of beverage intake and outcomes of interest, regression modelling can be conducted using continuous component scores as independent variables (DiStefano et al. 2009).

Correlates

Sociodemographic and behavioural factors listed above in primary objectives.

Covariates

Age, sex and BMI z-score as above.

Statistical Analysis

To derive patterns, orthogonal rotation (varimax rotation in SPSS) was used to improve interpretability and create a simple structure, i.e. ensure beverage patterns did not correlate with one another and one type of beverage demonstrated a high factor loading ≥0.3 on one exclusive pattern (Henrion et al. 1994). The Kaiser-Meyer-Olkin (KMO) values ≥0.5 were used as a cut-off to indicate sampling adequacy and suitability of the dataset for PCA. Components with eigenvalues ≥1.0, which coincided with the break in the scree plot arm (indicating a plateau in total variance explained) were assessed to determine the number of components to retain. Along with these parameters, the interpretability of the rotated component matrix was examined and factor loadings (measure of an individual item's correlation with that component) ≥0.3 were decided to be important characterizing items for that component (Emmett et al. 2015; Fernández-Alvira et al. 2014). Factor loadings <0.10 were suppressed.

To determine relationships between patterns of beverage intake and sociodemographic and behavioural factors, component scores were automatically generated during PCA. Component scores indicated adherence to each defined pattern and were generated for every participant (DeCoster 1998). Scores were used as continuous outcomes to assess the relationship between sociodemographic factors (ethnicity, household income, guardian education, household status) and behavioural variables (eating habits, physical activity, screen time). Significant predictors related to beverage pattern scores were determined using univariate linear regression analyses

($p<0.05$) and were then included in multiple linear regression models adjusted for covariates. Collinearity was assessed as described in primary objectives.

Secondary Objective 2:

Explore the relationship between beverage intake and metabolic health outcomes (lipid profile, measures of glycemia, liver enzymes) in children and youth with obesity.

Outcomes

The relationship of beverage intake to health outcomes was of interest in this population. In particular, the relationship with lipids, glycemia and liver enzymes were explored. Fasting clinical bloodwork collected at time of enrollment was extracted from the clinical charts at each site in a standardized manner. Outcomes included fasting plasma glucose (mmol/L) and HbA1c (%) as measures of glycemia, and lipid profile which included TG (mmol/L), TC (mmol/L) and HDL (mmol/L) which were measured directly using standardized protocols. LDL; mmol/L was determined using the Friedewald formula [(TC-HDL -TG)/2.2] while non-HDL cholesterol (TC – HDL; mmol/L) was also calculated. Given the potential for LDL to be underestimated in the event of hypertriglyceridemia when using the Friedewald equation (Li et al. 1994; Martin et al. 2013; Sibal et al. 2010), non-HDL was calculated to provide a more robust measure of other atherogenic particles including very low-density lipoprotein cholesterol, intermediate-density lipoprotein cholesterol, and lipoprotein(a) (Srinivasan et al. 2006). Liver Enzymes ALT (U/L) and AST (U/L) were also collected from clinical charts.

The frequency (N, %) of individuals with abnormal laboratory values were described according to normative ranges for metabolic outcomes adapted from the American Heart Association cardiovascular risk values for pediatric populations (de Ferranti et al. 2019) and values derived from biochemical assay results assessed for Canadian children (CALIPER normative ranges)

(Adeli et al. 2017). Detailed information on the classifications of metabolic abnormalities are described in Table A2 (Appendix, Section 1).

Correlates

Component scores described in secondary objective 1 were used as independent variables to determine the relationships with metabolic health outcomes.

Covariates

Age, sex and BMI z-score were controlled for.

Statistical Analysis

Univariate linear regression analyses were first conducted between each continuous metabolic outcome (dependant) and all component scores. Significant component scores ($p<0.05$) were included in the multivariate models adjusted for age, sex, and then BMI z-score in a second model to determine if BMI z-score explained a greater variance in metabolic health outcomes or attenuated the effect of a component score on health outcomes. Collinearity between exposures of interest in the final model was assessed once again using Pearson correlation coefficients <0.7 (Dormann et al. 2013) and VIF values <10 (Ghasemi et al. 2012). The variance explained (R^2) and overall significance of the model was reported.

Sensitivity Analyses

Grouping Beverages Prior to PCA:

Given that PCA is a hypothesis generating method of analysis and is influenced by the decision of the researcher, pre-defined beverage groupings were created and PCA was run again. Pre-defined groups for the 15 beverages were defined based on previous literature using clustering analysis (Danyliw et al. 2012) and similarities in nutritional content. These beverage groupings included: i) SSB, ii) unsweetened drinks (water, diet soda, and vegetable juice), iii) total milk (all milk and alternatives) and iv) fruit juice. Once groups were established, PCA was re-run as in secondary objective #1 to determine if there were differences in resulting patterns of intake. These results were compared to the initial PCA descriptively, and related demographic and behavioural factors were investigated as described in secondary objective #1.

Chapter 3. Results

Participant Sociodemographic Characteristics

The pilot and main study cohorts were combined as the measures used in each were identical. The primary analysis was conducted in those who had full beverage intake information (n=1425). These participants were nearly equal male (48.0%) and female (52.0%) and had a median age of 12.25 (IQR: 9.83, 14.83). The median BMI z-score was 3.57 (IQR: 2.82, 4.01) and the distribution of z-scores was positively skewed (Figure 1). All descriptive information is detailed in Table 1. Among guardians with full information for education level, more female (n=1035) than male guardians (n=838) completed college or university. The study population was predominantly white and lived in one primary residence. Participants who were grouped in "other" identified most often as Black (8%), Latin American (7%) South Asian (6%), and/or Canadian First Nation (5%). More than a quarter of participants reported an annual household income <$50,000.

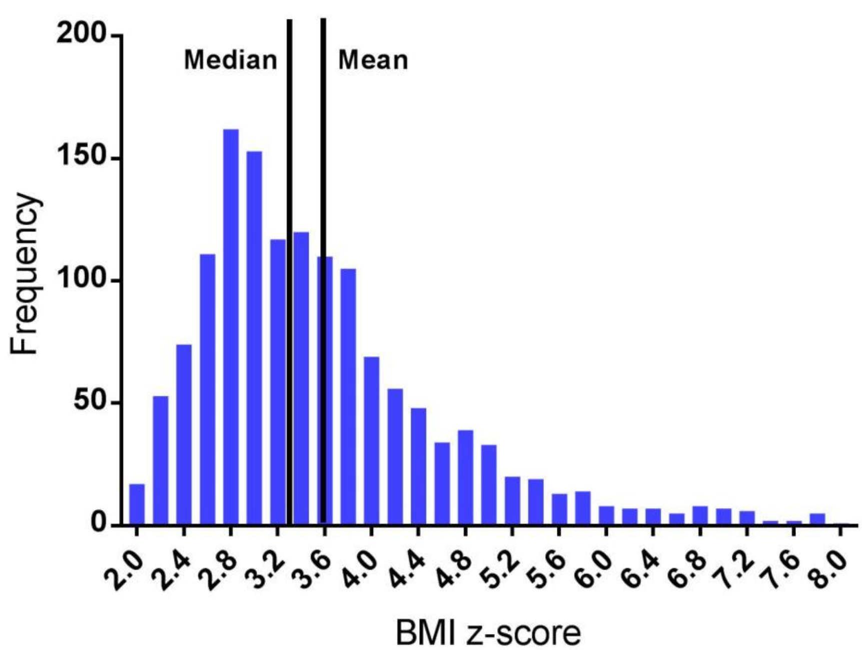

Figure 1. Distribution of BMI z-scores at baseline (n=1425)

Table 1. Participant characteristics (n=1425).

	Median	IQR
Age N=1425	12.25	9.83, 14.83
Sex N=1425	**N**	**%**
Female	741	52.0
Male	684	48.0
Racial Background N=1425		
White	985	69.1
Other	440	30.9
Income N=1423		
<49,000	390	27.4
50-79,000	296	20.8
80,000-99,000	206	14.5
100,000	448	31.4
Female Caregiver Education Level N=1421		
No Highschool	16	1.1
Some Highschool	67	4.7
Highschool Diploma	282	19.8
College/University	921	64.8
Post Graduate	114	8.0
Male Caregiver Education Level N=1423		
No Highschool	31	2.2
Some Highschool	85	6.0
Highschool Diploma	351	24.7
College/University	724	50.9
Post Graduate	114	8.0
Household Status N=1422		
One	1261	88.7
Multiple	161	11.3

Behavioural and Lifestyle Information of Participants

Participants generally consumed meals out or ordered once per week ate as a family seven days a week and ate one meal per week in front of the TV. Children and adolescents participated in physical activity 5.0 hours per week and accumulated 3.50 hours per day of screen time (Table 2). Given the large range in responses for behavioural variables, the distribution of eating habit frequencies, hours of physical activity per week and screen time per day is illustrated in Figures A1-A2 in the appendix.

Table 2. Behavioural information reported at baseline.

	N	%	Median	IQR
Eating Habits Eating Out/Ordering In (Weekly)	1421	99.7	1.0	0.5, 3.0
Family Meals (Weekly)	1421	99.7	7.0	1.0, 7.0
Meals in Front of TV (Weekly)	1402	98.4	1.0	0.0, 7.0
Physical Activity (hrs/wk)	1271	89.2	5.0	2.5, 8.5
Screen Time (hrs/day)	1402	98.4	3.50	2.5, 5.5

Metabolic Health Outcomes at Baseline

The metabolic health outcomes were assessed in multiple ways: reported on the clinical chart, based on available laboratory measures extracted from the clinical chart (as described in the Methods section). Applying American Heart Association and CALIPER cut-off values (Table A2, Appendix, Section 1), the most frequently observed abnormal metabolic health parameter was HDL (n=736) for which close to 65% of participants had abnormal laboratory values. Following HDL, elevated ALT affected nearly half of this population (45.8%). Far fewer had elevated AST levels (13%), which may indicate liver dysfunction given that ALT is primarily produced by hepatocytes (Giannini et al. 2005). Other abnormalities included elevated TG (27%), elevated non-HDL (21%), TC and HbA1c (12% each). Impaired FPG and increased LDL were less common. The most frequently diagnosed co-morbidities in children and adolescents at time of enrollment were dyslipidemia (n=248) and NAFLD (n=115) (Table 3).

Table 3. Health outcomes of participants at baseline.

Health Outcome	**N**	**Median**	**IQR**	**Abnormal**	
				N	**(%)**
BMI	1425		27.67, 37.43	-	-
BMI z-score	1425		2.82, 4.01	-	-
Laboratory Values					
Total Cholesterol	1136	4.20	3.73, 1.88	132	11.6
HDL	1162	1.13	.97, 0.43	736	64.3
LDL	1136	2.45	2.07, 0.59	122	2.2
Non-HDL	1135	3.04	2.57, 0.0	239	21.1
Triglycerides	1142	1.21	.87, 0.29	303	26.5
HbA1c%	889	5.30	5.10, 0.50	103	11.6
Fasting Plasma Glucose	1120	4.90	4.60, 3.30	96	8.6
AST	1023	24.00	20.0, 10.00	156	13.4
ALT	1103	24.00	18.0, 0.00	532	45.8
Diagnosed Co-Morbidities					
Pre-Diabetes	1425	-	-	53	3.7
Type 2 Diabetes	1425	-	-	16	1.1
Dyslipidemia	1425	-	-	248	17.4
NAFLD	1425	-	-	115	8.1

Primary Objective #1: Proportion Meeting Thresholds for SSB And Milk

The full beverage consumption data is included in the Appendix, Table A3, Section 2. Water was the most highly consumed beverage for the children and youth in this cohort and they consumed a median of 4.50 (IQR: 2.50, 6.0) servings daily. Given that weekly consumption of one or more servings of SSB or fruit juice was assessed, the median weekly consumption of SSB, fruit juice and milk is also depicted in Figure 2. The most highly consumed SSB included fruit juice (Median= 0.14; IQR: 0.07, 1.0) servings per day, flavoured milk (Median= 0.07; IQR: 0.0, 0.14) servings per day and soft drinks (Median= 0.07; IQR: 0.0, 0.14) servings per day. When all milk types were considered, youth consumed a median 1.0 (IQR: 0.43, 2.50) servings per day.

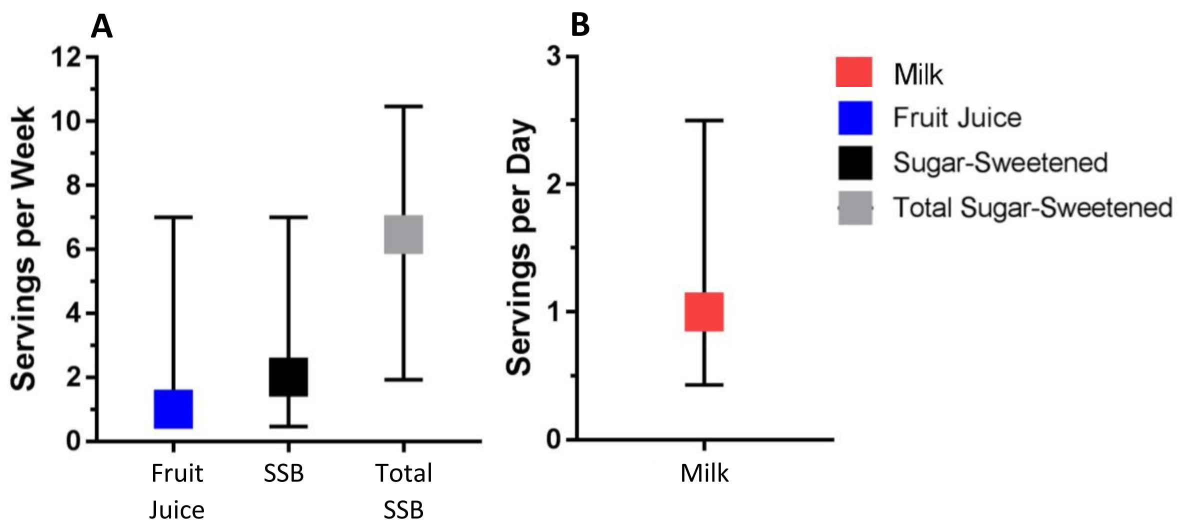

Figure 2. Average A) weekly consumption of fruit juice, sugar-sweetened beverages and total sugar-sweetened beverages (fruit juice + sugar-sweetened beverages). B) daily consumption of milk reported at baseline. Median and IQR are displayed (n=1425).

More than 95% of study participants consumed at least some SSB each week. Furthermore, 44% of the children and youth (n=487) consumed at least one serving of SSB or fruit juice per week (Table 4). Fewer than 5% (n=79) of study participants did not consume either SSB or fruit juice.

Table 4. Frequency of youth who report any sweet beverage intake or consumption of at least one sweet beverage per week servings per day (n=1425).

	Sugar Sweetened Beverages Only		Fruit Juice Only		Total Sugar Sweetened Beverages	
Frequency	**N**	**%**	**N**	**%**	**N**	**%**
Drink any SSB (Fail to drink 0 SSB/wk)	1229	86.2	1105	77.5	1346	94.5
Drink SSB once per week (Fail to drink <1 SSB/wk)	870	61.1	630	44.2	1156	81.1

Nearly 95% (n= 1338) of children and youth consumed at least one serving of cow's milk (exclusive of chocolate milk) daily. Additionally, 66% (n=943) of children and youth with obesity met the cut-off for milk of two or more servings each day.

Primary Object #2: Sociodemographic and behavioural correlates of failing to meet beverage intake thresholds

Sugar-Sweetened Beverages Only

As part of the primary outcomes, the potential sociodemographic and behavioural correlates of the likelihood of not meeting the pre-determined beverage intake thresholds were explored. This was repeated for fruit juice only, as it was of interest to examine if correlates related to failure to meet recommended beverage intake differed between fruit juice and SSB (described in Chapter 2). As the proportion who did not consume any SSB was very small (<5%), the factors related to the failing to meet any SSB was not assessed. This was because the use of logistic regression in the instance of a rare event may underestimate the probability of this rare event from occurring in binary analyses (King and Zeng 2001; Bai et al. 2011). Therefore, participants who consumed SSB at least once weekly with those who did not were compared.

In chi-square analyses, weekly intake of SSB was associated with sex, annual income level and female and male guardian education level. Compared to those that met SSB intake recommendations, those who drank SSB weekly had a higher frequency of eating out/ordering in and eating meals in front of the TV, but ate as a family less often. Youth who consumed SSB daily also reported significantly higher daily screen time (Table 5). BMI z-score was significantly greater in children and youth with obesity who failed to meet recommended SSB intake.

Table 5. Chi-square and independent t-test univariate analyses investigating relationship between demographic and behavioural variables and failing to meet SSB intake.

Categorical Variables – Chi-Square Test		**<1 Serving per week SSB**	**≥1 Serving per week SSB**	**Chi-Square**	
		N (%)	**N (%)**	**X^2**	**Sig**
Sex	Female	314 (56.6%)*	427 (49.1%)^	**7.63**	**0.006**
	Male	241 (43.4%)*	443 (50.9%)^		
Racial Background	White	187 (33.7%)	253 (29.1%)	3.38	0.066
	Other	368 (66.3%)	617 (70.9%)		
Income	<50,000	129 (24.6%)*	261 (32.0%)^	**8.60**	**0.003**
	>50,000	396 (75.4%)*	554 (68.0%)^		
Female Guardian Education Level	Highschool or less	108 (19.7%)*	257 (30.2%)^	**19.19**	**0.000**
	University/college	441 (80.3%)*	594 (69.8%)^		
Male Guardian Education Level	Highschool or less	156 (30.0%)*	311 (39.6%)^	**12.59**	**0.000**
	University/college	364 (70.0%)*	474 (60.4%)^		
Household Status	1 Residence	494 (89.2%)	767 (88.4%)	0.22	0.640
	Multiple	60 (10.8%)	101 (11.6%)		

Continuous Variables- Independent Sample T-Test

Variable	**Serving per week of SSB**	**N**	**Mean**	**SD**	**Mean Difference**	**Sig.**
Age	<1	555	12.06	3.52	0.00	0.987
	≥1	870	12.06	3.24		
BMI z-score	<1	555	3.46	1.02	**-0.18**	**0.002**
	≥1	870	3.64	1.08		
Eating Out/Ordering In (weekly)	<1	555	1.08	1.79	**-0.48**	**0.000**
	≥1	866	1.57	2.14		
Frequency of family meals (weekly)	<1	553	7.55	6.75	**0.79**	**0.029**
	≥1	868	6.76	6.51		
Frequency of meals in front of the TV (weekly)	<1	546	3.34	5.40	**-1.60**	**0.000**
	≥1	856	4.94	6.73		
Physical Activity (hrs/wk)	<1	488	5.84	4.21	-0.09	0.729
	≥1	783	5.93	4.32		
Screen Time (hrs/day)	<1	546	3.70	1.92	**-0.56**	**0.000**
	≥1	856	4.26	2.03		

*****Differences in proportion within <1 Serving per week fruit juice cut-off

^ Differences in proportion within ≥1 Serving per week fruit juice cut-off

In the multivariate model (Nagelkerke $R^2 = 0.09$; $p<0.001$) (Table 6), sex persisted as a significant predictor of SSB intake and males were over 40% more likely to fail to meet recommended one serving of SSB per week compared to females. Each year older was associated with a 9% lower likelihood of consuming at one or more SSB per week. Income level and male guardian education level were no longer associated with SSB consumption after adjustment for covariates, however youth with a female guardian who completed post secondary education were 36% less likely to fail SSB recommendation (i.e. were more likely to consume fewer than one serving of SSB per week). As in the univariate analysis, eating more meals out/ordering in more often increased the likelihood of failing to meet SSB cut-off and an additional meal eaten as a family slightly lowered these odds. The frequency of meals eaten in front of the TV was no longer was associated with weekly SSB intake, however screen time remained an important predictor of SSB intake and an additional hour of screen time per day increased the likelihood of failing to meet the SSB recommendation by 15%. In contrast to findings in previous population-based studies, BMI z-score was not a significantly related SSB consumption and did not significantly influence the odds of failing to meet SSB intake thresholds.

In summary, failing to meet SSB only recommendations was more likely among males, those with lower educated families, and those who ate more meals out and reported higher daily screen time. Alternatively, more family meals reduced the likelihood of failing to meet SSB intake of once per week.

Table 6. Logistic regression model assessing the OR of failing to meet sugar-sweetened beverages recommendation (one or more servings per week) (n=1180).

	□	S.E.	Sig.	OR	95% CI (OR)	
					Lower	**Upper**
Sex (Males)	0.35	0.13	.008	1.42	1.10	1.83
Age (Years)	-0.09	0.02	.000	0.91	0.87	0.96
BMI z-score	-0.03	0.07	.692	0.97	0.85	1.11
Income (>$50,000/year)	-0.08	0.15	.627	0.93	0.69	1.25
Female Guardian Education (Post-Secondary)	-0.44	0.16	.007	0.64	0.47	0.89
Male Guardian Education (Post-Secondary)	-0.27	0.14	.063	0.77	0.58	1.02
Eating Out/Ordering In (Weekly)	0.23	0.06	**.000**	**1.26**	1.13	1.40
Meals with the Family (Weekly)	-0.03	0.01	**.008**	**0.97**	0.96	0.99
Meals in Front of the TV (Weekly)	0.00	0.01	.786	1.00	0.98	1.03
Screen Time (hrs/day)	0.14	0.04	**.000**	**1.15**	1.07	1.24
Constant	1.62	0.45	.000	5.07		
R^2	Cox & Snell R^2= 0.06			Nagelkerke R^2=0.09		

Fruit Juice Only

Next, sociodemographic and behavioural factors were compared between those who failed to consume fewer than one serving per week of fruit juice and those who did not separately from SSB only. Chi-Square analysis showed that sex and income level were related to weekly fruit juice consumption. Behaviours including frequency of meals in front of the TV and the average number of meals eaten with the family per week were also significantly higher among those who failed to meet weekly fruit juice recommendation compared to those who met fruit juice cut-offs. BMI z-score was not related to failing to meet fruit juice intake thresholds (Table 7).

Table 7. Chi-square and independent t-test univariate analyses investigating relationship between demographic and behavioural variables and failing to meet fruit juice intake.

Categorical Variables – Chi-Square Test		**<1 Serving per week Fruit Juice**		**≥1 Serving per week Fruit Juice**	**Chi-Square**	
		N (%)		**N (%)**	**X^2**	**Sig**
Sex	Female	433 (54.5%)*		308 (48.9%)^	**4.38**	**.036**
	Male	362 (48.9%)*		322 (51.1%)^		
Racial Background	White	550 (69.2%)		435 (69.0%)	0.003	0.956
	Other	245(30.8%)		195 (31.0%)		
Income	<50,000	199 (26.7%)*		191 (32.0%)^	**4.50**	**0.034**
	>50,000	545 (73.3%)*		405 (68.0%)^		
Female Guardian Education Level	Highschool or less	191 (24.3%)		174 (28.4%)	3.03	0.082
	University/college	596 (75.7%)		439 (71.6%)		
Male Guardian Education Level	Highschool or less	247 (33.8%)		220 (38.3%)	2.88	0.09
	University/college	484 (66.2%)		354 (61.7%)		
Household Status	1 Residence	705 (88.9%)		556 (88.4%)	0.09	0.764
	Multiple	88 (11.1%)		73 (11.6%)		
Continuous Variables- Independent Sample T-Test						
Variable	**Serving per week of Fruit Juice**	**N**	**Mean**	**SD**	**Mean Difference**	**Sig**
Demographic and Behavioural Information						
Age	<1	795	12.21	3.36	0.34	0.058
	≥1	630	11.87	3.33		
BMI z-score	<1	795	3.53	1.05	-0.08	0.141
	≥1	630	3.61	1.07		
Eating in/Ordering out (weekly)	<1	792	1.34	2.16	-0.09	0.381
	≥1	629	1.43	1.85		
Meals with the family (weekly)	<1	794	6.72	6.52	**-0.78**	**0.027**
	≥1	627	7.50	6.72		
Meals in front of the tv (weekly)	<1	775	3.81	5.89	**-1.14**	**0.001**
	≥1	627	4.95	6.71		
Physical Activity (hrs/wk)	<1	705	5.79	4.30	-0.24	0.316
	≥1	566	6.03	4.25		
Screen Time (hrs/day)	<1	776	4.01	2.02	-0.07	0.490
	≥1	626	4.08	1.99		

*****Differences in proportion within <1 Serving per week fruit juice cut-off

^ Differences in proportion within ≥1 Serving per week fruit juice cut-off

In the fully adjusted model (Nagelkerke $R^2 = 0.02$; $p<0.05$), males were more likely to fail fruit juice recommended intake. The frequency of meals as a family and in front of the TV remained significant determinants of weekly fruit juice consumption (Table 8), slightly lowering and increasing these odds respectively (< 3%). Overall, fruit juice consumption among children and youth were predicted by fewer sociodemographic and behavioural variables compared to SSB intake. Additionally, no link between fruit juice and BMI z-score was identified, similar to SSB.

Table 8. Logistic regression model assessing the OR of failing to meet recommended fruit juice intake of one serving per week (n=1317).

	β	**S.E.**	**Sig.**	**OR**	**95% CI (OR)**	
					Lower	**Upper**
Sex (Males)	0.33	0.12	**.006**	**1.39**	1.10	1.76
Age (Years)	-0.02	0.02	.243	0.98	0.94	1.02
BMI z-score	0.06	0.06	.303	1.07	0.95	1.20
Income (>$50,000/year)	-0.19	0.14	.164	0.83	0.64	1.08
Meals with the Family (Weekly)	-0.03	0.01	**.005**	**0.98**	0.96	0.99
Meals in Front of the TV (Weekly)	0.03	0.01	**.003**	**1.03**	1.01	1.05
Constant	0.82	0.38	.031	2.26		
R^2	Cox & Snell $R^2 = 0.02$			Nagelkerke $R^2 = 0.02$		

Total Sugar Sweetened Beverages (SSB and fruit juice)

When SSB and fruit juice were combined, the factors related to total SSB intake did not vary greatly from those that were related to SSB only and will therefore only be briefly described here (full results in Appendix, Section 2, Table A4-A5). In the fully adjusted model, males were 62% more likely to fail the total SSB intake recommendation of less than once per week while younger children were 11% less likely similar to fail recommendations. Also similar to SSB intake, higher guardian education lowered the risk of failing total SSB thresholds (i.e. more educated families were related to lower total SSB intake). Specifically, male guardian education level significantly lowered the risk of failing total SSB intake recommendations by more than 30% instead of female guardian education seen in the analysis of SSB only. The frequency of eating out was once again associated with an increased odds (+28%) of failing total SSB intake and family meals lowered these odds marginally.

Milk

As part of the primary objectives, the relationship between milk consumption and different sociodemographic and behavioural factors examined. Given that children and youth with obesity rarely consumed less than one serving per day of milk (6%), the recommendation of two servings per day was assessed. Additionally, two servings per day of dairy products was recommended in the 2007 Canada's Health Food Guidelines, which were being implemented at the time of CANPWR data collection, and therefore two servings per day was selected as the recommended milk cut-off for which correlates were explored.

First, chi-square analyses revealed that sex was related to meeting milk recommendations. Those who failed to meet this milk intake recommendation were significantly older than those who did. Independent t-tests revealed no differences in measures of SES between youth with obesity who met or did not meet recommended daily milk intake. Multiple behavioural factors were related to milk intake, with the frequency of eating out/ordering in and eating in front of the TV significantly higher among those who did not meet the daily milk intake cut-off. Among other behaviours, screen time was higher among those who failed to meet milk intake recommendation compared to those who did. BMI z-score was not significantly different between those who met and failed to meet recommended milk intake in this population (Table 9).

Table 9. Chi-square and independent t-test univariate analyses investigating relationship between demographic and behavioural variables and failing to meet milk intake.

Chi-Square Test - Categorical Variables		**Failed to Meet Milk Rec.**		**Met Milk Intake Rec.**	**Chi-Square**	
		N (%)		N (%)	X^2	Sig
Sex	Female	529 (56.1%)		212 (44.0%)	**18.75**	**0.000**
	Male	414 (43.9%)		270 (56.0%)		
Racial Background	White	301 (31.9%)		139 (28.8%)	1.42	0.234
	Other	642 (68.1%)		343 (71.2%)		
Income	<80,000	252 (28.7%)		138 (29.9%)	0.235	0.628
	>80,000	627 (71.3%)		323 (70.1%)		
Female Guardian Education Level	Highschool or less	247 (26.5%)		118 (25.2%)	0.30	0.581
	University/college	684 (73.5%)		351 (74.8%)		
Male Guardian Educ	Highschool or less	319 (37.2%)		148 (33.0%)	2.25	0.134
	University/college	538 (62.8%)		300 (67.0%)		
Household Status	1 Residence	832 (88.5%)		429 (89.0%)	0.77	0.781
	Multiple Households	108 (11.5%)		53 (11.0%)		
Continuous Variables - Independent Sample T-Test						
Variable	**Serving per day of Milk**	**N**	**Mean**	**SD**	**Mean Difference**	**Sig.**
Age	<2	943	12.19	3.30	**0.37**	**0.045**
	≥2	482	11.81	3.42		
BMI z-score	<2	943	3.55	1.05	-0.06	0.282
	≥2	482	3.61	1.07		
Eating Out/Ordering In (weekly)	<2	940	1.24	1.78	**-0.41**	**0.000**
	≥2	481	1.65	2.41		
Frequency of family meals (weekly)	<2	942	6.35	6.64	**-2.13**	**0.000**
	≥2	479	8.48	6.34		
Frequency of meals in front of the TV (weekly)	<2	923	3.81	5.88	**-1.47**	**0.000**
	≥2	479	5.29	6.92		
Physical Activity (hrs/wk)	<2	850	5.77	4.30	-0.37	0.146
	≥2	421	6.14	4.23		
Screen Time (hrs/day)	<2	929	4.16	1.99	**0.34**	**0.003**
	≥2	473	3.82	2.01		

*Differences in proportion within <2 servings per day milk cut-off

^ Differences in proportion within ≥2 servings per day milk cut-off

In the multivariate model ($R^2 = 0.08$; p'0.001) adjusted for covariates, sex remained a significant predictor of milk consumption (Table 10). Females were nearly 70% more likely to fail to meet the recommended two cups of milk per day compared to males, however age was no longer a significant correlate of milk intake. Multiple eating habits persisted as important predictors of milk intake. Specifically, eating out/ordering in more frequently decreased the likelihood of failing to meet recommendation of milk by 7% while eating as a family and in front of the TV both slightly decreased this likelihood by 4% and 3% respectively. Alternatively, each additional hour of daily screen time by youth increased the likelihood of failing to meet milk intake recommendations by more than 10%. Once again, BMI z-score did not significantly influence the likelihood of failing to meet milk intake.

Table 10. Logistic Regression assessing all lifestyle and behavioural variables effect on failing to meet recommended 2 servings of milk per day (n=1377).

	β	**S.E.**	**Sig.**	**OR**	**95% CI (OR)**	
					Lower	**Upper**
Sex (male)	-.54	.12	**.000**	**.59**	.46	.74
Age (years)	.00	.02	.832	1.00	.96	1.04
BMI z-score	-.03	.06	.573	.97	.87	1.08
Eating Out/Ordering In (weekly)	-.07	.03	**.020**	**.93**	.88	.99
Meals with The Family (weekly)	-.04	.01	**.000**	**.97**	.95	.98
Meals in Front of The TV (weekly)	-.04	.01	**.000**	**.96**	.95	.98
Screen Time (hrs/day)	.12	.03	**.001**	**1.12**	1.05	1.20
Constant	1.17	.350	.001	3.22		
R^2	Cox & Snell R^2= .05			Nagelkerke R^2= 0.08		

To summarize the relationship between all variables and beverage recommendations, a heat map is displayed in Figure 4. When factors that influenced the likelihood of failing to meet the three beverage recommendations were compared, sex was an important determinant of failing to meet both SSB and milk recommendations; females were more likely to fail to meet milk recommendations (i.e. less than two servings per day) and males were more likely to fail to meet SSB, fruit juice and total SSB recommendations (i.e. drink more than one serving weekly). Therefore, it appears that males consumed more milk and SSB weekly than females. Age or guardian education were not significant predictors of meeting milk intake recommendations; however, younger age and lower guardian education significantly increased the likelihood of failing to meet SSB and total SSB intake cut-offs.

Among all beverage types, the frequency of family meals was the only variable that consistently influenced the odds of failing to meet all beverage recommendations and was associated with lower SSB, fruit and total SSB consumption but higher milk intake. Among other eating habits, more meals eaten out lowered the odds of failing to meet milk intake cut-offs but increased the odds of failing to meet SSB cut-offs. Screen time increased the odds of failing to meet milk and SSB recommendations respectively. In summary, the sociodemographic behavioural determinants of meeting or failing to meet SSB, fruit juice and milk intake differed, demonstrating unique predictors depending on the beverage assessed.

	Fail Recommendation			
	Less than one serving per week			Two servings per day
Variables	**Sugar-Sweetened**	**Fruit Juice**	**Total Sugar-Sweetened**	**Milk**
Sex (Male)	**	**	**	***
Age	***		***	
BMI z score				
Racial Background (White)				
Household Income Level				
Female Caregiver Education (Post-Secondary)	**			
Male Caregiver Education (Post-Secondary)			*	
Multiple Residences				
Eating Out/Ordering In (weekly)	***		**	*
Family Meals (weekly)	**	**	**	***
Eating in Front of TV (weekly)		**		***
Physical Activity (hrs/wk)				
Screen Time (hrs/day)	***			**

OR> 1.30		
OR = 1.20 to 1.29		
OR = 1.0 to 1.19		***p<0.001
p>0.05		* p<0.05
OR = 0.90 to 0.99		**p<0.01
OR = 0.80 to 0.89		
OR= 0.70 to 0.79		

Figure 3. Heat map of all variables and their relationship with each beverage intake recommendation. Colours represent significant OR indicated in legend beneath table.

Sensitivity Analysis: Multiple Imputation of Primary Objectives

As expected, given the nature of clinical research, missing information for several variables of interest occurred during data analysis. Missing data for these sociodemographic and behavioural variables is listed in Table A6 (Appendix, Section 3). Data was unavailable for analysis either because it was missing or it was reported as "not applicable" (N/A) for that individual. Truly missing data was unusual and approximately 6% of the participants did not complete the FFQ and therefore were missing data for all of the beverage intakes. All variables had missingness < 8%, with meals in front of the TV and weekly physical activity (7.7% each) responsible for highest number of missing values. When N/A or missing data are considered together, male guardian education level (10.9%) had the most missingness. While data cannot be confirmed missing at random not missing at random, this phenomenon may be due to the child living in a single parent home such as in the case that the primary caregiver role belonged to the female caregiver only. Guardians may also not share education level given the sensitive nature of the question. While these reasons can be hypothesized, it was not confirmed in the present analysis. To account for missing data in the primary objective, multiple imputation was undertaken for each logistic regression model investigating the relationship between sociodemographic and behavioural variables on SSB, fruit juice and milk recommendations. Results using imputed data demonstrated that factors influencing milk intake were unaffected by multiple imputation while slight differences were noted between factors related to SSB and fruit juice intakes. Differences between independent and dependant variables from imputed and original datasets were compared. Chi-square analyses were used to assess significant interactions between imputed data and the original data set for categorical variables (sex, income, guardian education, ethnicity, failing to meet beverage intakes). Independent t-tests were used to determine significant differences in continuous variables (age, BMI z-score, eating habits, weekly physical activity) between complete data and imputed data. Detailed information and resulting regression models of imputed data are presented in Appendix, Section 2, Table A6-10.

Secondary Objective #1: Patterns of Beverage Intake

In addition to determining the number of children and youth who failed to meet beverage intake recommendations, assessing how these beverages correlate was next examined. Using PCA to determine patterns of beverage consumption five unique components were identified. The results produced a KMO statistic of 0.553, indicating that PCA was appropriate for this dataset. Although the correlation matrix demonstrated relatively weak correlations of <0.3 (Table A11 Appendix, Section 4) (i.e. beverages are somewhat consumed together), the identified patterns explained 43.05% of variance in beverage intake (Table 11), that is close to half of the variability in beverage intake was explained by five patterns of consumption. While a break in scree plot at Component 2 was observed (Figure 4), Components 3-5 were retained as these explained an additional 7.1-7.8% each. Given that Component 1-2 explained the most variance (12 and 9% respectively), these two patterns and their related sociodemographic and behavioural factors will be presented here, information on Component 3-5 is briefly discussed here and further examined in the appendix (Section 4).

Table 11. Components 1-5 respective eigenvalues and variance (%).

Component	**Eigenvalue**	**% of Variance**	**Cumulative %**
1	1.80	12.02	12.02
2	1.30	8.63	20.65
3	1.18	7.86	28.51
4	1.102	7.344	35.856
5	1.079	7.194	43.049

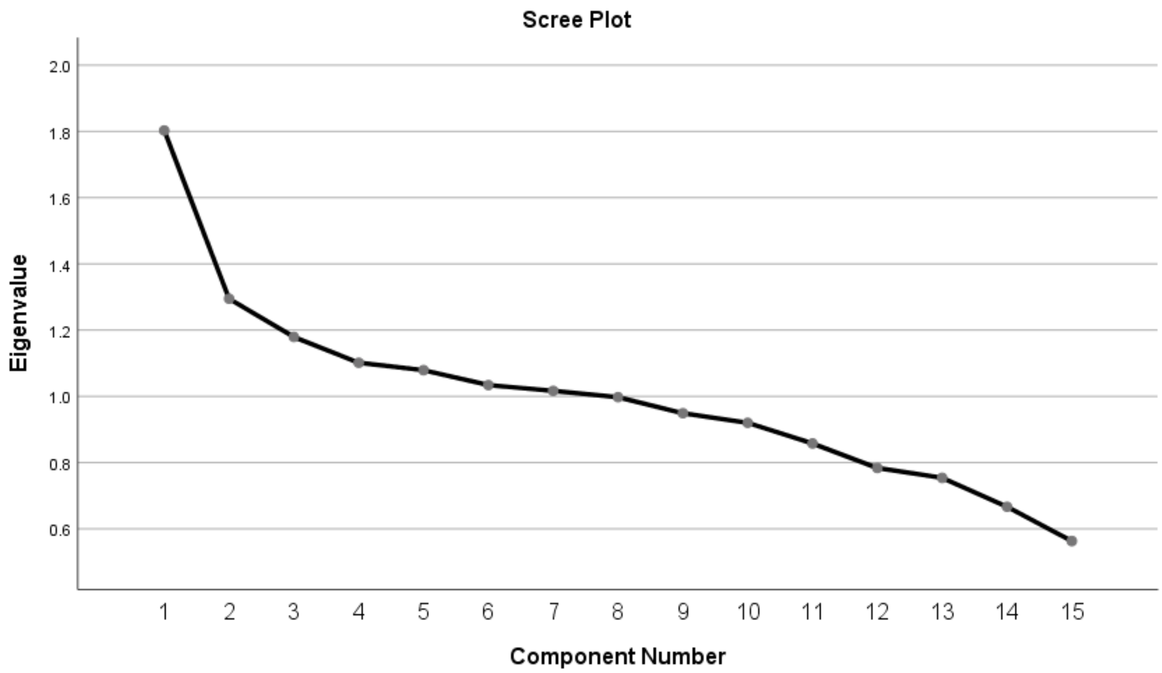

Figure 4. Scree plot for PCA. Eigenvalues were >1.0 for Components1-6 and break in scree plot was visible at Component 2.

Five components were retained as these components contained beverages that had factor loadings >0.3 for one exclusive pattern. These 5 patterns (or components) and items that loaded on them are described in Table 12. Component 1 has high factor loadings (≥0.3) on sweet beverages including regular soft drinks, energy drinks, fruit juice and fruit flavoured drinks. Component 2 loaded highly on 1% milk (0.834) and Component 3 had a factor loading equal to 0.529 for 2% milk. Further, Component 4 demonstrated high loading values for rice milk and diet soft drinks and Component 5 was characterized by high loadings in flavoured milks and sports drinks. These five patterns were unique from one another and demonstrated that different SSB (Component 1/5), types of milk (Component 2-3) and unsweetened beverages (Component 4) tended to be consumed together.

Table 12. Rotated Component Matrix of PCA of all beverages individually for five retained components (n=1425).

	Component				
	1	**2**	**3**	**4**	**5**
Milk 3.25%		-0.266	-0.103	-0.125	0.246
Milk 2%	0.102	-0.640	**0.529**		
Milk 1%		**0.834**	0.200		
Skim milk			-0.788		
Flavoured milk		0.118			**0.777**
Rice milk		0.114		**0.505**	
Soya milk					
Regular soft drinks	**0.632**		0.120	0.117	
Diet soft drinks	0.185		0.216	**0.571**	-0.144
Sports drinks	0.265		0.115		**0.561**
Energy drinks	**0.666**		-0.252	-0.222	-0.102
Fruit juice 100%	**0.632**		0.111	0.187	
Fruit flavoured drinks	**0.562**				0.220
Vegetable juice	0.109	0.120	0.139		-0.191
Water		0.116	0.226	-0.662	-0.169

Relationships Between Demographic and Behavioural Variables

The related sociodemographic and behaviours were next explored as part of the secondary objectives. To assess these relationships, the component scores for each of the five components were used which are detailed in Table A12 (appendix). Component score ranges varied for each pattern; however, all components were standardized to have a mean of 0, SD of 1.0 and 95%CI between -0.05, 0.05.

Component 1 (Soft drinks, energy drinks, fruit juice, fruit flavoured drinks)

Component 1 was largely characterized by SSB and explained 12% of variance in beverage intake. In univariate analyses, age, and was positively related to this pattern and males had significantly higher component scores compared to females. Alternatively, income and guardians' education level were inversely related to Component 1 scores. When behavioural variables were considered, eating in front of the TV, ordering in/eating out and screen time were all related to higher component scores. Physical activity was associated with lower scores for Component 1. Additionally, BMI z-score was also positively related to this component encompassing sweet beverages among children and youth with obesity (Table A13, appendix, Section 4)

In the multivariate model (R^2= 0.10; p<0.001), almost all of the aforementioned variables persisted as significant predictors (Table 13). Age and sex significantly related to this pattern, as males and older youth demonstrated a greater adherence to this sweet beverage pattern. SES was a significant predictor and guardian education was inversely associated with this pattern characterized by SSB. Eating habits that remained significant in the multivariate model included eating meals out/ordering in and eating in front of the TV which were directly related to Component 1 scores. Physical activity and daily screen time were no longer independently related to the Component 1 factor scores. However, BMI z-score remained a significant correlate of Component 1, indicating that youth who drank these SSB had greater weight status independently of age and sex.

Thus, this analysis suggests that intake of various sugared beverages clusters together. Higher loading on this beverage pattern is seen for males, increased age, lower family education and more frequent eating out, eating in front of the television and higher loading on this component was associated with having higher BMI z-scores.

Table 13. Linear regression models assessing factors related to component scores for Component 1 beverage pattern (n=1082).

	Unstd		Std β	Sig.	95% CI β	
	β	SE			Lower	Upper
Constant	-0.24	0.30		.437	-0.83	0.36
Sex (Male)	0.15	0.06	**0.07**	**.020**	0.02	0.27
Age (years)	0.04	0.01	**0.13**	**.000**	0.02	0.07
BMI z-score	0.08	0.03	**0.08**	**.011**	0.02	0.15
Total annual household income Level	-0.02	0.03	-0.02	.505	-0.07	0.04
Female Guardian Education Level	-0.10	0.05	**-0.06**	**.049**	-0.20	0.00
Male Guardian Education Level	-0.15	0.04	**-0.12**	**.000**	-0.23	-0.07
Eating Out/Ordering In (weekly)	0.06	0.02	**0.11**	**.000**	0.03	0.09
Meals in front of the TV (weekly)	0.02	0.01	**0.08**	**.007**	0.00	0.03
Physical Activity (hrs/wk)	0.00	0.01	-0.01	.767	-0.02	0.01
Screen Time (hrs/day)	0.01	0.02	0.03	.422	-0.02	0.05
Model R^2= 0.10; p<0.001						

Component 2 (1% milk)

Component 2 accounted for 8.6% of beverage intake variance and demonstrated a pattern that consisted of primarily 1% milk. Examination of univariate relationships with sociodemographic and behavioural variables revealed significant positive relationships between 1% milk adherence and ethnicity (white), income level, male guardian education, eating out/ordering in and physical activity. An inverse association was noted between Component 2 and screen time. BMI z-score was not significantly associated with the 1% milk pattern in this population (Table A14, appendix, Section 4).

In the fully adjusted model (Table 14), ethnicity (white) persisted as a significant predictor of Component 2 adherence whereas did household income. Male guardian education was not significantly related to Component 2 after adjustment for covariates. The frequency of eating meals out/ordering in was positively related to Component 2 while screen time remained inversely related to this pattern after adjusting for covariates.

In summary, 1% milk appears to be consumed independently of other beverages. Individuals who adhered to this pattern were more often of white ethnicity, came from higher income households, consumed more meals out/ordered in more often and accumulated more screen time per day.

Table 14. Linear regression models assessing factors related to Component 2 beverage pattern scores (n=1107).

	Unstd		**Std β**	**Sig.**	**95% CI β**	
	β	**SE**			**Lower**	**Upper**
(Constant)	-0.50	0.26		.055	-1.01	0.01
Sex (Male)	0.05	0.06	0.03	.397	-0.07	0.17
Age (years)	0.01	0.01	0.04	.245	-0.01	0.03
BMI z-score	-0.04	0.03	-0.04	.213	-0.10	0.02
White	0.22	0.07	**0.10**	**.001**	0.09	0.34
Total annual household income Level	0.06	0.03	**0.07**	**.029**	0.01	0.11
Male Guardian Education Level	0.05	0.04	0.04	.159	-0.02	0.12
Eating Out/Ordering In (weekly)	0.03	0.02	**0.07**	**.025**	0.00	0.06
Physical Activity (hrs/wk)	0.01	0.01	0.04	.246	-0.01	0.02
Screen Time (hrs/day)	-0.03	0.02	**-0.07**	**.048**	-0.07	0.00
Model R=0.04; p<0.001						

Component 3 (2% milk)

Component 3 represented a pattern of 2% milk exclusively and explained 7.9% of beverage intake variance. It was of interest that Component 2 and 3 dietary patterns identified were single item and were related to different cow's milk products. Independent predictors of this pattern included lower household income, eating meals as a family and eating meals in front of the TV (Table A15-16, Appendix, Section 4). In summary, few sociodemographic variables were similar to Component 2/3. Interestingly, household income and Component 2 was directly related to income while Component 3 was inversely associated with income level. Neither of these dietary patterns were associated with BMI z-score in contrast to the SSB pattern (Component 1).

Component 4 (rice milk, diet soft drinks)

The fourth beverage pattern included rice milk and diet soft drinks and explained approximately 7% of the variance in beverage intake (Table A17-18, Appendix Section 4). In contrast to the first component, this pattern was comprised sugar-free diet soft drinks and a milk alternative rather than cow's milk present in Component 2/3. In the multivariate model, this group of beverage alternatives (i.e. rice milk and diet soft drinks) were consumed more often by younger individuals, those of white ethnicity and youth from lower educated families. Adherence to Component 4 was also greater among those who ate fewer meals as a family and had higher daily screen time. Lower BMI z-scores were associated with this pattern with high factor loadings on diet soft drinks and milk alternatives, thus youth with obesity with lower BMI z-scores may consume more alternative beverages than individuals with higher BMI z-scores in this population.

Component 5 (sports drinks, flavoured milk)

Explaining 5% of beverage intake variance, the final Component 5 which correlated flavoured milk and sports drinks was related to fewer sociodemographic variables and did not correlate with any behaviours of interest (Table A19-20, appendix). Component 5 was characterized by sports drinks and flavoured milks. Unlike Component 1, relationships between sociodemographic and behavioural factors or BMI z-score were not identified with despite containing two types of SSB (i.e. flavoured milks and sports drinks). Thus, it is possible that certain SSB beverages may be consumed together and different sociodemographic and behavioural factors may be related to these patterns of beverage intake.

Sensitivity Analysis: Impact of Beverage Groupings on Secondary Objectives

To investigate the effect of grouping beverages together on resulting PCA patterns of consumption, pre-defined groupings of beverages were used in a separate analysis: 1) Total milk and milk alternatives 2) Unsweetened beverages (water, vegetable juice, diet soda) 3) Sweetened beverages and 4) 100% Fruit juice.

Similar to the PCA which used all beverages individually, the grouped PCA generated a KMO of 0.511 and was suitable for PCA. The resulting correlation matrix reported in Table A21, appendix. The use of beverage groups in PCA generated only two components (SSB and Unsweetened, Table A22) with eigenvalues values >1.0 (Table A23 and Fig.A3), fewer than the original PCA of all individual beverages which produced five components. This grouped solution also explained approximately 20% more variance in beverage intake compared to the PCA analysis with single beverages. Detailed results are presented in the Appendix section 5, Tables A21-27. A heat map of all correlation coefficients for each component and significant variables is illustrated in Figure 5.

	Beverage Pattern						
	Component 1	Component 2	Component 3	Component 4	Component 5	Grouped Component 1	Grouped Component 2
Sex (Male)	*				*	*	***
Age (years)	***			**	**		***
BMI z score	*			**			
Racial Background (White)		**		**			
Household Income Level		*	**		*		
Female Caregiver Education	*			**		**	
Male Caregiver Education	***					**	
Multiple Residences							
Eating Out/Ordering In (weekly)	***	*				*	**
Family Meals (weekly)			***	***			***
Eating in Front of TV (weekly)	**		**			***	***
Physical Activity (hrs/wk)							
Screen Time (hrs/day)		*		**			

Stdβ>0.10		***p<0.001
Stdβ = 0.05 to 0.09		* p<0.05
Stdβ =0.01 to 0.04		**p<0.01
p>0.05		
Stdβ = -0.01 to -0.04		
Stdβ = -0.05 to -0.09		
Stdβ< -0.10		

Figure 5. Heat map of all variables and their relationship with each beverage intake recommendation. Colours represent significant OR indicated in legend beneath table.

Secondary Objective #2: The Relationship of Beverage Patterns to Metabolic Outcomes

In addition to exploring sociodemographic and behavioural correlates of beverage patterns, the influence of these beverage patters on metabolic health outcomes was explored. In univariate analyses (Table A29-A30, appendix, Section 6), Component 1 (SSB) score was related to lower HDL (mmol/L) (Unstdβ= -.025; $p<0.005$) and directly related to levels of ALT (U/L) (Unstdβ= 1.933; $p<0.05$). Lower HbA1c (%) levels were found with Component 2 (1% milk) adherence (Unstdβ= -0.05; $p<0.05$) while Component 3 (2% milk) was directly related to HbA1c (%) (Unstdβ= 0.05; $p<0.05$). Component 4 (rice milk, diet soft drinks) was also positively related to HbA1c (%) (Unstdβ= 0.08; $p<0.001$) and inversely related to HDL (mmol/L) (Unstdβ= -0.2; $p<0.01$). Component 5 factor scores were not significant predictors of any metabolic parameters.

In multivariate models, Component 4 pattern (rice milk, diet soft drinks) was related to lower HDL levels after independent of age, sex and BMI z score (Table 15), suggesting that Component 4 is related to unfavourable metabolic health outcomes. No other patterns were independent predictors of metabolic health. The mediating effect of demographic and physical measures on the link between beverage intake and metabolic health outcomes points most likely is a result of too many contributing factors, thus metabolic health and the isolation of beverages' impact alone on metabolic health is difficult to ascertain.

Table 15. Multivariate analysis of the effect of Component score 4 on HDL concentration (n=1144).

	Unstd		**Stdβ**	**Sig.**	**95.0% CI β**	
	β	**SE**			**Lower**	**Upper**
(Constant)	1.475	.058		.000	1.360	1.589
Sex (Male)	.013	.019	.023	.478	-.023	.050
Age (years)	-.019	.003	**-.212**	**.000**	-.024	-.013
BMI z score	-.031	.009	**-.122**	**.000**	-.048	-.014
Component 4	-.026	.009	**-.093**	**.004**	-.044	-.008
R^2 = 0.06 p<0.001						

Grouped PCA from the sensitivity analysis were also assessed for their relationship with metabolic heath outcomes. In multivariate models, Grouped Component 1 (SSB and fruit juice) was significantly inversely associated with HDL concentration after adjustment for sex and BMI z-score (Table A31, appendix). No other significant relationships persisted after adjusting for age, sex and BMI z-score.

Chapter 4. Discussion

Utilizing a cohort of children and youth (n=1425) entering one of ten pediatric weight management clinics, the primary objectives of this study were to assess the frequency of children and youth with obesity that met or did not meet recommended sugar-sweetened beverage (SSB) and milk intake recommendations and to identify social and behavioural factors that may be related to the likelihood of meeting targets. Less than 5% of the children studied met the recommendation of no SSB consumption and 80% drank these beverages at least once per week. Additionally, almost all youth with obesity reported consuming milk once or more per day (94%) but only one-third consumed two or more servings per day (34%).

When patterns of beverage intake were assessed, patterns grouping SSB and fruit juice together were evident (Component 1, Component 5) and patterns characterized by milk were also derived (Component 2-3). When relationships between these beverage recommendations and patterns were explored, associated sociodemographic and behavioural factors were similar to SSB and milk intake using both analyses. Thus, assessing beverage intake using pre-determined thresholds or dietary analysis methods resulted in similar beverages intake (SSB, milk) and related factors among children and youth with obesity.

Sugar-Sweetened Beverages

When the frequency of SSB and fruit juice were considered, reported intakes by youth with obesity were comparable to consumption by healthy weight populations. In the current analysis, 44% of children and youth with obesity consumed fruit juice weekly, 61% drank SSB weekly and 81% accumulated one or more total SSB per week. Although beverage intake among youth with obesity exclusively is not well described in the literature, close to 50% and 80% of Canadian youth aged 13-18 years (N=10,188) reported consuming one or more serving of SSB or fruit juice the previous day respectively in 2010 (Vanderlee et al. 2014). Similarly, multiple cross-sectional analyses of national surveys in the United States reported high SSB intake among youth, with an estimated 60% of children and adolescents consuming one or more SSB per day from 2009 to 2014 (Haughton et al. 2018; Papandreou et al. 2013; Rosinger et al. 2013) and 20% of high school students consuming fruit juice daily (Miller et al. 2017).

In other populations outside of Canada, SSB consumption is also comparable to the current findings. In two population-based studies, approximately 20% of Columbian youth aged 5-17 years (Ramirez-Velez et al (2015) and Saudi Arabian children aged 7-12 years (Alsubaie et al 2017) reported drinking SSB weekly. Estimates of consumption tend to be higher in the US, with 87% and 80% of Mexican-American children aged 8-10 years living in the US reporting SSB and fruit juice consumption per week respectively (Beck et al. 2014). While the ability to compare these results to the current study's findings is limited given the different demographic characteristics, many healthy weight children and youth consume SSB daily or weekly, similar to the present findings in this population of children and youth with obesity.

Although differences in SSB and milk intake among different study cohorts presented here are descriptive, a direct comparison of CANPWR pilot participants (n= 310) and CHMS (Cycle 2) cohort data (n=3,788) was conducted by Tremblay et al. (2015). This study demonstrated that participants age 12-17 years from the CANPWR pilot study drank significantly fewer sweet beverages per day (1.0 ± 1.10) compared to the age-matched children and youth from the CHMS population. In line with findings by Tremblay et al. (2015), it appears that individuals from the main and pilot CANPWR cohorts combined continued to report lower intake of SSB compared to nationally representative children. However, more recent statistical analysis is needed to fully compare SSB intake between the complete CANPWR cohort and CHMS sample populations.

Component 1 contained beverages similar to total SSB and grouped fruit juice with other SSB such as soft drinks. In previous literature, fruit juice and SSB have been primarily categorized into different beverage patterns. In the cluster analyses by Danyliw et al. (2012), LaRowe et al. (2007) and Marshall et al. (2017), the derived patterns consistently separated fruit juice from other fruit drinks, SSB or soda patterns, however in the current study fruit juice was grouped with soft drinks and other SSB in both the primary PCA and grouped PCA (sensitivity analysis). Therefore, it appears that individuals who consume SSB may also tend to drink fruit juice regularly. This is important to consider given that the WHO classifies free sugars such as those in fruit juices as contributors to daily energy intake from added sugars (WHO 2015). Furthermore, elimination of fruit juice from the diets of children and youth with obesity is recommended in pediatric weight management settings (Styne et al. 2017). Thus, fruit juice consumption may be indicative of less favourable beverage intake such as drinks high in added sugar.

When the relationships between SSB intake (both SSB recommendation and Component 1/5) were considered, various social and behavioural determinants of SSB consumption among youth with obesity were observed and fewer factors examined were related to fruit juice intake. The likelihood of failing to meet SSB, fruit juice or total SSB intake recommendations and consume a beverage pattern high in SSB (Component 1 / 5) was significantly higher among males. Furthermore, SES was an important determinant of SSB intake, with higher education of families and income level associated with lower SSB intake and decreased adherence to SSB-dominated patterns. Eating habits also influenced SSB and fruit juice intake in the same direction. Specifically, eating out was associated with SSB intake (total SSB and Component 1) while individuals who ate more meals as a family had lower SSB and fruit juice intake. Eating in front of the TV increased fruit juice and SSB intake (Component 1) as did screen time.

Although few studies have examined predictors of SSB intake in youth with obesity exclusively, relationships between sociodemographic factors and consumption of SSB in the current study are similar to previous population-based studies. Consistent with findings presented here, males have been noted to consume more SSB and fruit juice per day (Larson et al. 2014; Winkvist 2016), with one study estimating that the odds of consuming SSB such as sports drinks everyday was nearly double among males vs females [OR= 1.97; CI: 1.62, 2.41] (Cordrey et al. 2018), especially during and after physical activity and participation in sports (Broughton et al, 2016; Ranjit et al. 2010; White et al, 2018). The current analysis concurs with these relationships to a lesser degree, with males 30% more likely to consume any type of SSB daily compared to females. Furthermore, these relationships are similar to those cited by La Rowe et al. (2007) who derived a “soda” cluster among males aged 6-11 years only but not among other age groups or females. Similarly, in the analysis by Danyliw et al. (2012) described previously described in Chapter 1, it was found that boys aged 6-18 comprised a greater component of the soft drink cluster compared to females and younger children aged 2-5 years.

Differences in factors related to SSB consumption arose for age, as older children were more likely to adhere to Component 1 but older children were less likely to fail to meet SSB intake or adhere to Component 5 (i.e. older youth consumed less flavoured milks and sports drinks). This difference may have been contributed to by the specific beverages assessed and their association with age. SSB recommendations was inclusive of all SSB while Component 1 (fruit juice, soft drinks, energy drinks, fruit-flavoured drinks) and Component 5 (flavoured milks, sports drinks) were characterized by different beverages. Previous research in healthy weight populations chiefly points to a positive relationship between age and sweet beverage intake. In a cross-sectional analysis of the NHANES cohort demonstrated that consumption of soft drinks appears to be lowest among children <12 years (Rosinger et al 2017) and increases with age, as grade 11 youth have reported consuming significantly more SSB than younger peers in other population-based studies (Evans et al. 2010; Winkvist et al. 2016). However, the current analysis presents a reduced risk of failing to meet SSB recommendation of once per week by nearly 10% each year older and inverse relationship between Component 5 and age. Although inconsistent with previous trends, the inverse relationship between age and SSB intake was alluded to by Danyliw et al. (2012). This study used dietary pattern analysis and demonstrated that chocolate milk generally clusters with other high fat or flavoured milks among young children 2-5 years old or 6-11 years old (Danyliw et al. 20 12). Therefore, given the discrepancy between methods of analyzing beverage intake, different SSB appear to be consumed by different age groups.

An additional hypothesis for the inverse relationship between SSB and age found in the current analysis may point to underlying causes such as a rise in popularity of coffee and teas since the early 2000's among older adolescents which were not captured in the CHMS-sampled FFQ administered at baseline. These beverages may be consumed in place of other SSB like soft drinks (Kit et al. 2013; Branum et al. 2014). Therefore, youth may consume other SSB such as sweetened coffee, lowering the risk of failing to meet SSB intake found in this study. However, older children and youth with obesity may potentially possess greater awareness and understanding of healthy dietary choices. Older adolescents may be more wary of their nutritional choices and individuals who have demonstrated better understanding of nutritional information tend to consume fewer SSB and adhere to a healthier diet (Haidar et al. 2017) which may have occurred here.

Among other social factors, the inverse relationship between SES level (income, guardian education) and SSB intake is consistent with previous research investigating dietary intake in children and youth of healthy weight status (del Carmen Bisi Molina et al. 2010). No significant relationships between fruit juice intake and social factors were observed in the current analysis, however few studies have investigated fruit juice intake independently of other sweet beverages. Determinants of SSB consumption in the literature generally focus on SSB such as soft drinks and flavoured beverages exclusively.

Guardian education is known to influence home food environment (i.e. healthy food availability) (Schrempt et al. 2016) and diet quality of youth (Scaglioni et al. 2018). Previously identified beverage patterns from FFQ responses of pre-school aged children identified three patterns and among these, lower income was a stronger predictor of adherence to an “unhealthy” dietary pattern (which encompassed soft drinks) while maternal education was significantly associated with a “mixed diet” and “snack” pattern (which had high factor loadings on juices) (Nobre et al. 2012). Interestingly, male guardian education level was more strongly related to Component 1 and total SSB recommendations compared to female guardian education while income level predicted Component 5 adherence. In previous literature, maternal education has been primarily used as a covariate in multiple studies to assess trends in beverage intake in youth populations (Ambrosini et al. 2014; Camara et al. 2015). To summarize, it appears that in this population, multiple different indicators of SES may influence SSB intake among children and youth with obesity and lower SES is related to increased SSB consumption.

Concerning behavioural factors, eating meals out/ordering in more often increased the odds of failing to meet SSB, intake by nearly 25%. and was positively related to Component 1. This was similar to previous evidence from analyses of healthy weight individuals. These studies demonstrated a direct association between meals eaten at fast food restaurants and SSB intake (Godin et al. 2018), as well as a decreased tendency to consume soft drinks with more frequent home-cooked meals throughout the week independent of SES and energy intake (Vagstrand et al. 2009). Among other eating habits, consuming more meals in front of the TV slightly increased the odds of failing to meet SSB recommendations by <3% in this study and was also related to Component 1 (fruit juice, soft drinks, fruit-flavoured drinks). Although meals in front of the TV was a relatively weak predictor of failing to meet SSB recommendation, this relationship was in agreement with previously identified trends in beverage intake. For example, a previous analysis of the children 5-7 years found that family dinners eaten in front of the TV were associated an average increase in SSB intake of 0.12 [CI: 0.01, 0.24] serving per meal independently of similar covariates including sex, ethnicity and sex (Trofolz et al. 2019). Given this, it is evident that eating habits were correlated with SSB intake in children and youth with obesity and these relationships were similar to population-based studies of healthy children.

In addition to modifiable behaviours such as eating habits, the total time spent using electronic devices has been correlated with poorer diet quality including the consumption of SSB (Calaramro et al. 2012; Jashinksy et al. 2017). This relationship was no different in the current analysis, which identified a direct link between screen time and the increased odds of failing to meet the SSB recommendation. It was interesting that screen time was not significantly related to fruit juice intake, total SSB or Component 1 (which included fruit juice). It appears that screen time is related to increased consumption of non- fruit juice SSB exclusively. Previous studies have estimated that an additional hour of screen time is estimated to increase SSB intake by 0.5 servings per day (Hicks et al. 2019), and when five hours or more per day of screen time were accumulated among US teenagers, the odds of consuming SSB once a week doubled (Kenney et al. 2017). Furthermore, Rey-Lopez et al. (2011) assessed lifestyle habits including time spent watching TV and beverage intake. They found that in a sample of European youth aged 12.5–17.5 years, youth who watch TV more than two hours per day also consumed SSB daily. These findings presented in previous literature are concerning given that the current study population reported 3.5 hours of screen time use per day. Consequently, these inter-related modifiable behaviours may be an important target in weight management settings.

With regards to weight status, SSB intake has been associated with increased total energy intake (Jashinksy et al. 2017), increased risk of obesity (Kelishadi et al. 2017) and higher body fat percentage (Marshall et al. 2019). In this population, BMI z-score did not significantly increase the odds of failing to meet SSB or fruit juice cut-offs. However, Component 1 was positively related to BMI z scores (even amongst this cohort, all of who had obesity) independently of age and sex and other factors such as SES and eating habits. This finding was similar to previously defined beverage patterns in in healthy children and youth (La Rowe et al. 2007, Danyliw et al. 2012). For example, children in a “soft drink” cluster were more likely to be obese, independent of total energy intake, age, and sex, income, ethnicity, and food security (Danyliw et al. 2012). Furthermore, Marshall et al. (2017) also described distinct patterns for each fruit juice 100% and SSB. It was reported that a 3.2-unit higher BMI was identified among those who adhered to the SSB pattern compared to the “100% juice” pattern. While these patterns demonstrate that youth consumed fruit juice independently of other SSB, Component 1 characterized a pattern of both fruit juice and SSB, thus fruit juice consumed in combination with soft drinks and fruit-flavoured beverages may be related to increased weight.

Although methodology among previous beverage pattern analyses used different methods of dietary pattern analysis such as cluster analysis, similar positive relationships between body mass and SSB patterns was consistent. This relationship between weight status and Component 1 is important to consider in this population of children and youth with obesity as this may highlight an import modifiable behaviour that could be targeted to improve health outcomes in these individuals. Additionally, no significant relationship between BMI z-score and Component 5 was identified (unlike Component 1 which loaded on all other SSB). The absence of this relationship between BMI z-score and Component 5 may be due in part to the different SSB that characterized Component 5, as the relationship between weight status and flavoured milk intake is generally inconsistent among children and youth (Fayet-Moore et al. 2016; Patel et al. (2018).

It is of interest that imputation of missing values in this study resulted in similar results. When imputed data was assessed, models resulted in male guardian education becoming a positive predictor of failing to meet SSB intake. The relationships with weekly fruit juice intake recommendations were most greatly affected by imputation and the significance of meals with the family was attenuated, no major changes in related factors of total SSB (fruit juice and SSB) were found when multiple imputation was implemented.

Milk

While SSB consumption among youth with obesity in the current population is generally similar to population-based studies, milk consumption among this cohort of youth with obesity appears to be higher than reported intakes of healthy weight youth in population-based studies. In the previously mentioned analysis by Tremblay et al. (2015) which compared the CHMS outcomes to the pilot study measures, the CANPWR population consumed significantly more daily servings of milk (Mean= 3.1 ± SD 2.5 serving per day) than age matched children and youth. Furthermore, in the US, it has been estimated that 38% of older adolescents consume one serving per day of milk (Miller et al. 2017), far fewer than the 94% of children and youth presented here.

Among Canadian children, dietary intake data from CHMS and CCHS collected from 2004-2012 provide estimates of dairy intake per day. Although these surveys are >10 years old, this information is still relevant to the CANPWR cohort to a degree, as the CANPWR pilot study initiated data collection in 2013. In 2004, the CHMS 2.2 estimated that 53% of children aged 4 to 9 years and 39% of males and 17% of females aged 10 to 16 years consumed 2 servings of milk and alternatives per day (Garriguet et al 2007). While that analysis of the CHMS 2.2 defined total milk and alternatives to include other sources of dairy such as yogurt and cheese, it can be inferred that on average, frequency of milk intake twice a day may be similar or higher among youth with obesity compared to Canadian children >10 years old, especially given that evidence points to a decrease in milk intake per capita in Canada since 2009 (St. Pierre et al. 2017).

When dietary pattern analysis was used, the formation of Component 2 and Component 3 appeared to distinguish those who consume different types of milk in the study population (1% and 2% respectively). This may suggest that, families tend to purchase one type of milk consistently and consumption of milk and dietary choices are somewhat dependent on home food availability (Zarnowiecki et al. 2014). In previous research, milk items have been grouped together to form beverage patterns, and specific types of milk have been identified separately from others. For example, La Rowe et al. (2007) identified a "high-fat milk" pattern with high factor loadings on 2% milk and whole milk and lower factor loadings on other types of beverages including reduced fat milk. However, LaRowe et al (2007) grouped flavoured milks and unflavoured milks prior to cluster analysis unlike the methods implemented here which separated milks with and without added sugars. However, the results presented by LaRowe et al. (2007) included different patterns of milks consumed together based on fat percentage exclusively of other beverages such as water or juice as seen in this analysis.

While some relationships were consistent with previous research in healthy youth populations, some factors influencing the odds of meeting milk recommendations were not. Results showed that milk intake was significantly influenced by sex and males were less likely to consume less than two or more servings per day (i.e. consume more milk), similar to previous studies demonstrating higher intake of milk among males (Evans et al. 2010; Winkvist et al. 2016). Alternatively, amongst the cohort studied here, milk intake was not related to age. This was inconsistent with population-based studies, in which milk intake is described to be higher in childhood and decrease as youth enter adolescence (Bleich et al. 2018; Evans et al. 2010).

Furthermore, higher household income predicted a greater adherence to Component 2 (1% milk) but lower adherence to Component 3 (2% milk). In line with Component 2, a review by Manyanga et al. (2017), who compiled dietary patterns from multiple countries for 9-11 year-old children and found that skim and low-fat milks had high factor loadings on healthy diet patterns which were related to higher income independent of the country the study was conducted in. While this study did not specifically assess beverage intake alone, the current analysis also found that lower fat milk such as 1% milk in Component 2 was directly related to higher SES (income). Given the differences in Component 2 (1% milk) and Component 3 (2% milk) relationship with income level amongst children and youth with obesity, it appears that this relationship between SES milk intake may be dependant on the type of milk.

Moreover, those of white ethnicity were more likely to adhere to Component 2 (1% milk) which was simailar to the cluster analysis by La Rowe et al. (2007) in which it was found that Mexican American children comprised a greater proportion of the high-fat milk cluster. Thus, sociodemographic factors influencing milk intake were slightly more challenging to interpret as there were differences in the direction of the relationship between SES and component 2 (1%

milk) and Component 3 (2% milk). Furthermore, no relationship between age and milk intake was present among this population of children and youth with obesity as suggested in population-based studies. Rather, factors such as SES and sex were significantly related to milk intake.

All eating habits (eating out/ordering in, eating as a family and eating in front of the TV) significantly associated with greater milk intake. Similar to the relationships presented here, eating meals as a family 5-7 days per week has been associated with 1.23 [CI: 1.02, 1.47] increased odds of consuming two or more glass of milk per day among more than 11,000 American youth in grade 9-12 independently of age and race (Demissie et al. 2015). In the current study, individuals who ordered in/ate out more often consumed more 1% milk (Component 2) while those who ate in front of the TV primarily consumed a beverage pattern high in 2% milk (Component 3). These behaviours have not been consistently associated with higher milk intake in previous literature studying healthy weight youth. Opposite of trends seen in this study, eating in front of the TV has been identified as a risk factor for poor diet quality, often indicated by lower vegetable intake and higher SSB intake (Avery et al. 2017). However, a study by Trofholz et al. (2019) found no significant relationship between dairy intake and meals in front of the TV, similar to findings by Jackson et al. (2015) which did not determine a significant relationship between screen time and milk consumption in children. Therefore, meals in front of the TV appear to promote a less healthful diet but not specifically lower milk intake in youth, similar to the current findings. Furthermore, consuming fast food at least once per week was linked to a 40% decreased odds of consuming milk twice per day among males in grades 9-12 independent of age and race (Demissie et al. 2015). While the established relationships between milk intake and eating habits were inconsistent with previous literature, it should be emphasized that eating habits only weakly increased the odds of failing to meet daily milk consumption by 4-7% and thus do not have a large influence on milk intake.

Lastly, the relationship between higher screen time and lower milk intake (i.e. increased odds of failing to meet recommendations and lower adherence to Component 2) were somewhat comparable to findings reported by Kelishadi et al. (2017), who found that screen time totaling at least 4 hours per day significantly lowered the odds of consuming one serving of milk per day by 10%, similar to the decrease of 11% with an additional one hour per day of screen time found in the current study.

To summarize the relationships between milk consumption and sociodemographic and behavioural characteristics of children and youth with obesity, it appears that individuals who adhere to singular milk patterns may exhibit different eating habits depending on the type of milk consumed. These relationships differed somewhat to relationships previously reported in healthy youth populations and factors that may have contributed to the current results could be hypothesized. For example, it is possible that breakfast may be consumed in front of the TV and include cereal with milk or youth may choose milk at restaurants or with meals ordered in. However, further research on the relationship between milk intake and eating habits is needed to elucidate these relationships in children and youth with obesity. It should be noted that imputation of missing data did not lead to any changes in the factors related to milk intake.

When weight status and beverage intake were considered, BMI z-score was not significantly related to either total milk intake recommendations or components which loaded highly on only 1% or 2% milk. Although previous research on healthy weight populations have pointed to a protective effect of milk against obesity (Dror et al. 2014), there was no relationship between BMI z-score and these patterns.

Finally, when the fourth component was assessed, youth who adhered to Component 4 (rice milk and diet soft drinks) appeared to consume these alternatives more often if they were white, male and had a high daily screen time. BMI z-scores, higher female guardian education and a greater number of meals eaten together as a family were inversely related to this pattern. The relationship between reduced BMI z-score and adherence to this pattern is difficult to compare to previous literature given that a pattern similar to this has not been cited among other studies. However, the association with a lower BMI z-score was somewhat congruent with the meta-analysis findings by Toews et al. (2018), which reported a slight reduction in BMI z-score with artificial sweetener use such as those present in soft drinks. Additionally, it is unlikely that many children and youth strongly adhered to this pattern given that these individuals rarely consumed rice milk (Median= 0.0, IQR: 0.0, 0.0) or diet soft drinks (Median = 0.0; IQR: 0.0, 0.07) at time of enrollment into a pediatric weight management program. Therefore, it is possible that Component 4 may have grouped these beverages together if both these drinks were consumed by the same individuals, even if they were rarely consumed, due to the method of PCA which identifies linear relationships between items.

Few metabolic health outcomes were influenced by patterns of beverage intake. The association between increased sugar intake from sources such as those found in SSB such as in Grouped Component 1 (all SSB and fruit juice) with lower HDL levels among children and youth has been previously cited (Vos et al. 2017). However almost all other relationships did not persist after adjustment for age, sex and BMI z-score. Only Component 4 score (rice milk, diet soft drinks) was independently associated with lower HDL concentration. The link between ASB such as diet soft drinks and metabolic health outcomes is still unclear (Brown et al. 2010; Pereira 2014). Limited studies have demonstrated significant relationships between ASB and metabolic health outcomes. Findings that ASB may have similar metabolic effects as SSB have been reported, however these relationships require further research (Seifreidi et al. 2015). Given that children and youth with obesity are at a higher risk of metabolic co-morbidities, multiple other factors may be at play and thus metabolic health was not greatly influenced by different beverage patterns.

Limitations

Self-report bias is important to consider in this population for several reasons: participants and their families may already possess some knowledge as to what healthy lifestyle changes they should be implementing, or discrepancies between guardian and child responses may have occurred, especially among children <8 years old who may have difficulty recalling foods or beverages and portions consumed (Collins et al. 2010). Regardless, few methods of obtaining dietary intake information in large populations are available and the use of FFQ is an efficient and quick method to capture diet in large epidemiological studies (Spruijt-Metz et al. 2018). Structured FFQ with pre-defined foods and responses vs dietary recalls may be more ideal for younger children, as this method presents less burden on youth to recall foods and beverages recently consumed and also allows for the direct comparisons of food consumption between participants.

Similarly, physical activity was self-reported and may have been influenced by self-report bias (Slootmaker et al. 2009) which could have impacted relationships between beverage intake and physical activity. In an effort to accurately collect self-reported moderate to vigorous physical activity, CANPWR questionnaires sampled questions from the validated CHMS (Cycle 2.2) which provides the current study with a nationally representative comparative sample.

Other limitations of the current study include the inability to measure total energy intake as a control. Total energy intake can mediate the relationship between SSB, measures of adiposity and metabolic outcomes (Anderson, et al. 2015b; Jing et al. 2018; Zheng et al. 2014). Total energy intake has also been shown to correlate with SSB and milk intake independently of age, sex and BMI (Patel et al. 2018). Thus, controlling for total energy intake may have helped to more confidently determine the influence of sociodemographic factors and behaviors on beverage intake and adherence to beverage patterns independently of other contributing factors from youth diets.

Concerning the missing data in this study, there is no certain method of determining if data is missing at random or if the use of complete-case data or imputed data is correct. Multiple imputation has been suggested as a robust method to estimate missing values based on other information available for individual cases (Sterne et al. 2009) and thus was chosen to address bias of analyzing only complete cases. Multiple other ways to handle missing data in research could have included imputing zeroes for missing food/beverage intake (Pala et al. 2013), substituting the mean intake for the specific food or beverage response to replace missing values (Osler et al. 2000) or simply exclude participants with incomplete data all together (Lobo et al. 2019) as done in the primary analysis of this study. In conclusion, imputation models in this analysis were important to acknowledge missing values and resulted in few changes which did not significantly affect the primary objective results.

PCA is useful for determining the prominent patterns of food and beverage intake in a population rather than specific micronutrient intakes. However, this approach is highly dependent on decisions made by the researcher and is unique to one dataset. As seen in the sensitivity analysis, resulting patterns were influenced by the decision to pre-group beverages, thus logical and informed decisions need to be made by the researcher to determine the number of patterns to be included or excluded, which ultimately introduces bias (Jolliffe 2011). In summary, grouping beverages prior to PCA reduced the number of components formed and increased the variance explained. No correct way to determine beverage patterns exists, and given that patterns among youth with obesity are not well described among youth with obesity in the literature, this sensitivity analysis was mainly exploratory. In this analysis, the effect on resulting components when beverages are grouped apriori resulted in fewer beverage patterns and similar related sociodemographic and behavioural factors seen in the original analysis.

Considerations of Future Research and Implications of Findings

This baseline analysis of the CANPWR study cohort demonstrated that a large number of children and youth with obesity consume sweet beverages and a third met the previous milk and alternatives intake recommendation for youth at time of enrollment. Assessing beverage intake at time of follow up during CANPWR study visits (6-month, 12-month, 24-month and 36-month) will help to understand how beverage intake and related factors change over time. This may provide insight as to how youth are implementing lifestyle changes. Follow-up in pediatric weight management programs often fails to surpass six months (Peirson et al. 2015), therefore assessing beverage intake at the 12, 24 and 36 –month time point can offer crucial information that could help clinicians to guide youth to better health outcomes and identify areas for improvement or success. This will be particularly relevant if changes in beverage intake are related to changes in health outcomes.

Dietary patterns have been previously examined in longitudinal studies, though not in children and youth with obesity. Pala et al. (2013) assessed dietary intake and investigated the patterns' associations with BMI in nearly 15,000 children aged 2-10 years from various European countries at baseline and again two years later. Children who most strongly adhered to the vegetable pattern at baseline were 30% less likely to become overweight or obese after two years compared to those who did not adhere greatly to this pattern independently of baseline BMI, age, sex, physical activity and family income. Furthermore, a longer period of dietary tracking by Movassagh et al. (2017) demonstrated that baseline dietary patterns among children at 8 years old remained similar at multiple timepoints until age 34. Certain dietary pattern scores increased for components such as the vegetarian and wholemeal which included high factor loadings on unflavoured milk while the high fat pattern (including high factor loadings on soft drinks) scores decreased. These studies highlight the potential for dietary pattern analysis to be used to derive beverage intake at multiple time points and understand how dietary habits change over time with physical measures and other outcomes of interest which is relevant in weight management settings to track how overall diet and lifestyle choices change over time.

The number of children and adolescents with obesity who failed to consume less than one SSB weekly points to a regular consumption of SSB and fruit juice in this population. In this study, younger children were more likely to adhere to the SSB pattern (Component 1) and consume sweet beverages on a weekly basis, illustrating the need for early intervention of SSB consumption.

Outside of the home food environment (Mazerallo Paes et al. 2015), the school plays an important role in youth diets. Of concern, a study of food and beverage advertising in Canadian primary schools recently reported the presence of name-brand food items and student achievement awards sponsored by commercial food businesses (Kent et al. 2019). To combat SSB consumption and reduce SSB exposure to children at school, it has been suggested that polices to reduce corporate sponsorship and marketing of unhealthy foods and beverage to children in academic environments could be implemented (Kent et al. 2019). As such, recommendations by organizations such as the European Academy of Paediatrics and American Academy of Pediatrics strongly suggest banning sales of sweet drinks in schools, as well as their advertising to youth (Dereń et al. 2019; Schneider et al. 2011; Pound et al. 2017; Muth et al. 2019). Furthermore, school-based interventions to reduce SSB consumption and promote healthier diets overall in children and adolescents with or without obesity have been generally successful. In a review of these interventions (n=36), the interventions were either general educational programs (teaching health impacts of poor dietary choices like SSB and other counselling) or environmental interventions (i.e. reduced SSB availability). These authors reports that 72% were successful in reducing self-reported SSB intake (Vézina-Im et al. (2017).

Additional efforts to combat SSB intake at a much larger scale level includes the taxation of SSB. Evidence compiled by the Dieticians of Canada demonstrates that taxation of sugary beverages could lead to significant decreases in SSB consumption if a tax of 10-20% is applied (Dieticians of Canada, 2016). This may help to decrease the ease of SSB affordability for youth, especially given that youth report higher SSB consumption if they attend a school within one-kilometer proximity to food outlets where SSB are available for purchase (Godin et al. 2018). In Mexico, SSB tax implementation led to a decrease of 12% in the volume of SSB sold overall among in Mexico one year after tax implementation was reported (Colchero et al. 2016). Similar benefits could be seen in Canada among children and youth if action is taken.

Conclusion

Beverage consumption is a critical component of children and adolescents' diet that can influence health outcomes. Assessing beverage intake at the time of enrollment into pediatric weight management programs revealed that many children and youth with obesity failed to meet

SSB, fruit juice and milk recommendations. Distinct patterns of beverage intake were identified from reported consumption at baseline using PCA method of dietary pattern analysis. Sociodemographic factors including age, sex, ethnicity and SES and behaviours including eating habits and screen time influenced the odds of meeting or failing to meet SSB, fruit juice and milk intake and were related to identified beverage patterns. To conclude, modifiable behaviours including diet are at the forefront of the clinical management of pediatric obesity, thus identifying patterns of beverage consumption and related factors may help to assist clinicians to identify effective strategies help guide youth to improved health outcomes and allow clinicians to create personalized approaches for youth.

Chapter 5: References

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Chapter 6: Appendix

Section 1. Methods Supplementary

Table A1. Summary of beverages and behaviours assessed with corresponding conversions.

15 Beverages included	FFQ Responses	Conversion to Continuous
Milk (skim, 1%, 2%, whole) Milk Alternatives (rice, soy) Flavoured Milk 100% Fruit Juice Fruit Flavoured Beverages Regular Sodas Diet Sodas Energy Drinks Sports Drinks Vegetable Juice Water	"Never, less than 1/month"	0 servings per day
	"1-3 times/month"	0.07 servings per day
	"1/week"	0.14 servings per day
	"2-4 times/week"	0.43 servings per day
	"5-6 times/week"	0.79 servings per day
	"1/day"	1 serving per day
	"2-3 times/day"	2.5 servings per day
	"4-5 times per day"	4.5 servings per day
	"≥6 times/day"	6+ servings per day
Behaviours Assessed	**FFQ Responses**	**Conversion to Continuous**
Eating Habits 1) Meals eaten in front of the TV 2) Meals eaten together as a family 3) Meals eaten out or ordered in	"Never, less than 1/month"	0 times per week
	"1-3 times/month"	0.5 times per week
	"1/week"	1.0 times per week
	"2-4 times/week"	3.0 times per week
	"5-6 times/week"	5.5 times per week
	"1/day"	7.0 times per week
	"2-3 times/day"	17.5 times per week
	"4-5 times per day"	31.5 times per week
Physical Activity Sum of: 1) Organized physical activity outside of school	"None"	0
	"≤1 hours/week"	1 hour per week
	2-3 hours/week"	2.5 hours per week

2) Unorganized physical activity outside of school 3) Physical activity during free time at school	4-6 hours/week"	5 hours per week
	"≥7 hours/week"	7 hours per week
Screen Time	"<1 hour/day"	0.5 hours per day
	"1-2 hours/day"	1.5 hours per day
	"3-4 hours/day"	3.5 hours per day
	"5-6 hours/day"	5.5 hours per day
	"≥7 hours/day"	7+ hours per day

Table A2. Reference cut-off points for abnormal laboratory values.

Components	**Cut-Off**
Elevated Hba1c	≥5.7 %*
elevated FPG	≥5.5 mmol/L*
Elevated TG	≥1.7 mmol/L*
Elevated TC	≥5.2 mmol/L*
Non-HDL	≥3.7 mmol/L*
Low HDL	≤1.2 mmol/L*
LDL- Cholesterol	≥3.4 mmol/L*
Elevated ALT**	≥25 U/L (1 to <13 yrs) ≥22 U/L (Females 13 to <19 yrs) ≥24 U/L (Males 13 to <19 yrs)
Elevated AST**	≥44 U/L (1 to < 7 yrs) ≥36 U/L (7 to <13 yrs) ≥26 U/L (Females 13 to <19 yrs) ≥35 U/L (Males 13 to <19 yrs)

* American Heart Association cardiovascular risk reduction in high-risk pediatric patients (de Ferranti et al. 2019)

** Canadian laboratory initiative on pediatric reference intervals Adeli et al. (2017)

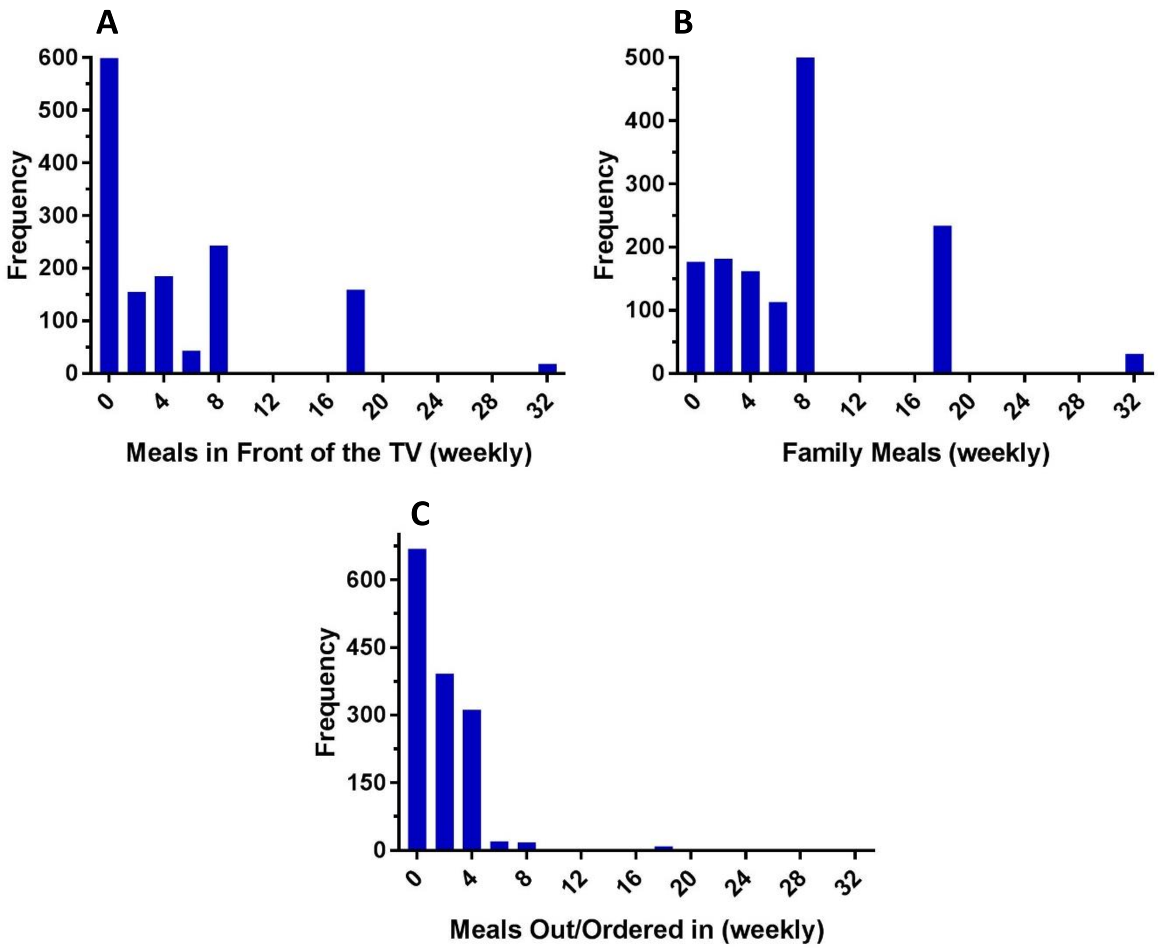

Figure A1. Histogram of A) Meals eaten in front the TV per week, B) Meals eaten as a family per week and C) Total weekly meals eaten out or ordered in per week.

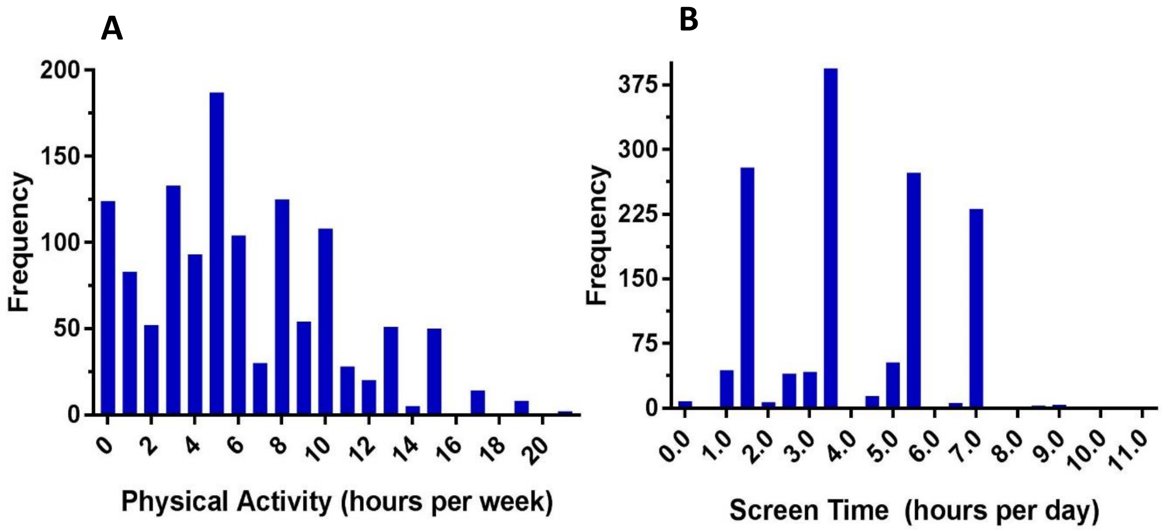

Figure A2. Histogram of A) total weekly physical activity in hours per week and B) total daily screen time in hours per day.

<u>Section 2. Primary Objectives Supplementary</u>

Table A3. Average intake of all sugar-sweetened beverages and milks at baseline (N=1425)

	Mean	SD	Median	IQR	
				Lower	Upper
Weekly Intake of SSB					
Fruit Juice 100%	3.80	5.88	1.0	0.46	7.0
Flavoured Milk	1.34	3.06	0.46	0	1.0
Soft Drink	1.47	3.96	0.46	0	1.0
Sports Drink	0.46	1.65	0	0	0.46
Energy Drinks	0.06	0.91	0	0	0
Fruit-Flavoured Drink	1.83	4.54	0	0	1.0
Daily Intakes of Milk					
Milk 3.25%	0.04	0.3	0	0	0
Milk 2%	0.52	0.98	0	0	0
Milk 1%	0.59	1.06	0	0	0
Skim Milk	0.22	0.7	0	0	0
Daily Intakes of Other Beverages					
Rice Milk	0.02	0.16	0	0	0
Soy Milk	0.03	0.19	0	0	0
Diet Soft Drink	0.1	0.37	0	0	0
Water	3.68	2	4.5	2.5	0
Vegetable Juice	0.03	0.2	0	0	0

Total SSB

Not controlling for covariates, significant differences in demographic and eating behaviours were evident between those who were weekly consumers of total SSB and those who met recommendations of less than one serving per week of total SSB. Total SSB intake was not independent of sex and those who consumed total SSB weekly were nearly 0.6 years younger. All SES proxies including income level, female and male guardian education were significantly associated with weekly total SSB intake. Youth who failed to meet recommendation also ate out/ordered in more meals, ate one less meal with their family per week and accumulated approximately 20 minutes of additional screen time per day (Table A4).

Table A4. Chi-square and independent t-test univariate analyses investigating relationship between demographic and behavioural variables and failing to meet total SSB intake.

Categorical Variables – Chi-Square Test			**<1 Svg/wk total SSB**	**≥1 Svg/wk total SSB**	**Chi-Square**	
			N (%)	**N (%)**	**X^2**	**Sig**
Sex	Female		161 (59.9%)*	580 (50.2%)^	**8.19**	**0.004**
	Male		108 (40.1%)*	576 (49.8%)^		
Racial Background	White		95 (35.3%)	345 (29.8%)	3.06	0.080
	Other		174 (64.7%)	811 (70.2%)		
Income	<80,000		57 (22.6%)*	333 (30.6%)^	**6.33**	**0.012**
	>80,000		195 (77.4%)*	755 (69.4%)^		
Female Guardian Education Level	Highschool or less		50 (18.8%)*	315 (27.8%)^	**9.02**	**0.003**
	University/college		216 (81.2%)*	819 (72.2%)^		
Male Guardian Education Level	Highschool or less		69 (27.4%)*	398 (37.8%)^	**9.60**	**0.002**
	University/college		183 (72.6%)*	655 (62.2%)^		
Household Status	1 residence		247 (92.2%)	1014 (87.9%)	4.0	0.05
	Multiple		21 (7.8%)	140 (12.1%)		
Continuous Variables- Independent Sample T-Test						
Variable	**Svg/wk total SSB**	**N**	**Mean**	**SD**	**MD**	**Sig.**
Age	<1	269	12.53	3.51	**0.58**	**0.010**
	≥1	1156	11.95	3.30		
BMI z-score	<1	269	3.49	1.01	-0.09	0.198
	≥1	1156	3.59	1.07		
Eating Out/Ordering In (weekly)	<1	269	1.14	2.10	**-0.29**	**0.038**
	≥1	1152	1.43	2.01		
Frequency of family meals (weekly)	<1	269	7.88	7.05	**1.01**	**0.033**
	≥1	1152	6.88	6.50		
Frequency of meals in front of the TV (weekly)	<1	263	3.78	5.95	-0.66	0.124
	≥1	1139	4.44	6.37		
Physical Activity (hrs/wk)	<1	232	5.52	4.37	-0.45	0.144
	≥1	1039	5.98	4.25		
Screen Time (hrs/day)	<1	263	3.74	1.89	**-0.37**	**0.005**
	≥1	1139	4.11	2.02		

*****Differences in proportion within <1 Svg/wk sweet beverage cut-off

^ Differences in proportion within ≥1 Svg/wk sweet beverage cut-off

In the fully adjusted model (Nagelkerke R^2 =0.07; p<0.001) (Table A5), sex remained a significant determinant total SSB intake, with males 62% likely to consume total SSB at least once weekly compared to males. Alternatively, the likelihood of failing to achieve this recommendation was lowered by 8% with each year increase in age. Only male education level remained significant, and youth who had male primary caregivers who completed post-secondary education were 33% less likely to consume total sweet beverages weekly. Behaviours including meals ordering in/eating out and screen time increased the risk of failing cut-offs by nearly 28% and 13% respectively. Alternatively, the frequency of meals eaten with the family marginally lowered the likelihood of consuming total SSB, similar to FJ and SSB separately.

Table A5. Logistic regression model assessing the OR of exceeding weekly intake (1 svg/wk) of total sweet drinks (n=1198).

					95% CI (OR)	
	β	**S.E.**	**Sig.**	**OR**	**Lower**	**Upper**
Sex (Males)	0.48	0.17	**.004**	**1.62**	1.17	2.25
Age (Years)	-0.12	0.03	**.000**	**0.89**	0.84	0.94
BMI z-score	-0.15	0.08	.078	0.86	0.73	1.02
Income (>$50,000/year)	-0.02	0.19	.938	0.99	0.68	1.44
Female Guardian Education (Post-Secondary)	-0.25	0.21	.235	0.78	0.52	1.17
Male Guardian Education (Post-Secondary)	-0.40	0.19	**.032**	**0.67**	0.47	0.97
Eating Out/Ordering In (Weekly)	0.25	0.07	**.001**	**1.28**	1.12	1.48
Meals with the Family (Weekly)	-0.04	0.01	**.003**	**0.97**	0.94	0.99
Screen Time (hrs/day)	0.12	0.05	**.011**	**1.13**	1.03	1.23
Constant	3.37	0.57	**.000**	**29.10**		
R^2	Cox & Snell R^2= .04			Nagelkerke R^2= .07		

<u>Section 3. Sensitivity Analysis Supplementary (Primary Objectives)</u>

Table A6. Missing and N/A values for behavioural and sociodemographic variables of interest.

	N	Missing		N	Missing OR N/A	
		Count	Percent		Count	Percent
Sex	1536	0	0.0	1536	0	.0
Age	1536	0	0.0	1536	0	.0
BMI z score	1536	0	0.0	1536	0	.0
Racial Background	1536	0	0.0	1536	0	.0
Household Income Level	1511	25	1.6	1406	130	8.5
Female Guardian Education	1515	21	1.4	1475	61	4.0
Male Guardian Education	1516	20	1.3	1368	168	10.9
Household Status	1508	28	1.8	1508	28	1.8
Milk 3.25%	1445	91	5.9	1445	91	5.9
Milk 2%	1441	95	6.2	1441	95	6.2
Milk 1%	1445	91	5.9	1445	91	5.9
Milk-skim	1445	91	5.9	1445	91	5.9
Flavoured Milk	1443	93	6.1	1443	93	6.1
Rice Milk	1441	95	6.2	1441	95	6.2
Soya Milk	1444	92	6.0	1444	92	6.0
Regular soft drinks	1442	94	6.1	1442	94	6.1
Diet soft drinks	1442	94	6.1	1442	94	6.1
Sport drinks	1443	93	6.1	1443	93	6.1
Energy drinks	1440	96	6.3	1440	96	6.3
Juice 100%	1496	40	2.6	1496	40	2.6
Flavoured juice	1444	92	6.0	1444	92	6.0
Vegetable Juice	1441	95	6.2	1441	95	6.2
water	1443	93	6.1	1443	93	6.1
Eating out/ordering in (weekly)	1441	95	6.2	1441	95	6.2
Meals with the family (weekly)	1440	96	6.3	1440	96	6.3
Meals in front of the TV (weekly)	1418	118	7.7	1418	118	7.7
Physical Activity (hrs/wk)	1418	118	7.7	1418	118	7.7
Screen Time (hrs/day)	1450	86	5.6	1450	86	5.6

SSB (Imputation)

In the final model (univariate chi-square and t-tests not shown here), sex and age remained important influencing factors on the likelihood of failing to meet SSB recommendations (Table A7), with males more likely to consume one or more SSB per week by 43% while each year older lowered the odds of failing to meet SSB recommendations by 8% (similar to original analysis). Using imputed data, higher male guardian education also became significant and lowered the odds of failing to meet SSB intake in addition to higher female guardian education which remained a significant determinant as seen in the original analysis. Among behavioural variables, the frequency of eating out/ordering in and total daily screen time both increased the likelihood of failing to meet the SSB cut-off by 37% and 17% respectively, similar to analyses with complete data (26% and 15% respectively). Eating meals with the family persisted as a significant variable, once again lowering the risk of failing to meet SSB marginally.

Table A7. Imputed estimates for SSB intake (n=1536). Shaded rows indicate variables that differ in significance from original analysis using only complete data.

	B	S.E.	Sig.	OR	95% CI (OR)	
					Lower	Lower
Sex (Males)	.35	.12	**.003**	**1.43**	1.13	1.80
Age (Years)	-.08	.02	**.000**	**.92**	.89	.96
BMI z-score	-.02	.06	.764	.98	.87	1.10
Income (>$50,000/year)	-.21	.14	.143	.81	.62	1.07
Female Guardian Education (Post-Secondary)	-.46	.15	**.002**	**.63**	.47	.85
Male Guardian Education (Post-Secondary)	-.28	.12	**.040**	**.75**	.58	.99
Eating Out/Ordering In (Weekly)	.31	.05	**.000**	**1.37**	1.24	1.51
Meals with the Family (Weekly)	-.02	.01	**.026**	**.98**	.96	1.00
Screen Time (hrs/day)	.15	.03	**.000**	**1.17**	1.09	1.25
Eating Out/Ordering In (Weekly)	1.52	.40	.000	4.56	2.09	9.93
Constant	Cox & Snell R^2= 0.07			Nagelkerke R^2=0.10		

Fruit Juice (Imputation)

When primary objectives investigating factors related to failing to meet fruit juice recommendations were repeated using imputed data, age was the only variable that was significantly related to fruit juice intake. Similar to the initial analysis using complete data, each year older significantly lowered the odds of failing to meet the weekly fruit juice cut-off by nearly 4% when imputed data was used (Table A8). The frequency of meals with the family or meals in front of the TV no longer significantly influenced the odds of failing to meet fruit juice intake unlike the initial primary analysis. However, family meals and meals in front of the TV significantly influenced fruit juice intake only by 3% (p<0.001) in the original analysis and thus was not a major risk factor. (Univariate chi-square and t-tests not shown here)

Table A8. Imputed estimates for fruit juice intake (n=1536). The frequency of family meals was no longer a significant predictor of fruit juice intake.

	β	**S.E.**	**Sig.**	**OR**	**95% CI (OR)**	
					Lower	**Lower**
Sex (Male)	.11	.11	.319	1.11	.90	1.37
Age (years)	-.04	.02	**.019**	**.96**	.93	.99
BMI z-score	-.03	.05	.532	.97	.88	1.07
Constant	.91	.30	.002	2.48	1.39	4.43
R^2	Cox & Snell R^2 = 0.04			Nagelkerke R^2 = .06		

Total SSB (Imputation)

When imputed data was used to determine if factors differed for total SSB intake (fruit juice and SSB intake), all variables in the complete-case analysis remained significant (Table A9) (univariate chi-square and t-tests not shown here).

Table A9. Imputed pooled estimate models investigating behavioural and sociodemographic variables influencing total SSB intake (fruit juice and SSB) cut-offs (n=1536).

	B	S.E.	Sig.	OR	95% CI (OR)	
					Lower	**Lower**
Sex (Males)	.42	.15	**.006**	**1.52**	1.13	2.05
Age (Years)	-.11	.03	**.000**	**.90**	.85	.94
BMI z-score	-.14	.08	.061	.87	.75	1.01
Income (>$50,000/year)	-.25	.18	.177	.78	.55	1.12
Female Guardian Education (Post-Secondary)	-.37	.20	.061	.69	.47	1.02
Male Guardian Education (Post-Secondary)	-.38	.18	**.030**	**.68**	.48	.96
Eating Out/Ordering In (Weekly)	.29	.07	**.000**	**1.333**	1.17	1.51
Meals with the Family (Weekly)	-.03	.01	**.002**	**.97**	.95	.99
Screen Time (hrs/day)	.13	.04	**.003**	**1.14**	1.04	1.23
Constant	3.55	.53	**.000**	**34.68**	12.33	97.54
R^2	Cox & Snell R^2= 0.07			Nagelkerke R^2=0.10		

Milk (Imputation)

When recommendations for daily milk intake were considered, logistic regression models using the imputed dataset did not lead to any major differences in the sociodemographic or behavioural variables related to milk intake (Table A10) (univariate chi-square and t-tests not shown here).

Table A10. Imputed pooled estimate models investigating behavioural and sociodemographic variables influencing milk intake cut-offs of 2 servings per day (n=1536).

	β	S.E.	Sig.	OR	95% CI (OR)	
					Lower	**Lower**
Sex (Male)	.49	.12	**.000**	**1.63**	1.30	2.06
Age (years)	.01	.02	.614	1.01	.97	1.05
BMI z-score	.02	.06	.775	1.02	.91	1.14
Eating Out/Ordering In (weekly)	.10	.03	**.002**	**1.11**	1.04	1.18
Meals with The Family (weekly)	.04	.01	**.000**	**1.04**	1.03	1.06
Meals in front of the TV (weekly)	.04	.01	**.000**	**1.04**	1.02	1.06
Physical Activity (hrs/wk)	.02	.01	.069	1.02	1.0	1.05
Screen Time (hrs/day)	-.10	.04	**.005**	**.91**	.84	.97
Constant	-1.51	.41	.000	.22	.10	.49
R^2	Cox & Snell R^2= .07			Nagelkerke R^2= 0.09		

In conclusion, the use of multiple imputation to address the missingness in data produced similar relationships for SSB and milk intake, however eating habits were no longer significant determinants of fruit juice intake. Although there is no correct approach to analyze data with missing values, it can be seen that the majority of relationships remained unchanged for SSB, total SSB and milk consumption when this imputation method was implemented. No major differences were found for any dependant or independent variables used in the primary objectives. Only total SSB was significantly different in two of the five imputed data sets compared to the original data, however this difference was <0.01 svg/day. Multiple regression analyses of total SSB did not reveal significant differences to the complete case analysis.

<u>Section 4. Secondary Objectives Supplementary</u>

Table A11. Correlation matrix of all beverages (n=1425).

	Milk 3.25%	Milk 2%	Milk 1%	Skim milk	Flavoured milk	Rice milk	Soya milk	Regular soft drinks	Diet soft drinks	Sports drinks	Energy drinks	Fruit juice 100%	Fruit flavoured drinks	Vegetable juice	Water
Milk 3.25%	1.00	0.00	-0.07	-0.03	0.04	-0.01	-0.01	0.06	-0.03	0.00	-0.01	0.03	-0.02	0.03	0.03
Milk 2%	0.00	1.00	-0.25	-0.16	-0.02	-0.01	-0.04	0.11	0.06	0.02	-0.01	0.10	0.04	0.05	0.06
Milk 1%	-0.07	-0.25	1.00	-0.12	0.09	-0.02	-0.05	0.00	-0.01	0.01	-0.02	0.01	0.01	0.03	0.10
Skim milk	-0.03	-0.16	-0.12	1.00	-0.02	-0.03	-0.03	-0.06	-0.02	-0.04	0.02	-0.03	-0.05	-0.03	-0.01
Flavoured milk	0.04	-0.02	0.09	-0.02	1.00	0.02	0.00	0.00	-0.03	0.12	-0.02	0.02	0.11	-0.01	-0.02
Rice milk	-0.01	-0.01	-0.02	-0.03	0.02	1.00	-0.02	0.07	0.06	-0.01	0.00	0.08	0.05	0.03	-0.02
Soya milk	-0.01	-0.04	-0.05	-0.03	0.00	-0.02	1.00	-0.02	0.00	0.01	0.00	0.02	-0.03	0.00	0.00
Regular soft drinks	0.06	0.11	0.00	-0.06	0.00	0.07	-0.02	1.00	0.13	0.14	0.21	0.28	0.15	0.02	-0.04
Diet soft drinks	-0.03	0.06	-0.01	-0.02	-0.03	0.06	0.00	0.13	1.00	0.03	0.02	0.13	0.04	-0.02	-0.09
Sports drinks	0.00	0.02	0.01	-0.04	0.12	-0.01	0.01	0.14	0.03	1.00	0.06	0.11	0.11	-0.02	-0.01
Energy drinks	-0.01	-0.01	-0.02	0.02	-0.02	0.00	0.00	0.21	0.02	0.06	1.00	0.17	0.21	-0.01	0.01
Fruit juice 100%	0.03	0.10	0.01	-0.03	0.02	0.08	0.02	0.28	0.13	0.11	0.17	1.00	0.21	0.07	-0.04
Fruit flavoured drinks	-0.02	0.04	0.01	-0.05	0.11	0.05	-0.03	0.15	0.04	0.11	0.21	0.21	1.00	0.05	-0.04
Vegetable juice	0.03	0.05	0.03	-0.03	-0.01	0.03	0.00	0.02	-0.02	-0.02	-0.01	0.07	0.05	1.00	0.01
Water	0.03	0.06	0.10	-0.01	-0.02	-0.02	0.00	-0.04	-0.09	-0.01	0.01	-0.04	-0.04	0.01	1.00

Table A12. Factor score descriptive statistics for Component 1 - 5.

	Mean	**SD**	**Range**		**Median**	**95% CI**	
			Min	**Max**		**Lower**	**Upper**
Component 1	0.00	1.00	-1.16	23.76	-0.23	-0.05	0.05
Component 2	0.00	1.00	-4.66	4.35	-0.12	-0.05	0.05
Component 3	0.00	1.00	-8.08	5.01	0.09	-0.05	0.05
Component 4	0.00	1.00	-8.57	10.39	-0.17	-0.05	0.05
Component 5	0.00	1.00	-5.65	12.98	-0.24	-0.05	0.05

Table A13. Univariate analyses between Component 1 and sociodemographic and behavioural factors.

Variable	**Unstd β**	**SE (β)**	**R^2**	**Adj R^2**	**Sig**
Age	0.04	0.01	0.02	0.02	**.000**
Sex (Male)	0.18	0.06	0.01	0.01	**.007**
BMI z score	0.10	0.03	0.01	0.01	**.000**
Racial Background (White)	0.03	0.06	0.00	0.00	.585
Household Income Level	-0.09	0.02	0.01	0.01	**.000**
Female Caregiver Education	-0.20	0.04	0.02	0.02	**.000**
Male Caregiver Education	-0.20	0.03	0.03	0.03	**.000**
Multiple Residences	-0.03	0.08	0.00	0.00	.744
Eating in Front of TV (weekly)	0.02	0.00	0.02	0.02	**.000**
Family Meals (weekly)	0.00	0.00	0.00	0.00	.643
Eating Out/Ordering In (weekly)	0.09	0.01	0.02	0.02	**.000**
Physical Activity (hrs/wk)	-0.02	0.01	0.01	0.01	**.001**
Screen Time (hrs/day)	0.07	0.01	0.02	0.02	**.000**

Table A14. Univariate analyses between Component 2 and sociodemographic and behavioural factors.

Variable	**Unstd β**	**SE (β)**	**R^2**	**Adj R^2**	**Sig**
Age	0.00	0.01	0.00	0.00	.737
Sex (Male)	0.06	0.05	0.00	0.00	0.295
BMI z score	-0.03	0.03	0.00	0.00	.182
Ethnicity (White)	0.25	0.06	0.01	0.01	**.000**
Household Income Level	0.09	0.02	0.01	0.01	**0.000**
Female Caregiver Education	0.07	0.04	0.00	0.00	.067
Male Caregiver Education	0.07	0.03	0.00	0.00	**.026**
Multiple Residences	-0.05	0.08	0.00	0.00	.523
Eating in Front of TV (weekly)	0.00	0.00	0.00	0.00	.536
Family Meals (weekly)	0.01	0.00	0.00	0.00	0.077
Eating Out/Ordering In (weekly)	0.03	0.01	0.00	0.00	**.026**
Physical Activity (hrs/wk)	0.01	0.01	0.00	0.00	**.051**
Screen Time (hrs/day)	-0.03	0.01	0.00	0.00	**.033**

Component 3

Like Component 2, univariate analysis revealed a significant relationship with household income, however this was in the opposite direction of Component 2. Behaviours including meals eaten as a family, meals in front of the TV, eating out/ordering in and screen time were all positively related to Component 3 (Table A15).

Table A15. Univariate analyses between Component 3 and sociodemographic and behavioural factors.

Variable	Unstd β	SE (β)	R^2	Adj R^2	Sig
Age	0.01	0.01	0.00	0.00	.236
Sex (Male)	0.05	0.05	0.00	0.00	.313
BMI z score	0.05	0.03	0.00	0.00	**.038**
Ethnicity (White)	-0.07	0.06	0.00	0.00	.219
Household Income Level	-0.08	0.02	0.01	0.01	**.000**
Female Caregiver Education	-0.05	0.04	0.00	0.00	.174
Male Caregiver Education	-0.04	0.03	0.00	0.00	.294
Multiple Residences	0.03	0.08	0.00	0.00	.690
Eating in Front of TV (weekly)	0.02	0.00	0.02	0.02	**.000**
Family Meals (weekly)	0.01	0.00	0.01	0.01	**.001**
Eating Out/Ordering In (weekly)	0.04	0.01	0.01	0.01	**.003**
Physical Activity (hrs/wk)	-0.01	0.01	0.00	0.00	.458
Screen Time (hrs/day)	0.03	0.01	0.00	0.00	**.029**

In the multivariate model, (Model R^2= 0.02; p<0.001), BMI z-score was no longer associated with Component 3, however income remained inversely related to this pattern of 2% milk. Eating out/ordering in and screen time were no longer related to Component 3 (Table A16).

Table A16. Linear regression models assessing factors related Component 3 pattern scores (n=1286).

	Unstd		Std β	Sig.	95% CI β	
	β	SE			Upper	Lower
(Constant)	-0.40	0.19		.038	-0.78	-0.02
Sex (Male)	0.02	0.06	0.01	.781	-0.10	0.13
Age (years)	0.02	0.01	0.05	.097	0.00	0.04
BMI z-score	0.04	0.03	0.04	.189	-0.02	0.09
Household Income Level	-0.08	0.02	**-0.09**	**.001**	-0.12	-0.03
Eating Out/Ordering In (weekly)	0.02	0.01	0.05	.105	-0.01	0.05
Meals with the family (weekly)	0.02	0.00	**0.10**	**.000**	0.01	0.02
Meals in front of the TV (weekly)	0.01	0.01	**0.09**	**.003**	0.01	0.02
Screen Time (hrs/day)	0.01	0.02	0.03	.365	-0.02	0.05
Model R^2= 0.024; p<0.001						

Component 4

Univariate regression models (Table A17) showed that white ethnicity was a significant predictor of Component 4 adherence while female guardian education level was inversely related to Component 4 scores. Interestingly, all three eating habits were inversely related to Component 4. Screen time was also linked to higher component scores for this pattern. BMI z scores were not significantly related to this pattern of diet soft drinks and rice milk.

Table A17. Univariate analyses between Component 4 and sociodemographic and behavioural factors.

Variable	Unstd β	SE (β)	R^2	Adj R^2	Sig
Age	-0.01	0.01	0.00	0.00	.388
Sex (Male)	-0.04	0.05	0.00	0.00	.426
BMI z score	-0.05	0.03	0.00	0.00	.059
Ethnicity (White)	0.14	0.06	0.00	0.00	**.018**
Household Income Level	0.02	0.02	0.00	0.00	.387
Female Caregiver Education	-0.11	0.04	0.01	0.01	**.005**
Male Caregiver Education	-0.03	0.03	0.00	0.00	.458
Multiple Residences	-0.06	0.08	0.00	0.00	.511
Eating in Front of TV (weekly)	-0.01	0.00	0.00	0.00	**.041**
Family Meals (weekly)	-0.02	0.00	0.02	0.02	**0.000**
Eating Out/Ordering In (weekly)	-0.03	0.01	0.01	0.00	**.009**
Physical Activity (hrs/wk)	-0.01	0.01	0.00	0.00	.137
Screen Time (hrs/day)	0.04	0.01	0.01	0.01	**.004**

When the multivariate model was assessed, age became inversely related to Component 4 score, which was opposite of Component 1 (characterized by SSB), thus younger individuals appear to adhere to this pattern of alternatives more strongly than older youth. Ethnicity persisted as a predictor of Component 4, with those of white ethnicity more strongly adhering to this alternative beverage pattern. Female guardian education also remained significantly positively related to Component 4. Among behavioural variables, only the frequency of eating meals as a family and total daily screen time were independent predictors of adherence to Component 4: each family meal was associated with a decrease in Component 4 scores while screen time was positively related to Component 4. Lastly, BMI z score became negatively associated with component score of Component 4 (Table A18).

Table A18. Linear regression models assessing factors related to component scores Component 4 pattern (n=1356).

	Unstd		**Std β β**	**Sig.**	**95% CI β**	
	β	**SE**			**Lower**	**Upper**
(Constant)	1.03	0.24		.000	0.57	1.49
Sex (Male)	-0.04	0.06	-0.02	.487	-0.15	0.07
Age (years)	-0.03	0.01	**-0.11**	**.001**	-0.05	-0.01
BMI z-score	-0.08	0.03	**-0.09**	**.002**	-0.14	-0.03
Racial Background (white)	0.14	0.06	**0.06**	**.022**	0.02	0.25
Female Guardian Education Level	-0.12	0.04	**-0.08**	**.002**	-0.19	-0.04
Eating Out/Ordering In (weekly)	-0.02	0.01	-0.04	.199	-0.04	0.01
Meals with the family (weekly)	-0.02	0.00	**-0.10**	**.000**	-0.02	-0.01
Meals in front of the TV (weekly)	-0.01	0.01	-0.05	.110	-0.02	0.00
Screen Time (hrs/day)	0.05	0.02	**0.10**	**.001**	0.02	0.08
Model R2=0.04 p <0.001						

Component 5

From univariate analysis, it was evident that age was inversely related to Component 5 and males, older youth and those from lower income families were more likely to adhere to this pattern of flavoured milk and sports drinks.

Table A19. Univariate analyses between Component 5 and sociodemographic and behavioural factors.

	Unstd β	**SE (β)**	**R^2**	**Adj R^2**	**Sig**
Age	-0.03	0.01	0.01	0.01	**.001**
Sex (Male)	0.12	0.05	0.00	0.00	**.029**
BMI z score	0.03	0.03	0.00	0.00	.205
Ethnicity (White)	0.06	0.06	0.00	0.00	.280
Household Income Level	-0.05	0.02	0.00	0.00	**.038**
Female Caregiver Education	-0.04	0.04	0.00	0.00	.239
Male Caregiver Education	-0.03	0.03	0.00	0.00	.327
Multiple Residences	-0.06	0.08	0.00	0.00	.452
Eating in Front of TV (weekly)	0.00	0.00	0.00	0.00	.320
Family Meals (weekly)	0.00	0.00	0.00	0.00	.787
Eating Out/Ordering in (weekly)	-0.01	0.01	0.00	0.00	.627
Physical Activity (hrs/wk)	0.01	0.01	0.00	0.00	.122
Screen Time (hrs/day)	0.01	0.01	0.00	0.00	.337

The final multivariate model (Model R^2=0.01; p <0.001) revealed that age, sex and household income level remained significantly associated with Component 5 component scores (Table A20). Youth who consumed this pattern of SSB (flavoured milk and sports drinks) were generally males, younger individuals, and from lower income households.

Table A20. Linear regression models assessing factors related to component scores Component 5 pattern (n=1340).

	Unstd		**Std β**	**Sig.**	**95% CI β**	
	β	**SE**			**Lower**	**Upper**
(Constant)	0.29	0.19		.124	-0.08	0.65
Sex (Male)	0.12	0.06	**0.06**	**.035**	0.01	0.22
Age (years)	-0.03	0.01	**-0.09**	**.002**	-0.04	-0.01
BMI z-score	-0.01	0.03	-0.01	.672	-0.07	0.04
Annual household income level	-0.05	0.02	**-0.06**	**.036**	-0.09	0.00
Model R^2=0.01; p <0.001						

Section 5. Secondary Objectives Sensitivity Analysis Supplementary

Table A21. Correlation Matrix of beverage groups.

	Fruit juice 100%	Unsweetened	Sugar-Sweetened	Milk and Alternatives
Fruit juice 100%	1.000	-.012	.307	.082
Unsweetened	-.012	1.000	-.031	.134
Sugar-Sweetened	.307	-.031	1.000	.060
Milk and Alternatives	.082	.134	.060	1.000

Grouped Component 1 had high factor loading values for beverages including pre-grouped SSB and fruit juice, similar to Component 1 in the original analysis. Grouped Component 2 was characterized by high loadings on milk, milk alternatives and other unsweetened beverages (Table A22). Grouped Component 2 differed than the original PCA as the original analysis of 15 beverages individually resulted in separate unique patterns for milks (i.e. Component 2 and 3) and diet soft drinks/rice milk (Component 4). Additionally, flavored milks and sports drinks did not load on the same component with fruit-flavoured drinks, fruit juice and other SSB in the original analysis Thus, forcing these beverages into a pre-defined SSB group resulted in slightly different Component 1 and Grouped Component 1 patterns.

Table A22. Rotated component matrix of the 2-component solution from PCA. Bolded factor loadings indicate important beverages for that pattern. Factor loadings <0.1 were supressed. (n=1425)

	Component	
	1	**2**
Fruit juice 100%	**.796**	.052
Unsweetened (water, diet soda, vegetable juice)	-.144	**.775**
Sugar-Sweetened	**.799**	-.017
Milk and Alternatives	.181	**.729**

In summary, using pre-defined groups of beverages limited the number of possible correlations amongst beverages, resulting in a 2-component solution of SSB and unsweetened beverages rather than five identified in the ungrouped analysis. Furthermore, grouping the beverages prior to PCA resulted in greater variance in beverage intake explained compared to the original ungrouped analysis. The first pattern was similar to Component 1 and Component 5 (flavoured milks, sports drinks) using individual beverages while the Grouped Component 2 included beverages that were unrelated in the original analysis. Given these differences in the resulting patterns and variance explained, it is evident that pattern analysis is sensitive to decisions made by the researcher and grouping items prior to conducting dietary pattern analysis.

Table A23. Components, eigenvalues and respective variance explained (%) by the 2-component solution.

Component	Eigenvalue	% of Variance	Cumulative %
1	1.34	33.43	33.43
2	1.12	28.10	61.53

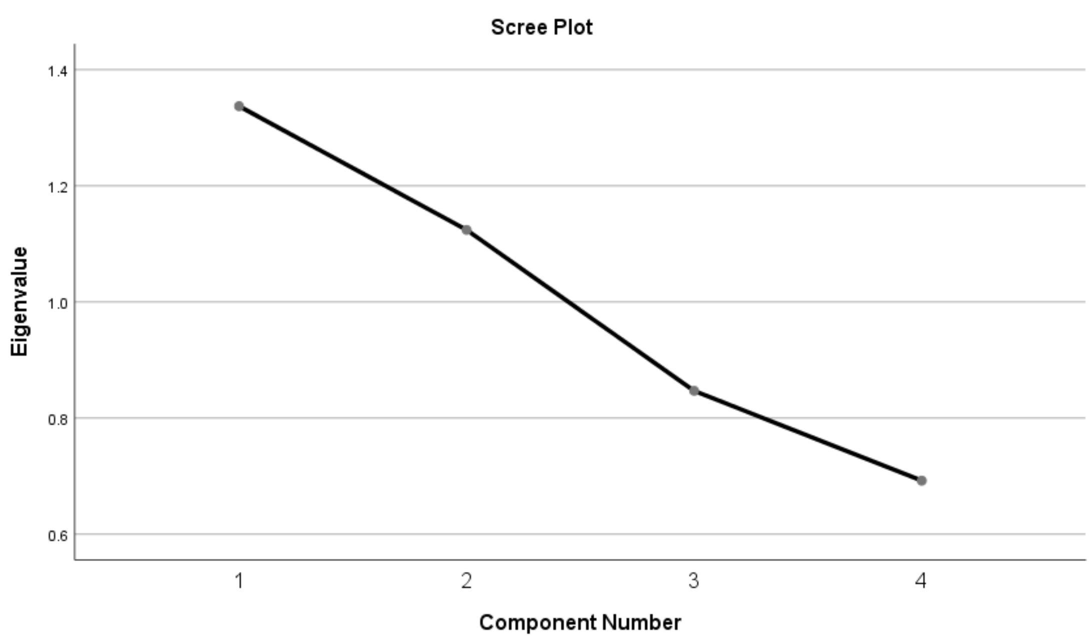

Fig. A3. Scree plot of PCA results for grouped beverages. Only Component 1 and 2 had eigenvalues > 1.0.

Table A24. Component scores for second grouped PCA.

	Mean	SD	Range		Median	IQR	
			Min	Max		Lower	Upper
Grouped Component 1	0.00	1.00	-1.05	11.37	-0.29	-0.05	0.05
Grouped Component 2	0.00	1.00	-2.09	3.23	0.06	-0.05	0.05

Grouped Component 1 (all SSB)

Grouped Component 1 explained 33% of variance in beverage intake and was similar to Component 1 (soft drinks, energy drinks, fruit juice, fruit flavoured drinks) and Component 5 combined (flavoured milks, sports drinks). Therefore, it was of interest to compare resulting relationships with sociodemographic and behavioural factors between the two patterns (univariate model not shown).

Table A25. Univariate analyses with sociodemographic and behavioural variables for Grouped Component 1.

	Unstd β	**SE (β)**	**R^2**	**Adj R^2**	**Sig**
Age	.008	.008	.001	.000	.327
Sex (Male)	.154	.053	.006	.005	**.004**
BMI z score	.091	.025	.009	.009	**.000**
Ethnicity (White)	.051	.057	.001	.000	.376
Household Income Level	.018	.017	-.107	.022	**.000**
Female Caregiver Education	-.224	.037	.026	.025	**.000**
Male Caregiver Education	-.178	.032	.023	.022	**.000**
Multiple Residences	-.060	.084	.000	.000	.475
Eating in Front of TV (weekly)	.025	.004	.024	.023	**.000**
Family Meals (weekly)	.001	.004	.000	-.001	.829
Eating Out/Ordering in (weekly)	.063	.013	.016	.016	**0.00**
Physical Activity (hrs/wk)	-.014	.007	.004	.003	**.027**
Screen Time (hrs/day)	.054	.013	.012	.011	**.000**

In the final model (R^2=0.08 $p<0.001$), sex (males) remained a significant predictor of Grouped Component 1 (Table 26) which was also predictive of Component 1 and 5. Male and female guardian education levels were inversely associated with Grouped Component 1 similar to Component 1 in the original analysis. Consuming more meals in front of the TV or eating out/ordering in during the week predicted a greater adherence to Grouped Component 1. These relationships were similar to those identified in the original ungrouped analysis for Component 1. Unlike the original Component 1, screen time was no longer associated with Grouped Component 1 after adjustment for covariates and younger age was not predictive of Grouped Component 1.

Table A26. Linear regression models assessing factors related to component scores for Grouped Component 1 (n=1082).

	Unstandardized Coefficients		**Stdβ**	**Sig.**	**95.0% CI β**	
	β	**SE**			**Lower**	**Upper**
(Constant)	0.41	0.29		.156	-0.16	0.96
Sex (Male)	0.15	0.06	**0.07**	**.016**	0.03	0.26
Age	0.00	0.01	0.01	.834	-0.02	0.02
BMI z score	0.05	0.03	0.05	.122	-0.01	0.11
Household Income Level	-0.03	0.03	-0.03	.284	-0.08	0.02
Education Level (Female Caregiver)	-0.16	0.05	**-0.11**	**.001**	-0.25	-0.06
Education Level (Male caregiver)	-0.11	0.04	**-0.09**	**.004**	-0.19	-0.04
Eating Out/Ordering In (weekly)	0.03	0.02	**0.07**	**.025**	0.00	0.06
Eating in Front of TV (weekly)	0.02	0.01	**0.12**	**.000**	0.01	0.03
Physical Activity (hrs/wk)	0.00	0.01	0.00	.943	-0.02	0.01
Screen Time (hrs/day)	0.03	0.02	0.06	.079	0.00	0.06
R^2=0.08 p<0.001						

Grouped Component 2 (unsweetened beverages, milks)

The second component scores explained 28% of beverage intake and consisted of water, diet soft drinks, vegetable juice, all milks and milk alternatives. This pattern differed from any previously identified component in analyses using individual beverages and thus was not directly compared to any component previously identified. Univariate analyses (Table A27) demonstrated that males, older children and all eating habits were positively related to Component 2 scores (univariate model not shown).

Table A27. Univariate analyses with sociodemographic and behavioural variables for Grouped Component 2.

	Unstd β	**SE (β)**	**R^2**	**Adj R^2**	**Sig**
Sex (Male)	.222	.053	.012	.012	**.000**
Age	.019	.008	.004	.004	**.014**
BMI z score	.037	.025	.002	.001	.137
Racial Background (White)	.026	.057	.000	-.001	.652
Household Income Level	-.008	.022	.000	-.001	.732
Female Caregiver Education	.005	.037	.000	-.001	.897
Male Caregiver Education	.035	.033	.001	.000	.302
Multiple Residences	.014	.084	.000	-.001	.867
Eating in Front of TV (weekly)	.034	.004	.048	.047	**.000**
Family Meals (weekly)	.042	.004	.078	.077	**.000**
Eating Out/Ordering In (weekly)	.077	.013	.024	.024	**.000**
Physical Activity (hrs/wk)	.004	.007	.000	-.001	.582
Screen Time (hrs/day)	-.012	.013	.001	.000	.369

In the multivariate model, males, older children and youth more strongly adhered to the Grouped Component 2 unsweetened beverage pattern. All eating habits remained positively related to unsweetened beverage intake in Grouped Component 2. BMI z-score was not significantly related to Grouped Component 2 score (Table A28).

Table A28. Linear regression model assessing factors related to component scores for Grouped Component 2 (n=1399).

	Unstd		**Stdβ**	**Sig.**	**95.0% CI β**	
	β	**SE**			**Lower**	**Upper**
(Constant)	-1.27	0.16		**.000**	-1.58	-0.97
Sex (Male)	0.19	0.05	**0.10**	**.000**	0.09	0.28
Age	0.03	0.01	**0.12**	**.000**	0.02	0.05
BMI z score	0.04	0.02	0.04	.092	-0.01	0.09
Eating Out/Ordering In (weekly)	0.04	0.01	**0.08**	**.003**	0.01	0.06
Family Meals (weekly)	0.04	0.00	**0.26**	**.000**	0.03	0.05
Eating in Front of TV (weekly)	0.03	0.00	**0.18**	**.000**	0.02	0.04
R^2 = 0.14 p<0.001						

To summarize, grouping the beverages prior to PCA nearly doubled the variance in beverage intake that was explained (28% vs 61%) and produced two beverage patterns. Although the two patterns offered an interpretable solution to PCA, using pre-defined groups did not allow for the different combinations of beverages seen in the first PCA using individual beverages. The sweet pattern (Grouped Component 1) was inclusive of all sweet beverages, and did not separate SSB into two separate patterns. While pre-defined groupings of foods and beverages used for beverage intake are important to use when a large number of items are collected by diet recall or FFQ or for simplicity (Movassagh et al. 2017), grouping the relatively small number of items (15 beverages) created only four groups to identify patterns for.

<u>Section 6. Secondary Objectives #2 Supplementary</u>

Grouped PCA and Metabolic Health Outcomes

Table A29. Univariate analyses between Component 1-5 (Comp 1-5) and Grouped Component 1-2 (Grped Comp 1-2) and lipid metabolic outcomes.

	Total Cholesterol (mmol/L)				**Non-HDL**				**HDL (mmol/L)**				**LDL (mmol/L)**				**Triglycerides (mmol/L)**			
	Unstd β	**SE (β)**	**R^2**	**Sig**	**Unstd β**	**SE (β)**	**R^2**	**Sig**	**Unstd β**	**SE (β)**	**R^2**	**Sig**	**Unstd β**	**SE (β)**	**R^2**	**Sig**	**Unstd β**	**SE (β)**	**R^2**	**Sig**
Age	.007	.008	.001	.387	.021	.008	0.006	**.009**	-.014	.003	.024	**0.000**	.006	.007	.001	.391	.041	.007	.029	**.000**
Sex	.045	.051	.001	.385	.028	.052	.000	.590	.019	.018	.001	.280	.047	.045	.001	.297	-.035	.046	.001	.441
BMI z score	-.061	.024	.005	**.012**	-.034	.024	.002	.163	-.027	.008	.009	**.001**	-.052	.021	.005	**.013**	.024	.022	.001	.265
Comp 1	-.019	.024	.001	.426	.006	.024	.000	.807	-.025	.008	.008	**0.002**	-.019	.021	.001	0.372	.038	.022	.003	.080
Comp 2	.003	.026	.000	.896	-.004	.026	.000	.894	.007	.009	.001	.422	.007	.023	.000	.753	.003	.023	.000	.889
Comp 3	-.006	.026	.000	.804	.001	.026	.000	.978	-.007	.009	.001	.434	-.004	.023	.000	.854	.013	.024	.000	.568
Comp4	-.008	.026	.000	.744	.015	.026	.000	.574	-.023	.009	.006	**.010**	-.006	.023	.000	.807	.036	.023	.002	.116
Comp5	0	.026	.000	0.997	.014	.026	.000	.595	-.014	.009	.002	.136	.005	.023	.000	.819	.016	.024	.000	.497
Grped Comp1	-.006	.025	.000	.820	.026	.025	.001	.298	-.032	.009	.012	**.000**	-.001	.022	.000	.953	.041	.023	.003	.072
Grped Comp 2	-.026	.026	.001	.319	-.028	.026	.001	.270	.003	.009	.000	.734	-.020	.023	.001	.384	-.034	.023	.002	.141

Table A30. Univariate analyses between Component 1-5 (Comp 1-5) and Grouped Component 1-2 (Grped Comp 1-2) and glycemia and liver metabolic outcomes.

	Fasting Plasma Glucose (mmol/L)				**HBa1c (%)**				**AST (U/L)**				**ALT (U/L)**			
	Unsated β	SE (β)	R^2	Sig	Unsated β	SE (β)	R^2	Sig	Unsated β	SE (β)	R^2	Sig	Unsated β	SE (β)	R^2	Sig
Age	.042	.008	.025	**.000**	.020	.006	.011	**.001**	-.168	.162	.001	.301	1.164	.256	.018	**.000**
Sex	.009	.052	.000	.862	-.002	.041	.000	.955	2.169	1.058	.004	**.041**	6.863	1.690	.015	**.000**
BMI z - score	.038	.024	.002	**.112**	.014	.019	.001	.462	2.134	.485	.018	**.000**	5.296	.775	.040	**.000**
Comp 1	.044	.024	.003	.074	.012	.018	.000	.510	.561	.482	.001	.245	1.933	.792	.005	**.015**
Comp 2	-.014	.026	.000	.600	-.049	.021	.006	**.019**	-1.040	.538	.004	**.053**	-1.030	.864	.001	.233
Comp 3	.005	.026	.000	.859	.045	.020	.006	**.024**	-.099	.527	.000	.850	.830	.854	.001	.331
Comp4	-.004	.026	.000	.885	.082	.019	.020	**.000**	-.332	.528	.000	.529	-1.127	.848	.002	.184
Comp5	.000	.027	.000	.986	-.019	.020	.001	.323	.393	.525	.001	.454	-.137	.861	.000	.874
Grped Comp1	.045	.025	.003	.074	.011	.019	.000	.566	1.013	.505	.004	**.045**	1.742	.825	.004	**.035**
Grped Comp 2	-.002	.026	.000	.931	.011	.020	.000	.596	.520	.531	.001	.327	1.846	.849	.004	**.030**

Compared to initial results of metabolic health outcomes among Component 1 to 5, original analysis identified that only a pattern correlating rice milk and diet soft drinks together (Component 4) was also negatively related to HDL. No other relationships between health outcomes and Grouped Component 1/2 remained significant after adjusting for age and sex. Once again, there are multiple factors that can influence these metabolic health outcomes.

Table A31. Multivariate model of Grouped Component 1 and HDL at baseline (n=1144).

	Unstd		**Stdβ**	**Sig.**	**95.0% CI β**	
	β	**SE**			**Lower**	**Upper**
(Constant)	1.448	.059		.000	1.332	1.564
Child's sex (Male)	.018	.019	.033	.326	-.018	.055
Age (years)	-.018	.003	**-.204**	**.000**	-.023	-.012
BMI z-score	-.028	.009	**-.110**	**.001**	-.045	-.011
Grouped Component 1	-.022	.009	**-.084**	**.012**	-.039	-.005
R^2 = 0.06 p<0.001						

Section 7. Food Frequency Questionnaires

Pilot FFQ Pg. 1

Participant ID: ☐☐☐ (Centre #) ☐☐☐☐ (Participant#) **Initials** ☐☐☐ (F M L)

Now some questions about this child's consumption of milk and other dairy products. Remember, think about all the foods they eat and drink, both meals and snacks, at home and away from home.

23. HOW OFTEN DOES YOUR CHILD USUALLY EAT THE FOLLOWING FOODS?

a) MILK AND DAIRY PRODUCTS	< 1Month/Never	Monthly	Weekly	Daily	*record # of times.* → # Times
Milk:					
ii) 3.25% (whole or homo)	☐	☐	☐	☐	☐☐
iii) 2%	☐	☐	☐	☐	☐☐
iv) 1%	☐	☐	☐	☐	☐☐
v) 0.5%	☐	☐	☐	☐	☐☐
vi) Skim or Non-Fat (including powdered milk)	☐	☐	☐	☐	☐☐
vii) Flavoured milk beverages (e.g chocolate milk or Oh Henry!)	☐	☐	☐	☐	☐☐
viii) Rice (enriched)	☐	☐	☐	☐	☐☐
ix) Soya (enriched)	☐	☐	☐	☐	☐☐
Dairy Products:					
x) Cottage Cheese	☐	☐	☐	☐	☐☐
xi) Yogurt (excluding frozen yogurt)	☐	☐	☐	☐	☐☐
xii) Ice cream, frozen yogurt	☐	☐	☐	☐	☐☐
xiii) Hard cheese (cheddar, marble, gouda)	☐	☐	☐	☐	☐☐

Now, a few questions about fruits and vegetables. Remember, think about all the foods this child eats, both meals and snacks, at home and away from home.

b) FRUITS AND VEGETABLES	< 1Month/Never	Monthly	Weekly	Daily	*record # of times.* → # Times
i) Fruit (fresh, frozen or canned)	☐	☐	☐	☐	☐☐
ii) Tomatoes or tomato sauce (exclude ketchup)	☐	☐	☐	☐	☐☐
iii) Lettuce or green leafy salad	☐	☐	☐	☐	☐☐
ix) Spinach, mustard greens or collards (exclude kale)	☐	☐	☐	☐	☐☐
x) All other types of vegetables (not mentioned above)	☐	☐	☐	☐	☐☐

(choose one: < 1Month/Never, Monthly, Weekly, Daily)

Pilot FFQ Pg. 2

Participant ID: ☐☐☐ *Centre #* ☐☐☐☐ *Participant#* **Initials** ☐☐☐ *F M L*

Next, some questions about this child's drink consumption. Think about all the things they drink, both at home and away from home.

c) BEVERAGES	< 1Month/Never	Monthly	Weekly	Daily	*record # of times.* → # Times
	choose one				
i) Regular soft drinks	☐	☐	☐	☐	☐☐
ii) Diet soft drinks	☐	☐	☐	☐	☐☐
iii) Sports drinks (Gatorade, Powerade)	☐	☐	☐	☐	☐☐
iv) Energy Drinks (Red Bull, Rage, XS etc)	☐	☐	☐	☐	☐☐

The next two questions are about the different kinds of juices or fruit flavoured drinks this child usually drinks. When we say fruit juice, we mean 100% pure fruit juices such as apple, orange or grapefruit, whether or not they are made from concentrate. When we say fruit flavoured drinks, we mean drinks such as Sunny Delight, fruit punch, or Kool-Aid.

	< 1Month/Never	Monthly	Weekly	Daily	# Times
v) Fruit juice (100 %)	☐	☐	☐	☐	☐☐
vi) Fruit flavoured drinks (Kool-Aid, Punch)	☐	☐	☐	☐	☐☐
vii) Vegetable juice	☐	☐	☐	☐	☐☐
viii) Water	☐	☐	☐	☐	☐☐

d) OTHER	< 1Month/Never	Monthly	Weekly	Daily	*record # of times.* → # Times
	choose one				
i.) Eating out or ordering in meals	☐	☐	☐	☐	☐☐
ii.) Have meals with the family	☐	☐	☐	☐	☐☐
iii.) Meals in front of the T.V	☐	☐	☐	☐	☐☐
iv.) How often does the child eat breakfast?	☐	☐	☐	☐	☐☐

Main Study FFQ Pg. 1

Participant ID: ☐☐☐ *Centre #* ☐☐☐☐ *Participant#*

Initials ☐☐☐ *F M L*

26. HOW OFTEN DOES YOUR CHILD USUALLY EAT THE FOLLOWING FOODS?
(both meals and snacks, at home and away from home)

a) MILK AND DAIRY PRODUCTS

Milk:	Avg Serving	Never, less than once/month	1-3/mo	1/wk	2-4/wk	5-6/wk	1/day	2-3/day	4-5/day	>6/day
ii) 3.25% (whole or homo)	1 cup/250ml	☐	☐	☐	☐	☐	☐	☐	☐	☐
iii) 2%	1 cup/250ml	☐	☐	☐	☐	☐	☐	☐	☐	☐
iv) 1%	1 cup/250ml	☐	☐	☐	☐	☐	☐	☐	☐	☐
vi) Skim or Non-Fat (including powdered milk)	1 cup/250ml	☐	☐	☐	☐	☐	☐	☐	☐	☐
vii) Flavoured milk (e.g chocolate milk)	1 cup/250ml	☐	☐	☐	☐	☐	☐	☐	☐	☐
viii) Rice (enriched)	1 cup/250ml	☐	☐	☐	☐	☐	☐	☐	☐	☐
ix) Soya (enriched)	1 cup/250ml	☐	☐	☐	☐	☐	☐	☐	☐	☐
Dairy Products:										
x) Cottage Cheese	1/2 cup/125ml	☐	☐	☐	☐	☐	☐	☐	☐	☐
xi) Yogurt (excl. frozen yogurt)	1 cup/250ml	☐	☐	☐	☐	☐	☐	☐	☐	☐
xii) Ice cream, frozen yogurt	1 cup/250ml	☐	☐	☐	☐	☐	☐	☐	☐	☐
xiii) Hard cheese (cheddar, marble, gouda)	1 slice/21g	☐	☐	☐	☐	☐	☐	☐	☐	☐

b) FRUITS AND VEGETABLES

i) Fruit (fresh, frozen or canned)	1 medium	☐	☐	☐	☐	☐	☐	☐	☐	☐
ii) Lettuce or green leafy salad	1/2 cup/125ml	☐	☐	☐	☐	☐	☐	☐	☐	☐
iii) Spinach, mustard greens or collards (excl. kale)	1/2 cup/125ml	☐	☐	☐	☐	☐	☐	☐	☐	☐
iv) All other types of vegetables (not mentioned above)	1/2 cup/125ml	☐	☐	☐	☐	☐	☐	☐	☐	☐

Main Study FFQ Pg. 2

Participant ID: ☐☐☐ ☐☐☐☐ **Initials** ☐☐☐

Centre # *Participant#* *F M L*

c) BEVERAGES

	Avg Serving	Never, less than once/month	1-3/mo	1/wk	2-4/wk	5-6/wk	1/day	2-3/day	4-5/day	>6/day
i) Regular soft drinks	1 cup/250ml	☐	☐	☐	☐	☐	☐	☐	☐	☐
ii) Diet soft drinks	1 cup/250ml	☐	☐	☐	☐	☐	☐	☐	☐	☐
iii) Sports drinks (Gatorade, Powerade)	1 cup/250ml	☐	☐	☐	☐	☐	☐	☐	☐	☐
iv) Energy Drinks (Red Bull, Rage, XS etc)	1 cup/250ml	☐	☐	☐	☐	☐	☐	☐	☐	☐
v) Fruit juice (100 %)	1 cup/250ml	☐	☐	☐	☐	☐	☐	☐	☐	☐
vi) Fruit flavoured drinks (Kool-Aid, Punch)	1 cup/250ml	☐	☐	☐	☐	☐	☐	☐	☐	☐
vii) Vegetable juice	1 cup/250ml	☐	☐	☐	☐	☐	☐	☐	☐	☐
viii) Water	1 cup/250ml	☐	☐	☐	☐	☐	☐	☐	☐	☐

d) OTHER

i.) Eating out or ordering in meals	☐	☐	☐	☐	☐	☐	☐	☐	
ii.) Have meals with the family	☐	☐	☐	☐	☐	☐	☐	☐	
iii.) Meals in front of the T.V	☐	☐	☐	☐	☐	☐	☐	☐	
iv.) How often does the child eat breakfast?	☐	☐	☐	☐	☐	☐			

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