Mount Saint Vincent University
Department of Applied Human Nutrition

Effect of Sugars in Solution on Subjective Appetite and Short-term Food Intake Regulation in Normal Weight 9- to 14-year-old Boys

by
Marissa Van Engelen

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Approved:

Dr. Nick Bellissimo, PhD
Thesis Supervisor
Assistant Professor of Nutrition
Ryerson University

Dr. Misty Rossiter, PhD, PDt
Assistant Professor of Applied Human Nutrition
Mount Saint Vincent University

Dr. Michelle Eskritt, PhD
Associate Professor of Psychology
Mount Saint Vincent University

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ABSTRACT

To examine the hypothesis that the physiologic regulation of short-term food intake (FI) in boys is affected by sugars source, the following study was conducted. The objective was to describe the effect of consuming 200 kcal of glucose, high-fructose corn syrup-55 (HFCS-55) and sucrose 60 min before a pizza meal on subjective appetite and short-term FI regulation compared to a Sucralose® control. On four separate mornings, fifteen normal weight (NW) boys received in random order one of the four equally sweetened sugars solutions 2 h after consuming a standardized breakfast. Food intake at an ad libitum pizza meal was measured 60 min after each treatment. Subjective appetite was measured at 15 min time intervals until the test lunch and immediately after. Only glucose resulted in a statistically significant decrease in FI (975 kcal ± 58) compared to the Sucralose® control solution ($P<0.01$). Mean FI after sucrose and HFCS-55 were not statistically different. Caloric compensation, a measure of FI regulation, after the glucose, sucrose and HFCS-55 solutions were scored 76%, 26% and 26%, respectively, but did not differ ($P=0.07$). Average appetite (AA) was higher after the HFCS-55 solution compared to glucose ($P<0.05$). Change from baseline AA scores following sucrose were significantly higher compared to the other three treatments ($P<0.01$), which suggest that hunger returned more quickly after sucrose. The energy content of the preloads, expressed as per kcal/kg body weight (BW), inversely associated with FI after sucrose and HFCS-55 ($P<0.05$), but not after glucose ($P=0.09$), suggesting dose was less of a factor after glucose compared to after sucrose and HFCS-55. Fat-mass (FM) positively correlating with FI after the control, sucrose and HFCS-55 solutions ($P<0.05$) suggests body composition is also a factor of FI regulation. In summary, only glucose suppressed FI at a test meal 60 min later, as a result of greater physiological effects on FI compared to isovolumetric and isocaloric solutions of sucrose and HFCS-55. In conclusion, the short-term regulation of FI in NW 9- to 14-year-old boys was affected by sugars source, treatment dose and body composition.

In Loving Memory of

Adrian Van Engelen

FOREVER IN OUR HEARTS

1953 – 2012

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LIST OF ABBREVIATIONS

A

ANOVA	Analysis of Variance
AA	Average Appetite

B

BG	Blood glucose
BIA	Bioelectrical Impedance Analysis
BMI	Body Mass Index
BW	Body Weight

C

CCHS	Canadian Community Health Survey
CCK	Cholecystokinin
CNS	Central Nervous System

D

DEBQ	Dutch Eating Behaviour Questionnaire
DTE	Desire to Eat
DXA	Dual X-ray Absorptiometry

F

FFM	Fat-free Mass
FI	Food Intake
FM	Fat Mass

G

GIP	Glucose-dependent Insulinotropic Polypeptide
GLP-1	Glucagon-like Peptide-1

H

H	Hour(s)
HFCS	High Fructose Corn Syrup

M

Min	Minute

N

NW	Normal Weight

O

OB	Obese
OW	Overweight

P

PFC	Prospective Food Consumption

S

SEM	Standard Error of Mean
SSB	Sugar-sweetened Beverage

U

USA	United States
USDA	United States Department of Agriculture

V

VAS	Visual Analogue Scale

Chapter 1

INTRODUCTION

1.1. *General Introduction*

Obesity among children and adolescents is a rapidly growing public health concern with the majority of obese (OB) children becoming OB adults (1). In Canada, the prevalence of overweight (OW) and obesity has increased over the past few decades. Between 1978/1979 and 2004, the combined prevalence of OW and obesity doubled among Canadian youth aged 6- to 17-years-old (2). Obesity is associated with an increased risk of chronic disease, as well as psychological and social consequences (3), which add to the health care burden of an unhealthy population. Developing appropriate obesity prevention strategies is of high priority to mitigate the consequences of obesity in childhood and adolescence.

The consumption of sugars in beverages has been blamed for the childhood obesity epidemic as a positive association between sugar-sweetened beverage consumption (SSB) and BW has been noted (4-6). It has been hypothesized that sugars bypass regulatory mechanisms of FI (7), therefore leading to overeating (8) and, subsequently, the development of OW and obesity (5, 9). However, this hypothesis is not supported by known mechanisms of physiological food intake regulation (10). Furthermore, little experimental evidence exists investigating the role of sugars in solution in regulating appetite and FI. There are only a handful of short-term studies published looking at the effect of sugars source on FI in adults (11-13), and there is currently no data available comparing the effect of the main sugars used in sweetened beverages among children. Furthermore, in comparison to glucose and sucrose, few studies have investigated the effect of HFCS on appetite and FI. This research is necessary to contribute to how physiological factors influence the regulation of FI and energy balance. Therefore, the primary objective of this research was to investigate the effect of 200 kcal of sucrose, HFCS-55 and glucose in 250 mL of

water at a test meal 60 min later on subjective appetite and short-term FI compared to a Sucralose® control in 9- to 14-year-old boys.

Chapter 2

LITERATURE REVIEW

2.1. Introduction

The literature review is comprised of five sections. The first section provides an introduction to the prevalence, causes and consequences of childhood obesity. In the second section, sugars intake as a factor of obesity is discussed, including discussion of epidemiology. In the third section, the effect of macronutrients on FI control, including a brief overview of methods to assess FI regulation, is discussed. The fourth section provides an overview of the physiological and hormonal determinants of FI regulation in adults. In the last section, test methods used in studies of intake control are described.

2.2. Childhood Obesity

Obesity is the consequence of an energy imbalance in which energy intake exceeds energy expenditure, resulting in body fat and BW gain. Obesity is associated with many health consequences, including cardiovascular disease, diabetes and hypertension (14). The prevalence of childhood OW and obesity in Canada has more than doubled from 14% to 29% over the past two decades (2), with the majority of OB children becoming OB adults (1) and contributing to the health care burden of an unhealthy population (15).

2.2.1. Diagnosis

Body mass index (BMI), calculated as weight in kilograms divided by height in meters squared, has been used to assess weight status in adults since the 1960's; however, it has only been used more recently as a diagnostic tool in children and adolescents (16, 17). Experimental studies comparing measurements of BMI to dual x-ray absorptiometry (DXA) have found that BMI positively associates with body fatness in children and adolescents (18, 19).

The Centers for Disease Control and Prevention (CDC) developed age- and sex-dependent BMI growth charts to monitor childhood and adolescent weight status in the United

States (USA) (20). A child is within the normal weight range when their BMI is between the 5th and 85th percentile for age and gender. To avoid "labeling" a child as OB, the CDC uses "at risk of OW" and "OW" to define a child above the normal range. A child is at risk of OW when their BMI is greater than the 85th percentile but below the 95th and is OW when their BMI is greater than the 95th percentile (20). While Canada uses the same charts as the USA, the terminology differs. In Canada, OW is defined as a BMI between the 85th and 95th percentile while obesity is greater than the 95th percentile (21).

2.2.2. Prevalence

According to data from the 2004 Canadian Community Health Survey (CCHS), 26% of Canadian children and adolescents aged 2- to 17-years were OW or OB, compared to 15% in 1978/1979 (2). Although increases in OW and obesity are similar among boys and girls in Canada, the percentage of OW and OB 2- to 5-year-olds in Canada remained virtually unchanged, whereas the percentage of OW and OB adolescents aged 12- to 17-years increased from 14% in 1978/1979 to 29% in 2004 (2).

2.2.3. Consequences

In 2006, 4.1% - an estimated $6 billion - of the total health care expenditures was associated with obesity in Canada (15). The economic cost of obesity will continue to rise and comprise a large percentage of Canadian health care spending unless solutions to the obesity epidemic are explored and implemented. If the prevalence of OW and obesity in Canada does not subside, it is anticipated that health care spending will increase to over $8 billion in upcoming years (15).

The consequences of childhood and adolescent obesity include type 2 diabetes, hypertension, elevated blood pressure, insulin resistance, and dyslipidemia. Psychological and

social consequences of obesity usually precede the physical consequences in children (22). Obese children often experience loneliness, nervousness and decreased self-esteem (23). In comparison to NW children, OB children report lower ratings of self worth and experience feelings of rejection more often (24). Furthermore, OB children are more likely to participate in unhealthy risk taking behaviours such as smoking and alcohol consumption (23).

2.2.4. Causes

The etiology of obesity is complex and can be attributed to environmental, social, physiological and biological/genetic factors. Several factors have been hypothesized to contribute to childhood obesity, including inherited factors (25-28), decreased physical activity (29), increased portion sizes (30-32), increased screen time (33), increased consumption of fast food (34), increased availability of added sugars in the USA and increased consumption of SSB (5).

Studies on monozygotic twins provide evidence for a genetic basis of obesity. In studying pairs of twins, both reared together and apart, Stunkard and colleagues (35) concluded that genetic influences on BMI are substantial. The intrapair correlation for monozygotic twins reared apart was 0.70 for males and 0.66 for females. A previous study found similar results, with concordance rates for different degrees of OW twice as high for monozygotic twins as for dizygotic twins (36). Similarly, a study by Bouchard and colleagues (28) found that monozygotic twins overfed by 10% had similar tendencies towards increased adiposity. These findings provide evidence for genetic influences that are present independent of environmental factors. However, since evidence for the role of inherited factors in the development and maintenance of obesity is limited, other factors, specifically those of environmental nature, have been the overwhelming focus.

Physical inactivity is likely to contribute to a positive energy balance in children and adolescents and is associated with obesity and metabolic disease (37-39). According to the Canadian Health Measures Survey (CHMS), only 7% of children and adolescents are meeting the daily recommendation for 60 min of moderate/vigorous physical activity at least six days a week (40). Data from the CCHS shows physical activity levels were significantly associated with OW and obesity in children and adolescents aged 12 to 17 years. For example, sedentary boys were more likely to be OB than active boys (16% versus 9%, respectively) (2), suggesting an inverse relationship between higher levels of physical activity and bodyweight. In reviewing the evidence of physical activity on health, Strong and colleagues (41) concluded that cross-sectional and longitudinal studies suggest that youth of both sexes who participate in moderately high levels physical activity have less adiposity than non-active youth.

The rise in childhood and adolescent obesity has been paralleled by an increase in the portion size of many foods (42). In examining the effect of portion size on a single meal, adults consumed 30% more energy when offered the largest portion of the test meal compared to the smallest portion (30). Similarly, Fisher and colleagues (31) found that 4 year-olds consumed 25% more when they were served a meal that was twice the size of an age-appropriate entrée. Interestingly, FI in 3 year-olds seems to be unaffected by portion size (32), suggesting that very young children are able to self-regulate their intake by responding to physiologic cues of hunger. This evidence suggests that physiologic cues of hunger are lost or overridden by environmental cues as we age.

A positive relationship between SSB consumption and obesity has been reported in the literature. According to data from the US Department of Agriculture (USDA), per capita consumption of soft drinks has increased by almost 500% in the past 50 years (43). Data from

observational studies indicate a positive relationship between SSB consumption, including soft drinks and juice, and weight gain (4-6). For example, a study by Ludwig and colleagues (5) found that for each additional SSB consumed, BMI and frequency of obesity increased in a group of 11 and 12 year-olds. However, observational studies do not demonstrate cause and effect and, as a result, the relationship between intake of SSB and weight status cannot be confirmed.

Consumption of food eaten away from home (i.e. fast food) has also increased over the past few decades (34, 44). Fast foods are universally available and heavily marketed to children and adolescents (45), with an estimated 75% of adolescents eating fast food one or more times per week (46). Observational data from a study by Gillis and colleagues (34) suggests that OB children and adolescents consume significantly more fast food compared to non-OB kids. A more recent study by Ebbeling and colleagues (47) found that OW adolescents consumed more total energy on days when they consumed fast food, but lean subjects consumed virtually the same whether or not they consumed fast food. These findings suggest low compensation to fat in childhood obesity.

Although the above evidence suggests a variety of environmental factors contribute to obesity, it is not clear whether environmental factors simply override physiological mechanisms of FI, or if the physiological mechanisms are compromised first. Further experimental research is required to understand of how the environmental, social, behavioural, and physiological factors may affect FI regulation in children and adolescents.

2.3. Sugars Intake and Obesity

"Sugars" is the term used to describe mono- and disaccharides commonly used to improve the palatability and sweetness of foods and beverages (48). It can also refer to "sugars

and syrups that are added to foods during processing or preparation," which is the definition used by The US Department of Agriculture (USDA) (48). While the term monosaccharide includes glucose, galactose and fructose, disaccharide includes sucrose, lactose and maltose (48, 49).

In contrast to popular belief, sugars consumption in Canada has not increased over the past few decades but rather is stable or has been modestly declining (50-52). Misinformation about sugars consumption is often linked to complications arising from estimation, which include lack of a comprehensive database of added sugars content in food and difficulty guessing waste adjustment to estimate consumption from availability (52).

It is important to identify the determinants of childhood obesity in order to develop targeted prevention and treatment approaches. Nicklas and colleagues (53) suggest that studying changes in eating patterns might help explain the marked increase in obesity among children and adolescents. On the intake side of the energy balance equation, total intake consumed is clearly paramount, but there is current interest in the effect of macronutrient composition on FI. In recent years, consumption of sugars in beverages has received considerable attention due to the hypothesis that they lead disproportionately to the development of obesity (8). Since children's diets tend to be higher in sugar than adults (54), and since parents often associate sugars with obesity (54), investigating trends in sugars availability and consumption is essential.

Although average daily sugar consumption differs with age, data from the 2004 CCHS indicates that, on average, 21% of daily energy intake for Canadians comes from sugar (55). While sugar consumption was lowest among women aged 71 or older, it was highest among teenage boys aged 14- to 18-years (55). Although this average estimate is higher than other reports (50, 52), data from the CCHS does not distinguish between sugars that are naturally occurring, such as those found in fruits, and sugars that are added, such as those commonly

added to manufacture SSB (55, 56). According to estimated intakes derived from USA disappearance data, average intakes of added sugars – which includes sugars from refined sugar, maple syrup, HFCS, honey and dextrose – in Canada have remained relatively stable (63.3 g/person in 1994 in comparison to 63.5 g/person in 2005) and account for approximately 13% of daily calories (50, 51). Statistics Canada data for apparent consumption of sugars and syrups indicates a slow decline over the past four decades, with estimated consumption decreasing from 76 g/day in 1970 to 51 g/day in 2010 (52, 57, 58).

The replacement of sucrose with HFCS in the food supply occurred concurrently with increases in the prevalence of childhood and adolescent obesity (8). Thus, it has been suggested that added sugars, specifically HFCS, play a causal role in weight gain (8, 59, 60). Data from the USDA shows an increase in the availability of HFCS since its introduction, increasing from 0.8 to 91.6 grams/person/day between 1970 and 2000 (43). High-fructose corn syrup was introduced in the USA food supply in the 1970's to replace sucrose (61) and is now the principal sweetener of soft drinks in the USA (13). Made by processing cornstarch to yield glucose, and then processing the glucose to produce a high percentage of fructose (8), HFCS as a replacement of sucrose was quickly accepted by the food and beverage industry due to its stability in acidic mediums (62, 63). Furthermore, HFCS is less expensive and requires little dilution before use (63). Available in two main forms, HFCS-42 and HFCS-55, HFCS is a liquid mixture of fructose and glucose (42% fructose and 58% glucose, and 55% fructose and 45% glucose, respectively). Although HFCS-42 was the principle component, HFCS-55 became the principle source in the early 1980's (8) and is the form used in soft drinks (62). HFCS-42, as percentage of total HFCS availability, decreased from 100% in 1970 to 38.8% in 2000 (43). This shift from HFCS-42 to HFCS-55 is an important factor in the SSB-obesity hypothesis.

It has been hypothesized that HFCS is a contributing factor of obesity (8). Although causal evidence is lacking, this assumption became widely accepted dogma in the public. In order to make sense of the HFCS-obesity hypothesis, inherent assumptions need to be discussed. For example, one assumption has been that HFCS and sucrose are physiologically unique, which means that their composition differs. Although its name is somewhat deceiving, HFCS, compared to sucrose, has a similar ratio of fructose and glucose. The original intent of including high-fructose in the name was to help distinguish it from common corn syrup (63). Another consideration is the relative sweetness of HFCS. A common misconception is that HFCS is sweeter than sucrose (63), and it has been suggested, since humans have a preference for sweet foods (64), that this increased sweetness leads to overeating. However, similar scores have been given for the relative subjective sweetness of sucrose and HFCS-55 (100 and 97, respectively) (65). A previous study by White & Parke (66) yielded similar results; HFCS-42 on the other hand is less sweet than sucrose, with a value of ~90 (66). National consumption patterns of HFCS are not predictive of obesity (63). When obesity rates were compared to HFCS as a percentage of national caloric sweetener use in five countries, further evidence against the HFCS-obesity hypothesis was established. The countries with the highest percentage use of HFCS were South Korea, Japan and Canada, while the highest obesity rates were in Argentina and Mexico (63). Further exploration of the relationship between added sugars, specifically HFCS, and the etiology of obesity is warranted as a causal relationship remains to be established.

Although the sugars and syrups category does not include corn sweeteners, The Canadian Sugar Institute suggests that data on soft drinks, which are principally sweetened with HFCS in the USA, can provide an indirect estimate of HFCS availability and trends (52). Although historical soft drink data in Canada has been quite variable, data from the 2011 Canadian Food

Statistics (57) report indicates a decline in soft drink availability in Canada over the past decade (3.9% energy available from soft drinks in 1995 compared to 3.0% in 2008). Although soft drink consumption in the USA is approximately double that of Canada, the trend in the USA is very similar (67, 68). Furthermore, regardless of the declining trend in availability of soft drinks, carbonated soft drinks continue to constitute the largest beverage category, both in volume and per capita consumption, in both Canada and the USA (69, 70).

Intake of added sugars in Canada are considerably below levels in the USA (71) as sugar availability in the USA increased by 30% between 1971 and 1997 (72). From 1970 to 2005, food disappearance data, which is the food available for consumption, from the USDA have shown a 20% and 100% increase in the availability of all caloric sweeteners and HFCS, respectively (69).

The consumption of sugars as a sole contributor to the increased prevalence of childhood and adolescent obesity is unclear. First, although both Canada and the USA have experienced similar increases in the incidence of childhood and adolescent obesity (2, 73), sugars availability and consumption in Canada has slightly declined (52), while the USA has experienced an increase (69, 72). Secondly, although availability of added sugars in the USA has increased, it has not increased disproportionately to other components in the food supply. A proportional increase in per capita availability of other foods occurred concurrently with the increased availability of sugars. For example, fats and oils increased by 47%, poultry by 84% and dairy products, such as milk, by 423% (70). Furthermore, overall energy also increased alongside sugar availability (15%) (70). Lastly, food consumption data are often estimated from disappearance data, which is reported on the basis of per capita for potential consumption and not on what is actually eaten (57, 67). Although a waste adjustment factor of approximately 30%

is usually applied to disappearance data (52), more recent work estimates food waste to be approximately 40% (58).

Much of the evidence assessing the relationship between sugars and obesity is complex and relies heavily on epidemiological research (5, 6, 74-77), which is limited by the fact that cause and effect cannot be determined. Since children and adolescents are believed to be the principal consumers of soft drinks, many studies have investigated the relationship between consumption of SSB in relation to obesity. SSB, which includes fruit juice and carbonated soft drinks, have been described as a potential source of high-energy, low-nutrient-dense beverages that could be a contributing factor in the increased prevalence of obesity, specifically among children and adolescents (78). Evidence resulting from epidemiological studies is now discussed.

Consumption of SSB among children and adolescents has changed in the last few decades. Secular trends from the Bogalusa Heart Study (79), a long-term epidemiologic study of cardiovascular risk factors from childhood to adulthood, revealed that the percentage of children consuming SSB significantly decreased from 1973/1974 to 1994/1994. Furthermore, this decrease was a result of a significant decrease in soft drink and sugar-sweetened coffee consumption. Data from this study do not support a linear relationship between total energy intake and SSB consumption despite overall increases in BMI during this decade (79). A similar study by Newby and colleagues (80) among a group of preschool children made comparable conclusions: there was no association between consumption of SSB and weight change or BMI.

Epidemiological studies finding a positive relationship between SSB consumption and weight status are often limited by their magnitude of effect, or effect size, having only weak effects on BW. For example, although studies by Collison and colleagues (6) and Berkey and colleagues (81) found that BMI and weight gain, respectively, positively correlated with SSB

consumption, this was specific to boys only. Similarly, Welsh and colleagues (4) determined that weight status only significantly related to SSB consumption for subjects who were at risk of becoming OW or those already OW at baseline.

As evidence is conflicting, the Canada-US Dietary Reference Intake report (48), published by the US Institute of Medicine, concluded that the relationship between BMI and increased sugars availability and consumption is inconsistent and therefore unclear. Plotting the trends of sugars consumption and obesity in Canada against one another supports this inverse relationship (52). Data from other countries, including Australia and the UK (82), show similar relationships between added sugars and obesity (52). The highly interrelated nature of dietary exposures makes assessing epidemiology difficult. Since key dietary components are consumed within their food matrix, overall patterns of consumption may have a greater cumulative impact on obesity than any single food or nutrient (53). Since epidemiological associations do not establish cause and effect, experimental studies assessing mechanisms of physiological control of FI in children and adolescents are required to define the relationship between sugars consumption and risk of obesity in children and adolescents.

2.4. Food Intake Regulation

Although there is extensive research of FI regulation in adults, very few studies have investigated the regulation of FI in the pediatric age range. Regulation of FI can be investigated by measuring caloric compensation, which is a term used to explain the reduction of energy intake at a test meal following a caloric preload compared to a non-caloric control. Studies demonstrate that young children compensate for energy in preloads by suppressing FI at a subsequent meal (83-85). For example, a study investigating FI regulation in preschoolers found that children aged 3- to 5-years-old compensated for calories from caloric sweeteners and fat

compared to a non-caloric control (83). In comparison, a study among a group of 9- to 10-year-olds found that the children did not compensate for calories in a sucrose preload compared to an aspartame control (86). Although this may suggest that there are developmental differences in responsiveness to energy density (87), a study among 4- to 6-year old children, 18- to 26-year-old adults and 61- to 86-year-old seniors found no differences in caloric compensation at a test meal provided 90 min after yogurt preloads varying in energy and macronutrient content (88).

Consumption of food produces a short-term suppressive effect on appetite sensations and subsequent FI (89) and contributes to energy regulation and homeostasis (90). Food intake during a test meal is dependent on a variety of factors, including dose, macronutrient composition of the preload, and the time interval between the preload and subsequent FI (91-93). Palatability and sweetness of the preload and test meal can also affect FI, suggesting that energy content cannot be solely used to predict energy intake during a test meal (91). Identifying key factors influencing increased FI, and therefore the increased prevalence of childhood and adolescent obesity, is important as the disease is associated with adverse health outcomes (14). Some of the factors affecting short-term FI are now described.

2.4.1. Macronutrients and Short-term Food Intake

Macronutrient composition is a more important determinant of FI regulation (94) than form (95, 96). Furthermore, evidence suggests that carbohydrate, protein, and fat vary in the extent to which they affect FI (97-99). A hierarchal effect of the macronutrients on subjective appetite and FI has been reported, in that protein is more satiating than carbohydrate, which is more satiating than fat (100, 101). Although little research exists investigating the effect of macronutrient composition on FI in children, the evidence available suggests that young children better compensate for calories in a snack or preload in comparison to adults (102).

2.4.1.1. Carbohydrate-induced Suppression of Short-term Food Intake

Carbohydrates are the main source of energy for humans; on average, between 50 to 70% of total daily energy intake comes from carbohydrates (103). An understanding of the mechanisms and action of carbohydrates on appetite and FI is important to define their role in relation to energy balance (91). The effect of sugars on FI in adults has received considerable investigation, with sucrose and its components, glucose and fructose, receiving the most attention (49). Studies reveal that these sugars decrease appetite and FI at subsequent meals (11, 104-108).

There is a large body of evidence examining the relationship between sugars consumption, appetite and FI in adults. Studies have found varying results, which may be a result of the source, composition, and time to next meal in relation with measures of satiety. Anderson and colleagues (11) tested the hypothesis that short-term appetite and FI responses to carbohydrate consumption is inversely related to the effect of carbohydrates on blood glucose (BG). When given a 75g glucose or sucrose preload, young men significantly lowered their FI at a subsequent test meal in comparison to the control (11, 105). Similarly, young men significantly suppressed FI after consuming a 50g glucose preload (105).

In children, the association between sugars and FI has received little investigation. Contrary to the hypothesis that sugars bypass regulatory mechanisms, a study by Birch and colleagues (104) found that 2- to 5-year-olds show excellent compensation for calories in sugars-containing preloads. The young children compensated for both the sucrose and aspartame + low glucose maltodextrin preloads during a 20 min snack period at 30 and 60 min post-preload; FI after these two preloads was significantly lower than FI after aspartame and the water control (104). Birch and colleagues hypothesized that the compensation observed in this group of young children was likely because

they had limited experience with external signals and therefore had a better reliance on internal cues of hunger. In contrast, Anderson and colleagues (86) revealed that sucrose failed to suppress FI in a group of 9- and 10-year-old children 90 min after preload consumption. Although this could be a result of dose, sensory-specific satiety, age or time to next meal, conflicting results in literature emphasize the need for further investigation regarding the role of various sugars on FI and appetite, especially in older children. Furthermore, it is important to consider that many of the studies in this area of literature are out-dated. Identifying the effect of sugars consumption on FI in older children and adolescents is important because of the crucial period of development these individuals are experiencing (109), where various environmental and physiological factors interact to modify FI regulation and behaviour.

Fructose differs in its methods of absorption and digestion in comparison to the other sugars and has a greater effect on subsequent FI (110). A potential reason for this is the rate of gastric emptying. In comparison with glucose, fructose is absorbed slower and therefore has a longer contact time with gastrointestinal receptors which initiate satiety signals (111). Food intake at a subsequent meal is suppressed to an even greater extent after a fructose-containing solution (106-108). For example, a study comparing the effect of various sugars solutions on FI found that the subsequent FI was suppressed to a greater extent following the fructose preload in comparison to following glucose, aspartame and water (106).

Unlike glucose and sucrose, pure fructose is less commonly used as a sweetener in high concentrations because even small amounts have been associated with gastrointestinal upset and malabsorption. A study assessing intestinal fructose absorption using measurements of breath hydrogen found that 71% of children experienced fructose malabsorption; breath hydrogen increased by over 10 ppm over basal values (112). A similar study measuring sequential breath-

hydrogen noted that more than half of subjects (58%) did not completely absorb fructose; furthermore, half of these reported abdominal discomfort, which is also commonly associated with high concentrations of pure fructose (113, 114).

In comparison to the other sugars, few studies have examined the effect of HFCS on short-term FI. Although it has been hypothesized that the replacement of sucrose with HFCS has contributed to the increased prevalence of obesity, the effects from short-term studies show HFCS suppresses subsequent FI in adults (12, 13, 115). For example, a study comparing the effects of HFCS and sucrose in comparison to milk and a diet-drink found that FI 50 min following HFCS did not significantly differ from FI following an isoenergetic preload of sucrose or milk (13). Similarly, in comparison of various glucose to fructose ratios, a similar study found that a HFCS-containing solution led to a caloric compensation score of 63%, which did not differ significantly from the other sugars solutions (i.e. glucose and sucrose) (12). Furthermore, studies comparing HFCS- and sucrose-containing preloads suggest that the two sugars are also similar in their effect on metabolic responses such as insulin, BG and ghrelin (12, 13, 115, 116). These results challenge the hypothesis that the introduction of HFCS is a causative factor of disproportionate FI and therefore the increased prevalence of OW and obesity. Furthermore, it still remains to be determined how HFCS-containing solutions affect FI regulation in children and adolescents, who are thought to be the principal consumers of SSB.

2.4.1.2. Fat-induced Suppression of Short-term Food Intake

The hierarchal effect of the macronutrients on FI, as found in various studies, proposes that fat is the least satiating macronutrient. However, studies assessing the effect of fat on subsequent FI suggest a role for dietary fat in satiation and satiety (83, 117, 118). The effect of fat consumption is important because establishing dietary fat recommendations for children has

raised controversy. Although it is well established that over nutrition and obesity are major concerns among children around the world today, maintaining positive energy balance during childhood is also important for normal growth and development (87).

Only a handful of studies have examined the role of fat in short-term FI among children and similar compensation for energy density differences was found (83, 117, 118), suggesting that children can accurately compensate for calories in fat-containing preloads. For example, a study exploring the responsiveness of young children to varying fat compositions in foods by manipulating the fat content of yogurt matched for protein and carbohydrate content, found evidence of caloric compensation for subjects who were both 33 and 48 months old (83).

Although evidence suggests younger children can precisely compensate for fat-containing preloads, studies assessing the effect of fat in young adults show little compensation. For example, one study made a direct comparison of the short-term effects of isoenergetic preloads, containing either sucrose or safflower oil, on subjective appetite and FI in young males (119). A significant suppression of FI was only found after the sucrose preload; the safflower preload did not significantly reduce subsequent FI at the test meal. Similarly, sucrose, but not safflower oil, caused a significant decrease in subjective appetite and subsequent FI in comparison to the control (119). Similarly, a study comparing the effects of carbohydrate and fat consumption found that a carbohydrate supplement, but not a fat supplement, suppressed appetite and FI at a subsequent test meal (120). The supplementary carbohydrate was derived from sucrose, maltodextrin and glucose, whereas the fat supplement consisted of margarine and dairy cream; both supplements were added to the standard preload to alter the macronutrient composition (120). Further studies are needed to elucidate the effect of fat on subjective appetite and

subsequent FI in both children and adults because much of variability in the energy content of foods is due to difference in fat content.

2.4.1.3. Protein-induced Suppression of Short-term Food Intake

Evidence suggests that dietary protein suppresses short-term FI at a subsequent meal in adults (121-123). However, very little research has investigated the role of dietary protein on appetite and FI in children. A study investigating the effects of a meals varying in macronutrient composition on satiety demonstrated that a meal high in protein (46g protein, 13g carbohydrate, 18g fat) suppressed subsequent FI in a group of NW preschool children more than a meal high in carbohydrate (12g protein, 67g carbohydrate, 9g fat) (94). The authors conclude that a meal high in protein might be beneficial for preschool children who are OW or OB since the high protein meal was more satiating (94).

Although few studies have assessed the role of protein on short-term satiety in children, some assumptions can be made based on the results of adult studies. In particular, it can be assumed that protein consumption would suppress FI during a test meal and decrease sensations of hunger in children. A handful of studies have demonstrated that dietary protein is more satiating than carbohydrate and fat in adults (97, 121, 123-125). In addition, many short-term studies investigating the role of protein on satiety and satiation in adults have reported that FI at a later meal was suppressed following protein consumption (121-123). For example, a study by Booth and colleagues (122) fed adults a meal either high (40 g) or low (6 g) in protein and measured subsequent FI at a test meal 2 or 3 h later. When fed the protein rich lunch, adults consumed fewer calories at the test meal in comparison to their intake after the low protein lunch (122). Similarly, a more recent study found that consumption of a high-energy protein-enriched

beverage reduced subsequent food consumption and hunger in a group of male subjects between the ages of 18 and 34 years more than the beverage low in protein (125).

2.4.2. Sweetness and Short-term Food Intake

Humans have a preference for sweet foods (64), which suggests that FI is influenced by sweetness (126). Sweetness is a sensation generated when sugar, or another sweetener, interacts with chemoreceptors on the tongue, resulting in a pleasure response. The role of sweetness on FI regulation is unclear. Results from studies assessing a relationship between sweetness and short-term FI are conflicting and, at present, there is no agreement on whether sweetness stimulates or suppresses FI.

Evidence suggests that there is a positive relationship between sweetness and FI. A study among university staff and students found that a low-energy, artificially sweetened solution made with aspartame and acesulfame-K increased energy intake at a test meal in comparison to water, suggesting a stimulatory effect of sweetness on appetite and FI (127). This short-term action on FI has been previously demonstrated using yogurt sweetened with saccharin (128) and preloads sweetened with saccharin (105), aspartame (105, 129) or acesulfame-K (105) as the carrying agent for sweetness. Aspartame, acesulfame-K, and saccharin are three non-caloric and non-nutritive sweeteners commonly used as a sugar substitute (105).

In contrast to the above, there is also evidence to suggest a suppressive effect of sweetness (9, 104, 119). For example, a study comparing pure sucrose and safflower oil found the effects of solutions containing 25 g and 50 g sucrose was not different from the non-caloric sweetened control, but was different from the water control. Food intake following water was approximately 518 kJ higher (119). Furthermore, a study comparing the effects of sucrose and maltose, a disaccharide made from two glucose units, conclude that the satiating effect of

sweetness is not only found in the absence of energy. When given a lemon-flavoured preload, sucrose solutions increased fullness and decreased prospective food consumption more than maltose, which is less sweet (130). Because this evidence challenges previous findings (127), it remains to be determined which factor plays a larger role in FI regulation: the hedonic value of sugars or the physiologic features (i.e. sweetness) of sugars and artificial sweeteners.

2.4.3. Food Variety in a Meal and Short-term Food Intake

Food variety in a meal is associated with increased FI in adults (131-133). For example, subjects fed a four-course meal consisting of a variety of foods ate 44% more than subjects consuming the same one food on four separate occasions (131). Similarly, when comparing FI following a meal with a food variety to FI following one without, it was concluded that subjects consumed one third more when offered sandwiches with four different fillings than when offered one type of sandwich (133). However, if the sensory qualities of the foods offered are too similar, increased FI may not occur. For example, subjects offered three types of yogurt similar in colour and texture did not eat significantly more than subjects offered only one type (134). This suggests that food variety, in part, is dependent on varying as many sensory characteristics possible within the meal.

There is no evidence to suggest that variety in a meal will increase FI among children. A study assessing the effect of food variety on FI found that, when given food choices, 33- to 47-month-old children accomplished caloric compensation in test meals following a preload by consistently consuming their most favoured foods and reducing their intake of non-preferred foods (118). This finding suggests that FI at a given meal is affected by foods previously consumed; whether children will eat more with increased food variety maintains to be determined.

2.4.5. Time to Next Meal and Short-term Food Intake

Time to the next meal, in addition to composition, is an important determinant of FI (86, 99, 135, 136), as varying results from preload studies have been suggested to be a result of different time intervals between the preload and test meal (137). Studies assessing FI following various preloads have found compensation by adults when the subsequent meal was 20 to 80 min later (12, 13, 119, 138, 139). A study investigating the subjective determinants of FI in adults found that time to next meal alone only accounted for a small variance (2%) in meal size (140); yet, when considered together with subjective sensations of hunger and prior stomach content, the three factors accounted for almost 30% of meal size (140).

Although less research has been done in children, studies demonstrate children compensate for energy in preloads when time to next meal is between 20 to 90 min (83, 84, 86, 104). For example, one study revealed that 9- to 10-year-olds were able to compensate for a sugar preload at a test meal 30 min, but not 90 min, after consumption (86). Similarly, a study by Bellissimo and colleagues (136) concluded that the effect of carbohydrate and protein on FI was dependent on time to the next meal. In NW 9- to 14 year-old boys, the effect of glucose decreased compensation, while the effect of whey protein increased compensation, between 30 and 60 min, respectively, suggesting that physiological mechanisms involving these two macronutrients are different.

2.5. Physiological Control of Food Intake

Food intake is controlled by a redundant system, which involves distinct and overlapping interactions between short- and long-term physiological mechanisms and the central nervous system (CNS) (141). Regulators of satiety, which act in the shorter term, transmit information to the CNS shortly after food is ingested (141). Satiety-induced signals are initiated by mechanical

or chemical stimulation of the stomach or small intestine and neural input related to energy metabolism in the liver (142), as well as humoral signals released upon nutrient stimulation of secretory cells lining the intestinal lumen (143). Although these hormones alone may not have a long-term effect on FI (144), these signals interact with the adiposity signals leptin and insulin, which are long-term regulators of FI control (145), and which are secreted in proportion to the amount of adipose tissue of the individual (90). Despite short-term discrepancies in energy balance, humans have an innate ability to match cumulative energy intake to energy expenditure over a longer period of time; this phenomenon, termed energy homeostasis (90), is controlled by an intricate interaction of neural centers involving the hypothalamus, brainstem and cortex (141).

2.5.1. Long-term Regulators of Food Intake and Energy Balance

Insulin was the first hormonal signal thought to be involved in the control of energy homeostasis and BW via the CNS (90). Once secreted from the pancreatic beta cells, insulin, a pancreatic hormone, enters the brain from the circulation (146) and acts there as an anorexigenic signal to regulate FI (147). Insulin is an adiposity signal and long-term regulator of energy homeostasis (90) and is circulated at levels proportional to body fat (148) so that plasma insulin increases in times of positive energy balance and decreases during the opposite (149). Woods and colleagues first proposed that insulin was a long-term regulator of FI, adiposity and energy balance in the 1970's (149). Since that time, evidence has surfaced in support of this hypothesis (145, 150, 151). For example, studies have shown that with an absence of elevated glucose, basal insulin is in direct proportion to adiposity (148, 151). Furthermore, insulin transport into the central nervous system (CNS) occurs over a long period of time after circulating concentrations of insulin increase, thus coinciding with a role in the long-term maintenance of adiposity rather than a short-term satiety signal (152). Evidence supporting insulin's effect to decrease FI

includes Woods and colleagues (147) finding that continuous infusion of insulin over a 20 day period into free-feeding baboons induced a sustained suppression of FI. A similar reduction of FI in rats has also been noted (153-155). In humans, ingestion of food elicits insulin secretion from the pancreatic beta cells (152, 156). To inhibit FI, insulin interacts with CCK and several other hypothalamic neuropeptides also involved in the regulation of feeding behaviour (90, 157). There is also evidence to suggest that insulin works in the brain to decrease FI in humans (152).

Leptin, which is secreted from adipocytes in direct proportion to the amount of stored fat within one's body (158-160), is transported across the blood-brain barrier where it binds to specific receptors on appetite-modulating neurons (161). Like insulin, levels of plasma leptin ('ob protein'), which is secreted from adipose tissues, varies proportionately with changes in adiposity (162) but has a greater biological impact when levels are decreasing than when circulating concentrations are increased (152). For example, although administration of leptin to humans who are not leptin-deficient only leads to modest weight loss (163, 164), small doses administered to subjects with a leptin deficiency reduced hyperphagia and resulted in decreased weight from body fat (165). Additionally, Keim and colleagues (166) demonstrated that increased sensations of hunger in women on a 12 week energy deficit correlated with reduction of plasma leptin levels; the greatest increase in hunger corresponded with the largest percentage decline in circulating leptin. These observations, together with the hypothesis that most OB individuals are resistant to the regulatory effect of leptin (167), support the proposition that leptin is a physiological regulator of hunger and FI. More recently, an important interaction between leptin and CCK has been demonstrated. A study by McMinn and colleagues (168) supports a model whereby signals involved in long-term regulation influence FI via an interaction with short-term regulators and satiety signals.

Although the mechanisms by which macronutrient consumption regulates FI are not fully understood, it appears that they are interrelated. Evidence suggests that the interaction between short- and long-term systems is essential for the control of FI and consequential continuing management of energy homeostasis.

2.5.2. Short-term Regulators of Food Intake and Energy Balance

A variety of hormones and signals have been identified as playing an independent or combined role in FI regulation. Despite short-term fluctuations in energy balance, humans have the ability to maintain a relatively stable BW (90, 169). This phenomenon, termed homeostasis, is controlled by an intricate interaction between short- and long-term regulatory mechanisms of FI (169). Both the long-term action of insulin and leptin, which indicate sufficient energy stores, and the short-term action of meal-related signals, such as those coordinated by glucagon-like peptide-1 and cholecystokinin, are important to discuss (169).

2.5.2.1. Glucagon-like Peptide-1

Glucagon-like peptide-1 (GLP-1), a derivative of the larger molecule proglucagon (170), has been well established as a regulator of FI in humans (171-176) and is considered to have a major role in the postprandial release of insulin. A study investigating the physiological role of GLP-1 in man concluded that this peptide meets the criteria necessary to be termed an incretin hormone (177). An "incretin effect" occurs when oral glucose elicits a greater insulin response than an infusion of intravenous glucose, even when the same dose is given (178). Following carbohydrate ingestion, GLP-1 is released from the endocrine cells in the intestinal mucosa and enhances postprandial insulin release (177). Furthermore, when men were infused with GLP-1, glucose and glucagon levels fell while insulin levels rose significantly (177). Studies assessing

the physiological activity of GLP-1 following carbohydrate ingestion have also found evidence suggesting this peptide plays a role in the regulation of gastric emptying (179).

2.5.2.2. Glucose-dependent Insulinotropic Polypeptide

A second peptide that meets the criteria of an incretin hormone is glucose-dependent insulinotropic polypeptide (GIP), which was the first to be characterized and discovered. GIP is released from the duodenal K cells, most notably in response to fat ingestion (180). Although a few studies have shown GIP is a potent regulator of glucose-dependent insulin in animals and humans (181-183), the incretin effect is not eliminated when GIP is removed from gut extracts (184). This finding led researchers to believe that other peptides existed with incretin-like activity (184); it was not until one decade later that GLP-1 was discovered.

2.5.2.3. Cholecystokinin

One of the most studied satiety signals is cholecystokinin (CCK), which is released from the I cells found in the proximal small intestine (185) and has receptors located in both the CNS and gastrointestinal (GI) tract (186). Although involved in several important activities, including pancreatic enzyme secretion (185), CCK is most known for its ability to increase feelings of satiety and suppress subsequent FI in animals (187-189) and humans (190-192). Following the ingestion of food, CCK is released and elicits several effects on the GI system, including gastric emptying, regulation of gut motility and gull bladder contraction (169, 193), as well as satiety regulation and the secretion of pancreatic enzymes (185).

2.5.3. Carbohydrate-induced Satiety

The presence of carbohydrate in the gastrointestinal tract plays an important role in FI regulation. Of key importance is the interaction between gastrointestinal receptors and carbohydrates. For example, in rabbits, intraduodenal infusion of glucose reduced FI, whereas

infusions of the same amounts of glucose into the hepatic portal circulation had no effect (194). In addition, a study in adult males found that BG concentrations were the same after an intraduodenal administration and intravenous infusion of glucose (195). These studies suggest that the presence of glucose in the gastrointestinal tract is the primary signal affecting FI, and not the rise in glucose per se (196). As discussed above, carbohydrates are the main energy source for most populations; quantitatively the most important macronutrient, it is easy to speculate that carbohydrates play a central role in energy metabolism and homeostasis (103).

More than five decades ago, Jean Mayer proposed that FI is regulated by glucoreceptors that are sensitive to changes in BG (197). According to this phenomenon, widely known as the glucostatic theory, an increase in BG concentrations results in increased feelings of satiety (197, 198) and, sequentially, a decrease in FI (199). Conversely, a decrease in BG concentrations would decrease feelings of satiety and increase FI (198, 199). Carbohydrate-induced satiety is mediated through a multiplicity of potential mechanisms, including changes in BG concentration and the interaction with hormones, including GLP-1, GIP and CCK. Ingestion of carbohydrate increases the concentration of BG, therefore stimulating the release of some of these gastrointestinal hormones (91); these mechanisms of short-term regulation interact with those signals of the longer-term satiety (insulin and leptin) to maintain energy homeostasis (145).

2.5.3.1. Blood Glucose as a Potential Mechanism of Carbohydrate-induced Satiety

Blood glucose is maintained at a relatively stable concentration in humans through the efforts of various hormones that establish glucose homeostasis. A key component of this regulation is detection of ambient glucose levels by the alpha and beta cells of the pancreatic islets and the resulting secretion of one of these hormones (156). For example, when BG levels are diminished, glucagon is secreted and stimulates glucose release from the liver. In contrast,

insulin helps lower BG levels by inducing glucose storage and uptake. Glucostats within the brain are also continually monitoring BG levels. These neurons are located in the satiety center of the brain (basal hypothalamus) and maintain tonic inhibitory control over neurons in the feeding center (lateral hypothalamus). When BG levels are low, signals are centrally transmitted to the brain and the satiety center no longer inhibits neurons in the feeding center, thus causing an increase in hunger and initiation of FI (156).

Jean Mayer first introduced the idea that appetite and FI relates to BG (199). According to the glucostatic theory, there is an inverse relationship between BG and FI (199) and this relationship has been found in studying the effect of macronutrients on appetite and FI (12, 200). For example, in assessment of various sugars solutions on FI and satiety hormones, it was concluded that suppression of FI after a 75 g sucrose or glucose solution was inversely related to the effect of the same solution on BG (12). Although it has been suggested BG contributes directly to satiety (49, 59), conflicting results suggest that it works in combination with other mechanisms to control energy intake (12, 91).

2.5.3.2. Incretin Hormones as a Potential Mechanism of Carbohydrate-induced Satiety

A variety of hormones have been identified in the exploration of mechanisms affecting appetite and FI regulation after carbohydrate ingestion. The incretin hormones, GLP-1 and GIP, have received considerable attention, however, although these gastrointestinal peptide hormones may inhibit appetite and FI (152), their physiological role in FI regulation has yet to be definitively established.

Previous studies have shown that GLP-1 is a physiological regulator of appetite and FI (173-176, 196) as it stimulates insulin secretion in the presence of elevated BG levels (156). For example, a study examining the effect of GLP-1 on subjective appetite and FI concluded that

peripherally administered GLP-1 significantly influences appetite sensation and reduces FI in healthy subjects (176). During the test meal, almost 80% of subjects consumed considerably less food during GLP-1 infusion in comparison to the saline control (176). A similar study found that concentrations of GLP-1, which were above baseline at 30 min, continued to rise while appetite decreased (196). However, a more recent study found evidence that argues against a major role for GLP-1 in the regulation of appetite (201). In determining the effects of oral fructose on GLP-1 secretion and appetite, Kong et al. found that 75 g of glucose and fructose have comparable effects on appetite and FI. However, GLP-1 concentrations were greater after ingestion of glucose in comparison to fructose. Specifically, at 30 min, plasma GLP-1 was 28.6 ± 3.6 pmol/l after glucose only and 17.6 ± 1.8 pmol/l after fructose-only ($P<0.0001$) (201). The observation that glucose is a more potent stimulant of GLP-1 (and insulin) argues against a major role of GLP-1 in the regulation of appetite. Conflicting results question the strength of the role GLP-1 plays in the stimulation of satiation by carbohydrate.

Although it has been established that approximately 50% of the insulin release after an oral glucose load is mediated by the incretin hormones (202), the relative role of GIP is uncertain. In a study assessing the relationship between plasma insulin, GLP-1 and GIP and the control of short-term satiety, Lavin and colleagues (196) showed that GIP and GLP-1 concentrations increased with infusion of intraduodenal glucose, but not intraduodenal saline. While GIP concentrations increased rapidly, GLP-1 concentrations responded more slowly and were associated with an increase in insulin and decrease in FI. Although this data supports the role of incretin hormones as a mechanism of FI regulation, the evidence is stronger for GLP-1 as the temporal relationship was much closer between the suppression of FI by intraduodenal glucose and the release of GLP-1 than by the release of GIP (196).

2.5.4. Fat-induced Satiety

Little is known about the role of fat in the mechanisms underlying satiety and satiation in humans. Evidence suggests that high-fat foods exert a weaker effect on satiation and satiety than do the other macronutrients (119, 203). Ingestion of fat, similar to the ingestion of protein, regulates FI by stimulating the release of CCK. In addition, it has been postulated that the oxidation of fat may have an effect on FI regulation by suppressing subsequent consumption (203). Two studies have found results to support this premise, in which the inhibition of fat oxidation by methyl palmoxirate (204) or 2-mercapto acetate (205) caused increases in FI. As it is unlikely that a single unitary association exists between the consumption of dietary fat and appetite regulation, further studies are needed to investigate the role of fat in the physiological control of FI.

2.5.5. Protein-induced Satiety

The observation of an inverse relationship between the concentration of serum amino acids and appetite, as found by Mellinkoff and colleagues in 1956, first suggested the idea that components of protein influence FI (206). This became known as the aminostatic hypothesis. However, because concentrations of plasma and brain amino acids rise relatively slow after protein consumption (207), it was later suggested that satiety signals after protein consumption begin in the gastrointestinal tract.

There are many mechanisms by which protein metabolism exerts an effect on satiety and FI, including the slowing of gastric emptying (208) and direct or indirect stimulation and increase of gut hormones, such as CCK (188, 209) and GLP-1 (210). Furthermore, studies have also found evidence suggesting that the source of the protein is another factor influencing FI regulation (211, 212). For example, a study by Hall and colleagues (212) found that FI and

subjective satiety in adult subjects was lower 90 min after a drink containing 400 kcal and 48 g of whey in comparison to a drink containing an equal amount of casein.

2.6. Measures of Satiety, Appetite and Body Composition in Children

This section outlines and describes terminology, instruments and test methods used in studies assessing satiety, FI, subjective appetite and body composition.

2.6.1. Hunger, Satiation and Satiety

Hunger, satiation and satiety are important terms to define, as they are central in the understanding of appetite and FI regulation. Hunger, a biological drive, determines what, how much and when to eat and initiates eating episodes (203). Satiation, often referred to as intra-meal satiety, is developed during the course of eating (203) and controls the amount of food consumed by bringing the meal to an end (91). Since meal ingestion usually occurs over a short period of time, satiation is likely to be controlled by factors that arise immediately during or right after eating. As satiation starts to develop, hunger declines (203). On the other hand, satiety, sometimes referred to as inter-meal satiety, is the inhibition of hunger and further eating as a result of food consumption (91, 203). The intensity of satiety can be measured by the duration of time before FI resumes or by the amount of food eaten during a subsequent meal (203).

The physiological regulation of appetite and FI is only one factor influencing how much and why we eat. Various other factors, including social and psychological determinants (213), can also have an impact on FI control, whether independently or in combination. For example, research suggests that children's eating patterns are influenced by a variety of socioeconomic and sociocultural factors (213), including parents' education (214, 215) and family values or beliefs (216, 217). Since children and adolescent's eating habits are influenced by a multitude of factors, prevention methods need to be targeted at the different levels of which these occur.

2.6.1.1. Visual Analogue Scales to Measure Subjective Appetite

The most widely used approach to measure motivation to eat or subjective appetite is by asking subjects a series of questions using visual analogue scales (VAS) (218). Hill and Blundell developed the first version of this questionnaire in 1982, which consisted of six questions addressing 1) desire to eat (DTE), 2) hunger, 3) fullness, 4) prospective food consumption, 5) urge to eat, and 6) preoccupation with thoughts about food (219). Corresponding with each question are contrasting statements, which are found at opposing ends of a 100 mm horizontal line (219). For example, the first question which asks, 'How strong is your desire to eat?' has the opposing statements "very weak" and "very strong."

There are several studies in the literature that report using VAS as a measure of appetite in both children (136, 220-222) and adults (12, 96, 219, 223, 224). However, support for VAS use as a measure of subjective appetite is a matter of debate in adults due to inconsistent findings. For example, although a study assessing predictive power reported a positive group correlation between subjective ratings of hunger and feeding behaviour in adults ($r=0.50$; $P<0.02$), there were no significant relationships between hunger ratings and energy content of eating bouts when the analysis was conducted within individuals (225). However, although this evidence suggests hunger ratings are not a good proxy for quantitative variables such as energy intake (225), a handful of studies have found evidence to support test-retest reliability of VAS hunger ratings (226-228). Furthermore, a retrospective analysis of four randomized controlled studies determined that FI is related to ratings of hunger and fullness as measured by VAS in older and younger adults (229). Specifically, FI positively related to perceptions of hunger and inversely related to perceptions of fullness (229).

The effectiveness of VAS as a measure of subjective appetite among children has also been investigated. A study using VAS to measure subjective appetite in young children following caloric and non-caloric preloads found that ratings of hunger, DTE and fullness fluctuated with time and nutritional state ($P<0.01$), whereas ratings of sweetness did not fluctuate appropriately with time (86). Similarly, a study in a group of 9- to 14-year-olds found that FI was positively associated with AA ratings measured by VAS (136). This data supports the view that children are able to complete VAS in a quantitative manner. A recent study assessing the reproducibility of subjective appetite following a glucose preload also supports the use of VAS in children (221). Although the reproducibility of baseline appetite scores in the 9- to 14-year-old boys was lower than reported in adults (221), the composite AA score and prospective food consumption was highly reproducible at 30 min. Furthermore, scores for AA, DTE, fullness and prospective food consumption did not differ between the two days when expressed as change from baseline (221).

2.6.2. Preload Design as Measure of Food Intake Regulation

In order to examine the effects of individual macronutrients on FI, preload paradigms are usually employed (91, 203). Carbohydrates, including glucose, fructose and sucrose, exert measurable effects on FI at a subsequent meal when given as a preload or in an experimental meal (14, 110, 203). A preload design allows the effect of the macronutrient to be tested over the various treatments by measuring the quantitative effect the preload has on subsequent FI (110). Preloads are usually given orally or administered directly into the stomach or small intestine if certain influences are to be excluded. A subsequent ad libitum meal is then provided to measure an effect on satiety (91). Satiety develops after food has been digested and can either delay the onset of the next meal or decrease FI (230). A preload solution or food with high satiety tends to

produce a longer period of time between eating episodes and/or decrease subsequent intake in comparison to a treatment that is reported to have lower satiety (230, 231). Foods producing only a weak effect on satiety are not expected to be effective in the maintenance of energy homeostasis and appetite (203), and may over time contribute to weight gain.

2.6.3. Measurement of Body Composition

Accurate assessment of body composition is important in many areas of obesity and nutrition-related research. Some of the more frequently used body composition techniques to estimate fat-mass (FM) or fat-free mass (FFM) in children and adolescents include measures of skinfold thickness, dual energy x-ray absorptiometry (DXA) and bioelectrical impedance analysis (BIA). These three measures of body composition are briefly discussed below.

2.6.3.1. Skinfold Thickness

Information on body composition is important for the assessment of nutritional status (232); however, measures such as underwater weighing are quite laborious (233). One inexpensive and simple measure of adiposity is the measurement of skinfold thickness, which is measured by pinching the skin of the individual and measuring the fold with a caliper at specific sites (234). The assumptions underlying the rationale of measuring skinfold thickness are that skinfold thickness is an adequate measure of subcutaneous fat and that there is a defined relationship between subcutaneous fat and total body fat (234).

Several studies have shown that measures of skinfold thickness in adults correlate with measures of body fat obtained by BIA or DXA, suggesting skinfold thickness is an accurate measure of body composition. Durnin and Rahaman (235) extended their study to include 12- to 16-year-old adolescents and found that the correlation coefficients for total skinfold thickness and body density in the boys and girls were -0.76 and -0.78, respectively ($P<0.001$). Brook (236)

further suggested that skinfold measurements are suitable for younger children because they are simple, painless and safe. Using the same regression equations of Durnin and Rahaman (235) for adolescents, Brook (236) assessed the use of these equations in the pediatric population by correlating the results of skinfold measurements in children with measurements of total body water using deuterium oxide. In conclusion of the results, Brook suggested that new equations were required to assess body density in the pediatric population. The Brook equation has since been used in various studies among 9- to 14-year-old children (136, 221, 237).

2.6.3.2. Dual Energy X-ray Absorptiometry

Dual energy x-ray absorptiometry (DXA) is a relatively new method to estimate body composition and is believed to be appropriate for children as young as 4 years old (238). Developed to measure bone mineral density, DXA allows for a more specific measurement of FM and FFM by measuring whole and segmental body fat as well as lean muscle mass (239). In assessment of the short-term (one week) reproducibility of DXA to assess body composition of young adults, Mazess and colleagues (240) concluded that total body and bone mineral density, percent fat and lean tissue mass can be determined with small precision error. The advantage of DXA as a measure of body composition is that it only requires 10 to 20 min, involves minimal radiation and gives regional values as well as total body values (240).

2.6.3.3. Bioelectrical Impedance Analysis

Bioelectrical impedance analysis (BIA) is also a relatively new method to assess body composition and measures impedance of the body to a small electric current (238). The principle of BIA is that fat free mass in the body is a better conductor of electricity than fat, which does not have large amounts of water and electrolytes (241). An individual with a greater contribution of total body water and FFM in the body will have less resistance to the flow of the electric

current in comparison to an individual with a greater contribution of FM. Although equations have been derived for obesity in the pediatric range (242), accuracy in younger individuals remains poor and measurements may be confounded by clinical status (238). However, bioelectrical resistance has been cross-validated in children against other measures such as total body water (243) and total body potassium (244). For example, in comparing FFM estimates from total body potassium and bioelectrical resistance, Schaefer and colleagues (244) demonstrated that bioelectrical resistance and age and a root mean square error of 1.98 could estimate FFM accurately ($r^2 = 0.98$).

2.6.4. Dietary Cognitive Restrained, Emotional and External Eating Behaviours

It is well established that restrained, emotional and external eating behaviours have the potential to affect FI. One tool useful in identifying the presence of these behaviours is the Dutch Eating Behaviour Questionnaire (DEBQ). First developed by Van Strien and colleagues in 1986 (245), this questionnaire contains scales for restrained, emotional and external eating. According to three theories, externality theory, psychosomatic theory, and restrained eating theory, these three factors may have an effect on FI, whether the result is an increase or decrease in overall energy intake (246-248). The externality theory is based on the concept that people differ in their sensitivity to external cues of hunger (249). Regardless of their internal state of hunger, an external eater eats in response to the cues they are most sensitive to. The psychosomatic theory, which focuses on emotional eating, suggests that emotional eaters eat in response to their emotions instead of in response to internal cues of hunger (246, 249). Lastly, the restrained eating theory emphasizes that restrained eaters are more likely to overeat than non-restrained eaters as bingeing can occur as a result of dieting (249-251). In a series of studies used to develop and assess use of the DEBQ, Van Strien et al. (245) found that the three scales have a

high internal consistency as well as a high factorial validity. Cronbach's alpha coefficients reflected adequate internal consistency for retrained (0.95), emotional (0.91) and external eating (0.80); furthermore, correlation coefficients for items within each scale were high (245).

There is sufficient evidence to support that restrained, emotional and external eating are factors affecting FI (249, 251-253). A study assessing the effect of manipulated perceptions of portion size found that subsequent FI differed based on different perceptions of portion size, even though all portions were identical (251). Subjects who believed their snack portion was larger than that given to others had differences in subsequent FI relative to the control, with the direction of effect dependent on restraint status. While non-restrained eaters consumed less at the test meal following their perception of a larger preload, restrained eaters consumed significantly more, therefore counter-regulating their FI (251). This finding is consistent with data from other studies, suggesting that restrained eaters eat a large amount when they become disinhibited (i.e. from perceiving that their preload was larger) but eat a small, reasonable amount when they are not (254-257). Furthermore, a study assessing the effect of restrained, emotional and disinhibited eating found that increased BW positively associated with restrained eating and negatively with external eating (249). Although there was no association between BW and emotional eating in girls, increased BW was negatively associated with emotional eating in boys (249).

2.7. Summary

There are many unexplored physiological variables that affect FI regulation in children, and the effect of sugars composition on energy balance and FI is unknown. Although it is hypothesized that children and adolescents consume more sugars than adults (54), there is little research investigating the role of sugars in solution in the regulation of appetite and FI in the pediatric population. Identifying the key dietary components contributing to positive energy

balances is necessary so that appropriate prevention and treatment approaches can be developed, and to dismiss anecdotal evidence of dietary components that are not contributing to the obesity epidemic. Therefore, the objective of this research was to examine the effect of various sugars solutions on appetite and FI compared to a Sucralose® control in NW 9- to 14-year-old boys.

Chapter 3

HYPOTHESIS AND OBJECTIVE

3.1 Hypothesis

Glucose will suppress FI to a greater extent than other sugars-containing solutions, with similar reductions in FI between sucrose and HFCS-55 in NW 9- to 14-year-old boys.

3.2 Objective

To describe the effect of 200 kcal of sucrose, HFCS-55 and glucose in 250 mL of water at a test meal 60 min later on subjective appetite and short-term food intake compared to a Sucralose® control.

Chapter 4

METHODS

4.1. Overview of Research Design

A within-subject repeated measures design was used to examine the effect of various sugars solutions on subjective appetite and FI regulation in NW 9- to 14-year-old boys. The experimental protocol was repeated on four separate weekend mornings, one week apart. On each of the four mornings the boys received, in random order, one of the four test solutions, after which they were given 100 ml of water to cleanse their palate. Subjects arrived at the Department of Applied Human Nutrition at Mount Saint Vincent University 2 h after consumption of a standardized breakfast of milk, cereal, and orange juice. Visual analogue scales (VAS) to assess motivation to eat and physical comfort were completed at baseline (0 min), and at regular intervals up to the test lunch, and immediately after. A pizza lunch was provided to subjects 60 min after consumption of each test solution. Subjects were instructed to eat until comfortably full. Following lunch, children completed a VAS to assess the palatability of the pizza meal.

4.2. Subjects

Fifteen NW boys (between the 5th and 85th BMI percentile for age and gender) between the ages of 9 and 14 years participated in this study. Subjects were recruited via flyers that were posted throughout the Halifax Regional Municipality and through word of mouth. In addition, an advertisement was placed in the Metro® newspaper. A recruitment letter outlining the study protocol was also given to the parent/guardian of potential subjects (Appendix 8.1). The Mount Saint Vincent University Research Ethics Board approved this study (# 2010-017).

To participate, the boys had to be born at full-term and normal birth weight (greater than 2500g) (258). Exclusion criteria included: those taking medication which could interfere with appetite or FI, those with significant learning, behavioral, or emotional difficulties, those on

special diets that would limit their ability to consume the standard breakfast and/or test meal and those who disliked or were not willing to consume the standard breakfast or test meal.

In order to ensure that subjects met the inclusion criteria, a two-step screening was done before participation in the experimental sessions. The first step was a telephone screening questionnaire (Appendix 8.2), which determined initial eligibility in the study. If the subject met the criteria, an in-person screening session was scheduled for the child and their parent(s). At the screening, the study was explained and informed written consent (Appendix 8.3) was obtained from the parent and written assent (Appendix 8.4) obtained from the child. The children selected the type of pizza they would like to eat during the test visits and were also exposed to the study questionnaires. Physical measurements of the child's height (cm) and weight (kg) were measured and recorded using a balance scale and skinfold measurements were taken at four points (triceps, biceps, suprailiac, and subscapular) (Appendix 8.5). Before leaving, parents and subjects chose a time for their session to begin based on the time the child normally consumes breakfast; subjects were asked to arrive at the same time for each subsequent session.

4.3. Experimental Procedure

Subjects arrived at the Department of Applied Human Nutrition 2 h after eating a standardized breakfast of fat-free skim milk (250 ml), Honey Nut Cheerios® (26 g), and Tropicana Orange Juice® (236 ml). The time at which the child arrived at the department was kept consistent across all four sessions. Prior to consuming the standardized breakfast, subjects were asked to fast for 10 to 12 h. Subjects were also requested not to exercise on the morning of the study and not to consume anything aside from the breakfast prior to arriving at the lab with the exception of water, which was allowed for 1 h prior to arrival.

Upon arrival, the children were asked if they consumed their entire breakfast, if any other foods were consumed 12 h prior to arrival and if they were taking any medication (Appendix 8.7). If significant deviations from original patterns were reported, subjects were asked to reschedule. Assuming all guidelines were adhered to, subjects were escorted to the test room where they consumed one of the three sugars solutions or a control solution in full after measuring their motivation to eat and physical comfort on a VAS. Motivation to eat (Appendix 8.8.1) and physical comfort (Appendix 8.8.2) were also measured at 15, 30, 45, 60 and 90 min from baseline. After consuming the test solutions each child was asked to drink 100 ml of plain water to reduce aftertaste. The solutions were prepared the day before, stored in a refrigerator overnight and served the following morning in plastic cups with lids left in place during drinking to prevent spills. After consumption of the sugars-containing preload, the boys were given separate VAS to measure sweetness (Appendix 8.8.3) and pleasantness (Appendix 8.8.4) of the preload solutions.

Between the treatment and test meal, subjects were allowed to engage in age appropriate indoor activities of their choice, but consistent for all sessions (i.e. board games, reading and puzzles). Sixty min after consuming the test solution, subjects were escorted back to the test room for lunch. The test meal consisted of pizza (McCain Foods: Deep and Delicious 5" Pizza) that was prepared in the Foods Laboratory in the Department of Applied Human Nutrition. An advantage of using these pizzas is the lack of crust, which results in a pizza with a more uniform energy content and the elimination of the possibility of subjects eating the denser filling and leaving the outside crust of the pizza. The pizza was served on individual trays set times following the preload. Three pizzas were served on each tray (average of 180 kcal/pizza, 49.5% of energy as carbohydrate, 31% as fat and 19% as protein depending on its variety), removing

the first tray after 10 min and silently providing the subjects with a second warm tray. The subjects were instructed to eat until they were comfortably full. Water was provided with all meals, and weighed before and after the test meal to determine consumption. After the test meal, subjects rated the pleasantness of the test meal (Appendix 8.8.5) as well as completed the other needed VAS measures.

The data collected was subjective appetite scores and caloric compensation. Subjective appetite was analyzed by obtaining a numerical value from the VAS. The numerical value was obtained by measuring the length between the left end of the line and the 'X' as indicated by the participant. Calculating the calories consumed at each of the four test meals assessed caloric compensation.

4.4. Materials and Methods

4.4.1. Test Meal

Two varieties of McCain Deep and Delicious 5" diameter pizzas were served at the test meal: pepperoni or three-cheese (**Table 4.1**). The pepperoni pizza (87 g) contains 9 g of protein, 6 g of fat and 23 g of carbohydrates for a total energy content of 180 kcal. Similarly, each three-cheese pizza (81 g) contains 9 g of protein, 6 g of fat and 22 g of carbohydrate for a total energy content of 180 kcal. A total of nine pizzas, with three pizzas per tray, were served in regular 10-min intervals for the total test meal duration of 30 min. The pizzas were selected due to their lack of crust and uniform energy and macronutrient composition. The boys had the option of choosing between the two types and were asked their preference at the screening interview.

The cooked pizzas were cut into four equal pieces and weighed before serving. After 30 min, the leftover pizza was weighed again and the end amount was subtracted from the weight before consumption to provide a measure of FI (net weight in grams). The energy consumed

(kcal) was calculated by converting the consumed net weight of the pizza (in grams) using information provided by the manufacturer. Caloric compensation is considered present if a satiety effect based on the sugar type of the sugars-containing solution decreases mealtime food consumption of the mini pizzas. A 100% caloric compensation indicates that the participant fully compensated for all of the calories in the preload during the test meal (102). The boys were escorted to the sensory evaluation room and seated in individual cubicles to minimize distractions. A bottle of spring water (500 ml) was given to all subjects during the test meal and was also weighed before and after to determine the net amount consumed.

Table 4.1 Nutrient Composition of Test Meal

Per 1 Pizza	Pepperoni (87 g)	3-Cheese (81 g)
Calories (kcal)	180.0	180.0
Fat (g)	6.0	6.0
Saturated Fat (g)	2.5	2.5
Trans Fat (g)	0.1	0.1
Cholesterol (mg)	15.0	15.0
Sodium (mg)	400.0	360.0
Carbohydrates (g)	23.0	22.0
Fiber (g)	2.0	2.0
Sugar (g)	4.0	4.0
Protein (g)	9.0	9.0

4.4.2. Treatment Solutions

Each participant received 200 kcal of glucose (Grain Process Enterprises Ltd., Scarborough, ON), sucrose (Redpath Sugar Ltd., Toronto, ON, purchased at Sobeys), and HFCS-55 (donated by Casco Inc., Etobicoke, ON), or a Sucralose® control (SPLENDA, donated by Tate and Lyle, Decatur, Illinois) over the course of the four sessions. The sugars solutions consisted of 1.1 g of aspartame-sweetened, orange-flavored crystals (Sugar Free Kool-Aid, Kraft Canada Inc., Don Mills, ON) and the appropriate amount of glucose (54.6 g), sucrose (53.3 g) or HFCS-55 (64.9 g). In addition, to match for sweetness the glucose, sucrose and HFCS-55 solutions contained 70 mg, 50 mg, and 20 mg of Sucralose®, respectively. Each solution was made up to 250 ml with water. The control solution consisted of 1.1 g of aspartame-sweetened, orange-flavored crystals and 250 mg of Sucralose®. The control solution was also made up to 250 ml with water.

A test panel examined the relative sweetness of the four test solutions prior to the start of data collection. There were no differences in sweetness among the test solutions (P=0.53). Sweetness of the control, glucose, sucrose and HFCS-55 solution was 77 mm, 80 mm, 72 mm and 77 mm, respectively.

Test solutions were prepared the evening before each test session and stored in the refrigerator. Sugars solutions were served chilled in a covered opaque cup the following morning. Subjects were required to consume the solution each test day in full and in <5 min followed by 100 ml of water to minimize aftertaste.

4.4.3. Motivation to Eat Visual Analogue Scales

Subjective appetite and thirst were measured using a Motivation-to-Eat Visual Analogue Scale (VAS) at baseline (0 min), 15, 30, 45, 60 and 90 min (Appendix 8.8.1). The VAS consisted

of five questions, each followed by a 100mm horizontal line with opposing statements at either end. Subjects were asked to mark an 'X' on the line to indicate how they were feeling. Scores were calculated by measuring the distance in mm from the left end of the line to the marked 'X.' The VAS to measure subjective appetite consists of five questions:

How strong is your desire to eat? ('Very weak' to 'Very strong')

How hungry do you feel? ('Not hungry at all' to 'As hungry as I've ever felt')

How full do you feel? ('Not full at all' to 'Very full')

How much food do you think you could eat? ('Nothing at all' to 'A large amount')

How thirsty do you feel? ('Not thirsty at all' to 'As thirsty as I have ever felt')

To determine an AA score, DTE, hunger and perspective food consumption (PFC) (i.e. How much food do you think you can eat) as well as 100 minus fullness are added and divided by four (average appetite (mm) = [(desire to eat + hunger + (100 – fullness) + PFC)/4]). This VAS, as well as the calculation for AA, has been used previously (86, 102, 136, 174, 221, 222, 237, 259) and validated in children (221).

4.4.4. Subjective Physical Comfort

The physical comfort VAS was used to assess the subject's well being by asking the subject 'How well do you feel?' with a range of 'Not well at all' to 'Very well' (102, 136, 221, 222). Each participant indicated their physical comfort at baseline and at 15, 30, 45, 60 and 90 min (Appendix 8.8.2).

4.4.5. Sweetness and Pleasantness of Sugars Solutions

Sweetness and pleasantness of the test solutions were measured using VAS. Subjects rated the sweetness of the solution by answering the question "How sweet have you found the beverage?' which was anchored by 'Not sweet at all' to 'Very sweet.' The question 'How

pleasant have you found the beverage?' was anchored by 'Not at all pleasant' to 'Very pleasant.' Subjects rated the sweetness (Appendix 8.8.3) and pleasantness (Appendix 8.8.4) of the preload at <5 min (immediately after consumption of sugars-containing solution).

4.4.6. Pleasantness of the Test Meal

Pleasantness of the test meal was measured using VAS at 90 min (directly following the test meal). The question 'How pleasant have you found the food?' was anchored by 'Not at all pleasant' to 'Very pleasant' (Appendix 8.8.5).

4.4.7. Estimation of Body Composition

The sum of skinfolds at four points (triceps, biceps, suprailiac, and subscapular) was the measure used to estimate body composition and was measured with a Lange skinfold caliper (Cambridge Scientific Industries, Cambridge, Md.) and recorded to the nearest 0.1mm. The mean of three consecutive skinfold measurements was used for estimation of fat mass (FM) from an age- and sex-specific regression equation (236). Body density was first calculated (Equation 1) and then applied to another calculation to determine percent body fat (Equation 2). Skinfold measurements were completed at the screening or information session by an experienced technician.

Equation 1: Density = 1.1690 – 0.0788 * log sum of skinfold thicknesses at 4 sites

Equation 2: Body fat % of weight = [(4.95/body density) – 4.5] * 100

4.4.8. Determination of Dietary Cognitive Restrained, Emotional and External Eating Behaviours

The DEBQ was used to determine the presence of dietary restrained, emotional or external eating behaviours (245). Younger subjects who may have difficulty interpreting the language of the questionnaire were given assistance to complete the survey. This questionnaire

was administered at the in-person screening interview prior to the first experimental session (Appendix 8.6).

The DEBQ consists of 33 questions and has specific questions that address the three main factors: dietary cognitive restraint, emotional disinhibition and external disinhibition (245). The emotional eating category was further broken down into two dimensions, one relating to eating in response to diffuse emotions and the other dealing with eating in response to specific emotions (245). Categorization of the questions into these three main factors provides averages for each main factor, as well as an overall DEBQ score; these numbers are used to assess whether the participant has a tendency towards restrained, emotional disinhibited or external eating behaviours.

4.5. Ethical Considerations

Parents signed a consent form (Appendix 8.3) during the screening session after the child's eligibility to participate was confirmed. During the screening visit, the purpose and design of the study were explained to the children and their written assent was obtained (Appendix 8.4).

Names of subjects were kept confidential by use of a code; participant codes were based on the initials of their first and last name and the number of children already enrolled. All files were kept in a locked cabinet in-between experimental sessions. Only the researcher and research assistants had access to these documents. All files will be kept in a secure location in The Department of Applied Human Nutrition at Mount Saint Vincent University for a period of five years, after which they will be destroyed.

4.6. Data Analysis

Statistical Analysis Software (SAS) Version 9.2 (SAS Institute Inc., Carey, NC) was used to perform all statistical analyses. All data are presented as mean ± standard error of the mean (SEM) and results were considered statistically significant at $P < 0.05$.

Treatment effects on food and water intake, cumulative FI, FI per kg, caloric compensation and subjective measures of sweetness and pleasantness were analyzed using the PROC MIXED MODEL procedure in SAS with preload treatment as the main factor. The motivation-to-eat and thirst VAS were analyzed using a two-way MIXED MODEL with preload treatment and time as main factors. Pre-meal measures of subjective appetite are reported as absolute scores. Subjective appetite scores are also expressed as change from baseline, to account for differences in appetite at baseline. Change from baseline scores were calculated by subtracting scores at 15, 30, 45 and 60 min from baseline scores (0 min). For all PROC MIXED procedures, a post hoc analysis was performed by use of Tukey–Kramer's test, adjusted for multiple comparisons, when treatment effects or interactions were statistically significant.

Correlations on dependent measures were derived by the use of Pearson's correlation coefficients. Associations between FI and subjective measures of appetite, thirst, preload sweetness and pleasantness, test meal pleasantness, water intake, measures of body composition and DEBQ traits, were analyzed.

Subjective measures of appetite, thirst and FI were compared in subjects with a lower versus higher BMI percentile by median split. A two-factor MIXED MODEL was used to determine the effect of preload treatment and weight status on food and water intake, caloric compensation, and subjective sweetness, and a three-factor MIXED MODEL (preload treatment, weight status, and time) on subjective measures of appetite.

Caloric compensation, a measure of how well subjects reduce their FI at the test meal after the sugars solutions relative to the control intake, was calculated using the following formula as reported previously (12, 102, 136, 221, 222, 237, 259):

Caloric compensation (%) = [Control intake (kcal) – Treatment intake (kcal) / kcal in treatment preload] x100

A 100% caloric compensation score indicates that the subject reduced his FI by 200 kcal on days he was given a sugars solution (200 kcal) compared to the day he was given the Sucralose® solution. A compensation score less than 100% indicates the child was unable to fully compensate at the test meal.

Chapter 5

RESULTS

5.1. Subject Characteristics

Fifteen NW boys between 9- to 14-years of age (12.2 ± 0.4 years), with a BMI percentile range between the 5th and 83rd percentile, participated in the study. Baseline characteristics of the subjects, including individual and combined DEBQ scores, are listed in **Table 5.1**.

Table 5.1 Baseline Characteristics for Test Subjects

Subject Characteristics	Subjects
Age (years)	12.2 ± 0.4
BW (kg)	45.4 ± 2.4
Height (m)	1.58 ± 0.04
BMI (kg/m^2)	18.0 ± 0.4
BMI Percentile	47.7 ± 6.7
FM (kg)[1]	8.4 ± 0.9
FM (%)	18.0 ± 1.0
FFM (kg) [1]	37.0 ± 2.1
FFM (%)	82.0 ± 2.0
DEBQ Average Score[2]	2.1 ± 0.1
Restraint[2]	1.9 ± 0.1
Average Overall Emotional[2]	1.8 ± 0.2
Diffuse Emotional[2]	1.9 ± 0.1
Specific Emotional[2]	1.7 ± 0.2
Overall Disinhibition[2]	2.3 ± 0.1
External Disinhibtion[2]	2.9 ± 0.2

Data are means ± SEM, n = 15. Abbreviations: BW, body weight; BMI, body mass index; BMI Percentile, body mass index percentile; FM, fat mass; FFM, fat-free mass; DEBQ, Dutch Eating Behaviour Questionnaire. [1]FM and FFM were calculated from the sum of skinfolds at four points (236). [2]Diertary restraint and disinhibition were measured using the DEBQ (245).

5.2. Food Intake

Preload treatment affected FI (kcal) at the test meal (P=0.005) (**Table 5.2**). Compared to the Sucralose® control, FI was reduced after the glucose solution, but not after sucrose or HFCS-55. Cumulative energy intake (FI + preload) was affected by preload treatment (P<0.05) (Table 5.2). Cumulative energy intake for the sucrose and HFCS-55 solution was significantly higher compared to for the control solution.

5.3. Caloric Compensation

Caloric compensation was not affected by preload treatment (P=0.07) (Table 5.2). Compensation scores after the glucose, sucrose and HFCS-55 solutions were 76%, 26% and 26%, respectively.

5.4. Water Intake

There was no effect of preload treatment on water intake (P=0.74) in NW 9- to 14-year-old boys (Table 5.2).

5.5. Sweetness of Sugars Solutions

Subjective sweetness did not differ among the four sugars solutions (P=0.80). The mean sweetness of the control, glucose, sucrose and HFCS-55 solutions were 87, 89, 90 and 90 mm, respectively (Table 5.2).

5.6. Pleasantness of Sugars Solutions

Pleasantness of the preload was affected by preload treatment (P<0.05). Glucose (P=0.04) and sucrose (P=0.01) solutions were rated more pleasant than the control solution, but none of the sugars solutions differed from each other (Table 5.2).

5.7. Physical Comfort

Absolute physical comfort was not affected by treatment (P=0.09) or time (P=0.98), and there was no treatment x time interaction (P=0.99).

Change from baselines physical comfort was not affected by treatment (P=0.28) or time (P=0.95), and there was no treatment x time interaction (P=0.99).

Table 5.2 Effect of Sugars Solutions on Food and Water Intake, Sweetness, Preload Pleasantness, Physical Comfort and Caloric Compensation in Normal Weight Boys

	Control	Glucose	Sucrose	HFCS-55
FI[1] (kcal)	1127 ± 56[a]	975 ± 58[b]	1074 ± 81[ab]	1075 ± 65[ab]
FI+Preload[2] (kcal)	1127 ± 56[a]	1176 ± 58[ab]	1274 ± 81[b]	1275 ± 66[b]
Caloric Compensation[3] (%)	-	76 ± 22	26 ± 22	26 ± 17
Water Intake (g)	251 ± 45	284 ± 38	260 ± 40	255 ± 41
Sweetness (mm)	87 ± 3	89 ± 3	90 ± 3	90 ± 3
Preload Pleasantness (mm)	57 ± 8[a]	71 ± 6[b]	73 ± 7[b]	68 ± 7[ab]

Treatment effects were analyzed using the PROC MIXED procedure with preload treatment as the main factor. Abbreviation: HFCS-55, high-fructose corn syrup-55; FI, food intake. Data are means ± SEM; n = 15. Means in a row with different letters differ at $P<0.05$ (Tukey's Test). [1]Pizza intake at test meal. [2]Cumulative energy intake from pizza meal and the preload treatments (Control, 0 kcal; Glucose, 200 kcal; Sucrose, 200 kcal; HFCS-55, 200 kcal). [3]Caloric Compensation (%) = control FI (kcal) – treatment meal (kcal)/preload (kcal) x 100.

5.8. Motivation to Eat Visual Analogue Scales

5.8.1. Average Appetite

Absolute AA scores were affected by preload treatment ($P<0.05$) and time ($P<0.0001$), but there was no treatment x time interaction ($P=0.78$). Average appetite scores were significantly higher after HFCS-55 compared to glucose. Average appetite scores increased over time irrespective of the preload treatment (**Figure 5.1a**).

Change from baseline AA scores were affected by preload treatment ($P<0.001$) and time ($P<0.0001$), but there was no treatment x time interaction ($P=0.89$). Change in AA scores was significantly higher after sucrose compared to all the other test solutions (**Figure 5.2a**).

5.8.2. Desire to Eat

Absolute DTE scores were not affected by treatment ($P=0.08$), but were affected by time ($P<0.0001$), and there was no treatment x time interaction ($P=0.45$). Scores for DTE increased over time irrespective of treatment (**Figure 5.1b**).

Change from baseline scores for DTE were affected by preload treatment ($P<0.001$) and time ($P<0.0001$), but there was no treatment x time interaction ($P=0.75$). Change in DTE scores was significantly higher after sucrose compared to all the other test solutions (**Figure 5.2b**).

5.8.3. Hunger

Absolute hunger scores were affected by treatment ($P<0.01$) and time ($P<0.0001$), but there was no treatment x time interaction ($P=0.94$). Absolute scores for hunger were significantly higher following the HFCS-55 solution in comparison to the glucose treatment. Hunger scores increased over time irrespective of treatment (**Figure 5.1c**).

Hunger scores expressed as the change from baseline were affected by preload treatment ($P<0.05$) and time ($P<0.0001$), but there was no interaction between the two ($P=0.93$). Change in

hunger scores was significantly higher after sucrose compared to after the control solution (**Figure 5.2c**).

5.8.4. Fullness

Absolute fullness scores were affected by time ($P<0.0001$), but not by preload treatment ($P=0.18$) or by a treatment x time interaction ($P=0.87$). Fullness scores decreased over time irrespective of treatment (**Figure 5.1d**).

Change from baseline fullness scores were affected by preload treatment ($P<0.05$) and time ($P<0.01$), but there was no treatment x time interaction ($P=0.96$). Change in fullness scores was significantly higher after sucrose compared to HFCS-55. Change from baseline fullness scores decreased over time irrespective of treatment (**Figure 5.2d**).

5.8.5. Prospective Food Consumption

Absolute prospective food consumption (PFC) was not affected by treatment ($P=0.07$), but was by time ($P<0.0001$), and there was no treatment x time interaction ($P=0.91$). Absolute PFC scores increased over time irrespective of treatment (**Figure 5.1e**).

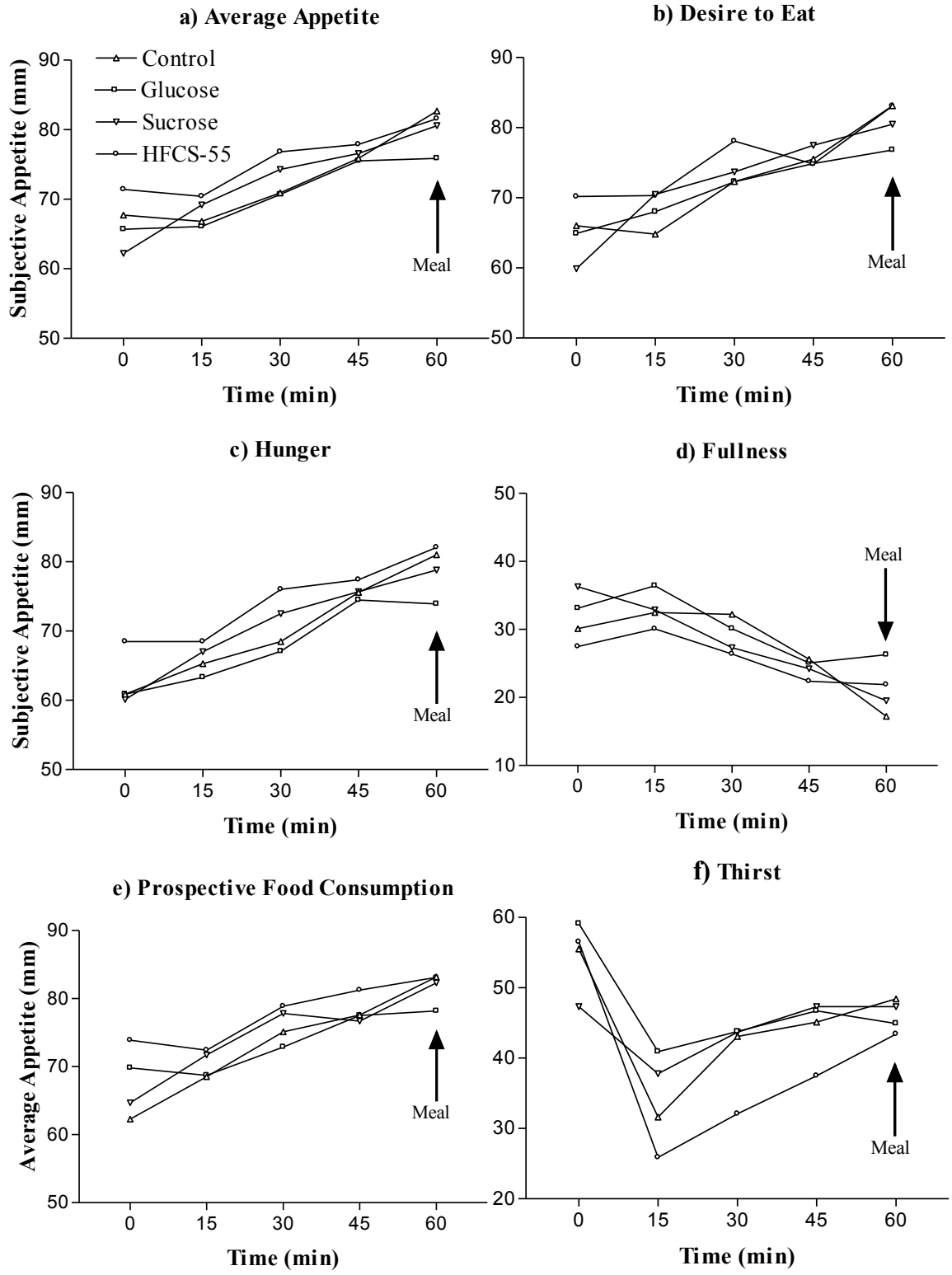
Change from baseline scores for PFC was affected by treatment ($P<0.01$) and time ($P<0.0001$), but there was no treatment x time interaction ($P=0.97$). Change in PFC scores was significantly higher after sucrose compared to all the other test solutions (**Figure 5.2e**).

5.8.6. Thirst

Absolute thirst was affected by preload treatment ($P<0.05$) and time ($P<0.0001$), but there was no treatment x time interaction ($P=0.74$). Thirst was highest after the glucose solution compared to HFCS-55. Absolute thirst scores increased overall irrespective of the treatment after decreasing first at 15 min (**Figure 5.1f)**.

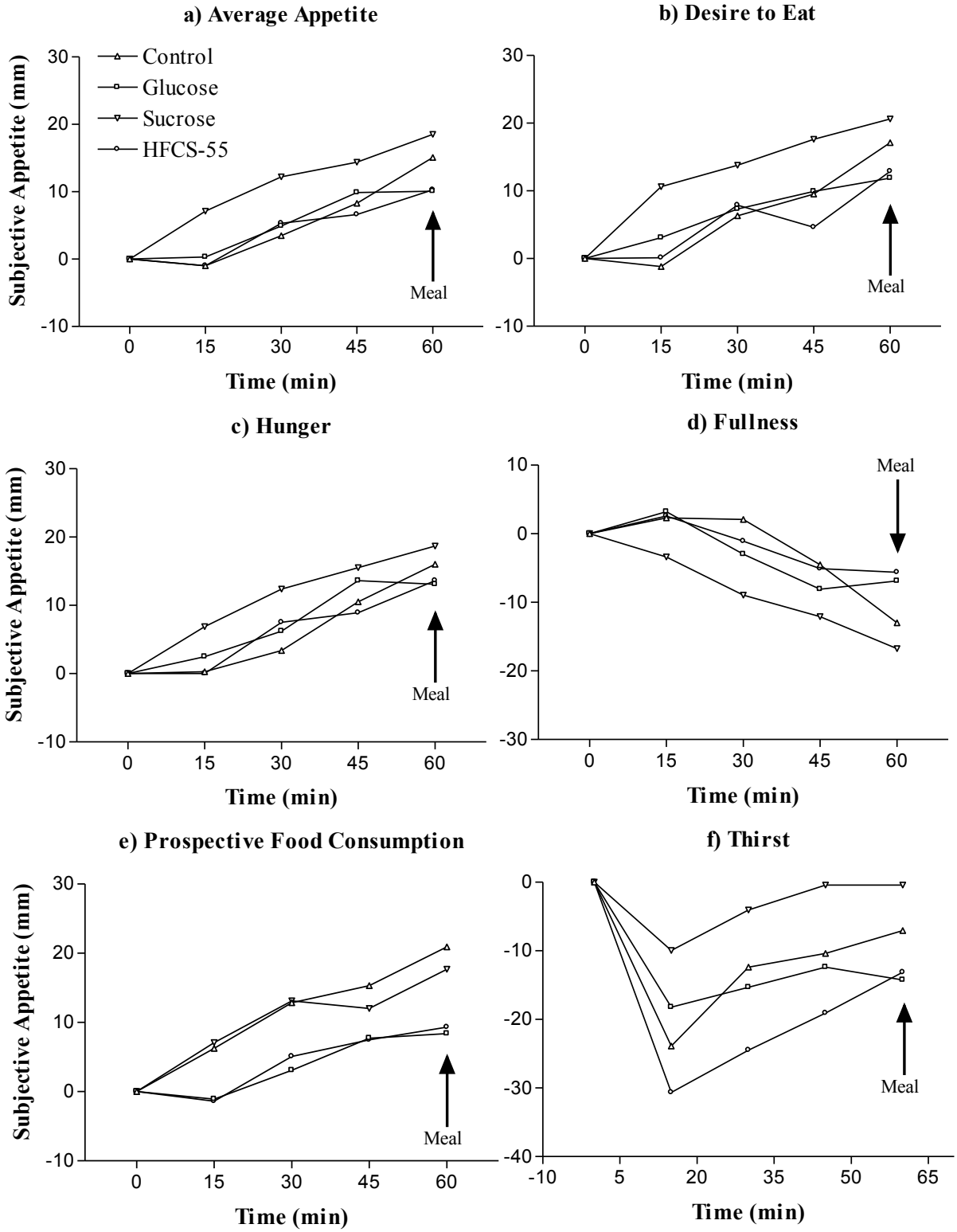
Thirst scores expressed as change from baseline were affected by treatment ($P<0.0001$) and time ($P<0.05$), but there was no treatment x time interaction ($P=0.98$). Change in thirst scores was significantly lower for glucose and HFCS-55 compared to sucrose. Thirst scores expressed as the change from baseline first decreased at 15 min following the solutions, and then increased over time irrespective of treatment but remained below baseline (**Figure 5.2f)**.

Figure 5.1 Subjective Average Appetite 60 Min After Sugars Solutions



Subjective average appetite ratings for a) average appetite, b) desire to eat, c) hunger, d) fullness and e) prospective food consumption at 0, 15, 30, 45 and 60 min. Values are means, n = 15. Average and individual appetite scores changed over time.

Figure 5.2 Change from Baseline Subjective Average Appetite 60 Min After Sugars Solutions



Change from baseline subjective average appetite ratings for a) average appetite, b) desire to eat, c) hunger, d) fullness and e) prospective food consumption at 0, 15, 30, 45 and 60 min. Values are means, n = 15. Average and individual appetite scores changed over time.

5.9. Associations With Food Intake

5.9.1. Body Composition

Food intake after the control preload positively correlated with BW (r=0.69, P=0.005). Fat mass positively correlated with FI following the control (r=0.66, P=0.008), sucrose (r=0.54, P=0.039) and HFCS-55 (r=0.75, P=0.001) solutions. Furthermore, caloric compensation did not correlate with any measures of body composition (**Table 5.3**).

Table 5.3 Associations Between Body Composition, Food Intake and Caloric Compensation

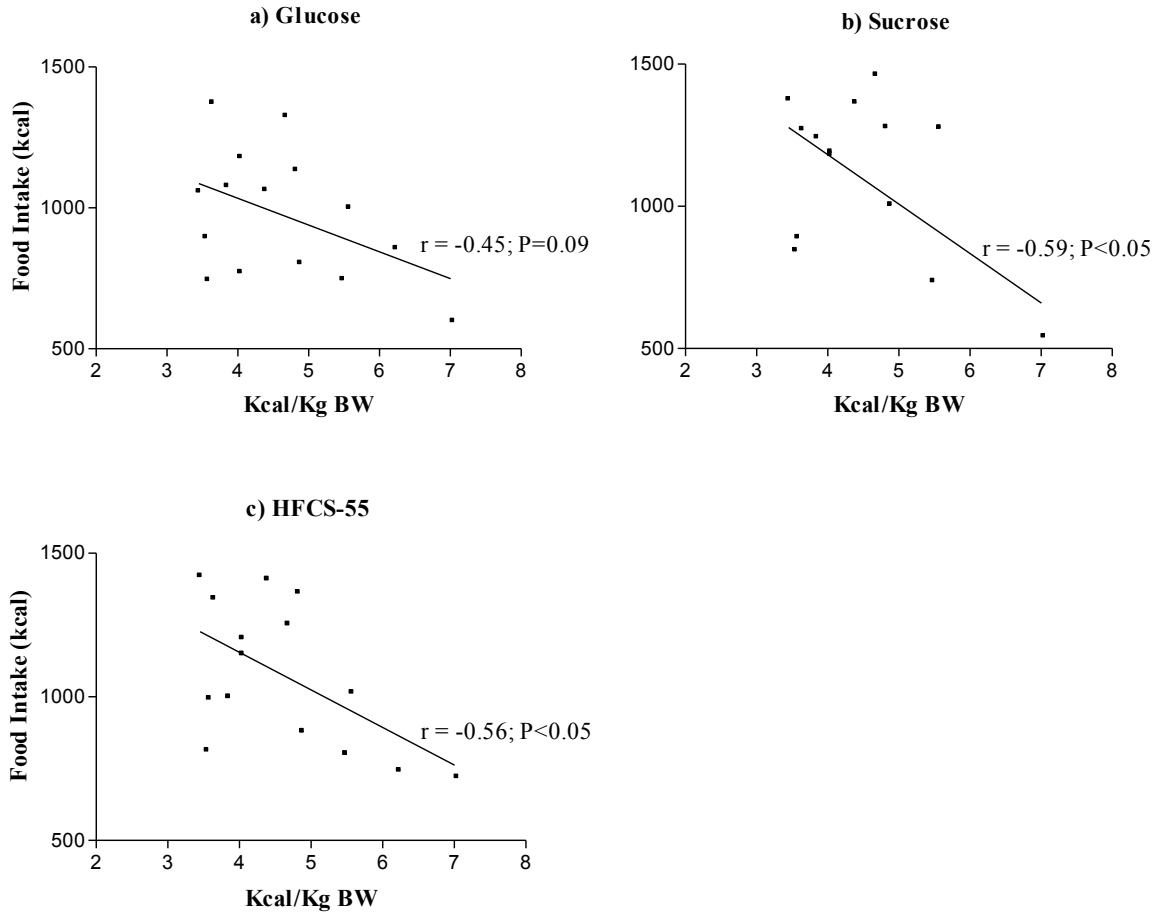
	BW	FM	FFM
FI Control	0.68906**	0.65874**	0.49650
FI Glucose	0.37890	0.48980	0.21689
CC Glucose	0.36826	0.18639	0.33824
FI Sucrose	0.49096	0.53625*	0.32427
CC Sucrose	-0.03010	-0.15348	0.03328
FI HFCS-55	0.49639	0.74668**	0.23771
CC HFCS-55	0.20046	-0.34014	0.37886

Pearson correlation coefficients; n=15. Abbreviations: BW, body weight; FM, fat mass; FFM, fat-free mass; FI, food intake; HFCS-55, high-fructose corn syrup-55; CC, caloric compensation.*P<0.05, **P<0.01.

5.9.2. Preload Kcal per Kilogram Body Weight

Energy content of the preload (kcal) expressed per kg of BW negatively correlated with FI. This relationship was more evident for sucrose (r=-0.59, P=0.02) and HFCS-55 (r= -0.56, P=0.03) compared to glucose (r=-0.45, P=0.09) (**Figure 5.3**).

Figure 5.3 Associations Between Preload Kcal Per Kilogram Body Weight and Food Intake



Energy content of the preload expressed as per kg BW correlated with food intake following the three caloric solutions. Abbreviations: HFCS-55, high-fructose corn syrup-55; Kg, kilogram; BW, body weight.

5.9.3. Average Appetite

Average appetite scores did not strongly correlate with FI at any of the measurement intervals following the preload treatments (**Table 5.4**).

Table 5.4 Associations Between Absolute Average Appetite and Food Intake

Time	Control	Glucose	Sucrose	HFCS
0	-0.40294	0.29122	-0.24677	-0.00570
15	-0.37323	0.47053	-0.11951	0.00671
30	-0.22528	0.40783	-0.21341	-0.05082
45	-0.34463	0.39476	-0.20075	0.06464
60	-0.17706	0.32428	-0.20043	-0.04929

Pearson correlation coefficients; n=15. Abbreviations: HFCS, high-fructose corn syrup.
*P < 0.05, **P < 0.01.

5.9.4. Sweetness and Pleasantness of the Sugars Solutions

Subjective sweetness of the preload did not correlate with FI after the sucrose (P=0.11), HFCS-55 (P=0.52), glucose (P=0. 66) or control (P=0.10) solutions (**Table 5.5**).

Pleasantness of the glucose solution positively correlated with FI at the test meal (r =0.66, P=0.01). There were no significant associations between pleasantness of the other test treatments and FI (Table 5.5).

Table 5.5 Associations Between Sweetness and Pleasantness with Food Intake at the Test Meal

	Control	Glucose	Sucrose	HFCS-55
Sweetness	0.44036; P=0.10	-0.12298; P=0.66	-0.42700; P=0.11	-0.18046; P=0.52
Pleasantness	0.31895; P=0.25	0.65760; P=0.01*	0.37787; P=0.16	0.27292; P=0.33

Pearson correlation coefficients; n=15. Abbreviations: HFCS-55, high-fructose corn syrup-55. *P<0.05.

5.10. Subject Characteristics by BMI Percentile

Participants were grouped into two groups based on BMI percentile using a median split, thus allowing for comparison of weight status within the NW range. When based on BMI percentile, eight boys (12.8 ± 0.5 years) with a BMI between the 5th and 49th percentile (17.1 ± 0.6 kg/m^2) and seven boys (11.5 ± 0.5 yrs) with a BMI between the 52nd and 83rd percentile (19.0 ± 0.3 0.4 kg/m^2) were included in this study. Baseline characteristics of participants based on BMI percentile are listed in **Table 5.6**.

Table 5.6 Baseline Characteristics for Test Subjects by BMI Percentile

Subject Characteristics	BMI < 50th Percentile	BMI > 50th Percentile
Age (years)	12.8 ± 0.5	11.5 ± 0.5
BW (kg)	44.7 ± 4.2	46.0 ± 2.5
Height (m)	1.60 ± 0.06	1.55 ± 0.04
BMI (kg/m^2)	17.1 ± 0.6	19.0 ± 0.3*
BMI Percentile	28.9 ± 6.8	69.1 ± 4.3**
FM (kg)[1]	7.0 ± 0.8	9.9 ± 1.7
FM (%)	16 ± 1.0	21 ± 2.0
FFM (kg) [1]	37.7 ± 3.7	36.1 ± 1.9
FFM (%)	84 ± 1.0	79 ± 1.0
DEBQ Average Score[2]	2.1 ± 0.1	2.2 ± 0.2
Restraint[2]	1.7 ± 0.2	2.1 ± 0.2
Average Overall Emotional[2]	1.7 ± 0.2	1.9 ± 0.3
Diffuse Emotional[2]	1.8 ± 0.2	1.9 ± 0.2
Specific Emotional[2]	1.6 ± 0.2	1.9 ± 0.3
Overall Disinhibition[2]	2.2 ± 0.2	2.3 ± 0.2
External Disinhibtion[2]	3.0 ± 0.2	2.8 ± 0.2

Data are means ± SEM, n = 8 in BMI < 50th percentile group and n = 7 in BMI > 50th percentile group. Abbreviations: BW, body weight; BMI, body mass index; BMI Percentile, body mass index percentile; FM, fat mass; FFM, fat-free mass; DEBQ, Dutch Eating Behaviour Questionnaire. [1]FM and FFM were calculated from the sum of skinfolds at four points (236). [2]Diertary restraint and disinhibition were measured using the DEBQ (245). Significantly different by student's unpaired t-test at *P<0.05, **P<0.01.

5.11. Food Intake by BMI Percentile

When comparing the groups based on BMI percentile, both preload treatment ($P<0.01$) and weight status group ($P<0.01$) affected FI, but there was no treatment x group interaction ($P=0.17$). Boys with a BMI below the 50th percentile (between the 5th and 49th) reduced their FI at the test meal only after glucose in comparison to the control. Boys with a higher BMI percentile did not suppress FI after any of the sugars solutions and consistently consumed higher kcal (**Table 5.7**).

Cumulative FI (FI + preload) was affected by preload treatment ($P<0.01$) and weight status ($P<0.01$), but there was no treatment x group interaction ($P=0.12$). Boys with a higher BMI percentile had higher cumulative FI after sucrose compared to the control (Table 5.7).

5.12. Caloric Compensation by BMI Percentile

Preload treatment ($P=0.06$), nor weight status ($P=0.14$), affected caloric compensation and there was no treatment x group interaction ($P=0.16$) (Table 5.7).

5.13. Water Intake by BMI Percentile

Preload treatment ($P=0.78$), nor weight status ($P=0.91$), affected water intake, and there was no treatment x group interaction ($P=0.14$) (Table 5.7).

5.14. Sweetness of Sugars Solutions by BMI Percentile

Preload treatment ($P=0.81$), nor weight status ($P=0.95$), affected subjective sweetness of the sugars solutions, and there was no treatment x group interaction ($P=0.21$) (Table 5.7).

Table 5.7 Effect of Sugars Solutions on Food and Water Intake, Sweetness and Caloric Compensation in Normal Weight Boys by BMI Percentile

	BMI < 50th Percentile				BMI > 50th Percentile			
	Control	**Glucose**	**Sucrose**	**HFCS-55**	**Control**	**Glucose**	**Sucrose**	**HFCS-55**
FI[1] (kcal)	1021 ± 83	827 ± 81	878 ± 110	941 ± 85	1248 ± 44	1107 ± 77	1299 ± 34	1227 ± 62
FI+Preload[2] (kcal)	1021 ± 83	1061 ± 66	1078 ± 110	1141 ± 85	1248 ± 44	1307 ± 77	1499 ± 34	1427 ± 62
Caloric Compensation[3] (%)	-	80 ± 29	72 ± 26	40 ± 15	-	70 ± 37	-25 ± 26	10 ± 31
Water Intake (g)	216 ± 56	315 ± 56	265 ± 55	269 ± 43	291 ± 73	248 ± 52	255 ± 63	240 ± 76
Sweetness (mm)	85 ± 4	91 ± 3	93 ± 3	88 ± 4	90 ± 4	86 ± 5	84 ± 6	93 ± 4

Treatment effects were analyzed using a two-way PROC MIXED procedure with preload treatment and weight status as the main factors. Abbreviations: BMI, body mass index; HFCS-55, high-fructose corn syrup-55; FI, food intake. Data are means ± SEM; n = 8 in BMI < 50th percentile group, n = 7 in BMI > 50th percentile group. [1]Pizza intake at test meal. [2]Cumulative energy intake from pizza meal and the preload treatments (Control, 0 kcal; Glucose, 200 kcal; Sucrose, 200 kcal; HFCS, 200 kcal). [3]Caloric Compensation (%) = control meal (kcal) – treatment meal (kcal)/preload (kcal) x 100.

5.15. Motivation to Eat Visual Analogue Scales by BMI Percentile

5.15.1. Average Appetite

Change from baseline AA scores were affected by treatment ($P<0.001$) and time ($P<0.0001$), but not weight status ($P=0.17$), and there was no treatment x group x time ($P=0.48$), treatment x group ($P=0.94$), treatment x time ($P=0.86$) or time x group ($P=0.43$) interaction. Average appetite reported as the change from baseline was significantly higher after sucrose compared to after the control, glucose and HFCS-55 solutions. Change from baseline AA scores also increased over time irrespective of the preload solution (**Figure 5.4a**).

5.15.2. Desire to Eat

Change from baseline DTE scores were affected by treatment ($P<0.001$) and time ($P<0.0001$), but not weight status ($P=0.09$), and there was no treatment x group x time ($P=0.84$), treatment x group ($P=0.08$), treatment x time ($P=0.70$) or time x group ($P=0.72$) interaction. Changes in DTE scores were significantly higher after the sucrose solution compared to the control, glucose and HFCS-55 solutions. Change from baseline DTE scores also increased over time irrespective of preload treatment (**Figure 5.4b**).

5.15.3. Hunger

Change from baseline scores for hunger were affected by treatment ($P<0.05$) and time ($P<0.0001$), but not weight status ($P=0.12$), and there was no treatment x group x time ($P=0.65$), treatment x group ($P=0.15$), treatment x time ($P=0.92$) or time x group ($P=0.61$) interaction. Change in hunger scores were significantly higher after sucrose compared to after the control. Change from baseline hunger scores increased over time for all treatments (**Figure 5.4c**).

5.15.4. Fullness

Change from baseline scores for fullness were affected by treatment ($P<0.05$) and time ($P<0.001$), but not weight status ($P=0.42$), and there was no treatment x group x time ($P=0.56$), treatment x group ($P=0.06$), treatment x time ($P=0.96$) or time x group ($P=0.61$) interaction. Change in fullness scores were significantly higher after sucrose solution compared to after HFCS-55. Change from baseline fullness scores decreased over time irrespective of treatment (**Figure 5.4d**).

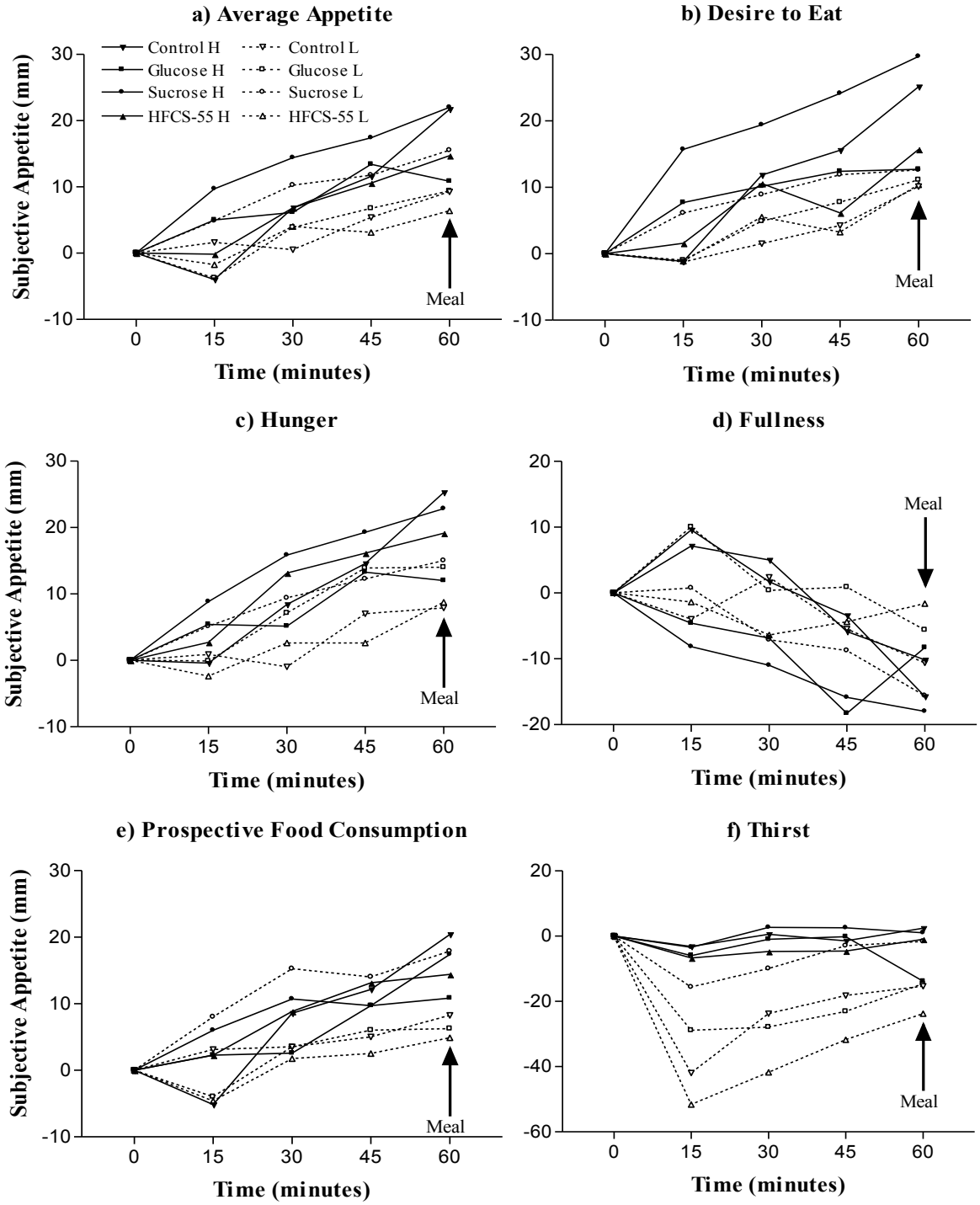
5.15.5. Prospective Food Consumption

Change from baseline PFC scores were affected by treatment ($P<0.01$) and time ($P<0.0001$), but not weight status ($P=0.30$), and there was no treatment x group x time ($P=0.65$), treatment x group ($P=0.13$), treatment x time ($P=0.96$) or time x group ($P=0.43$) interaction. Change from baseline scores for PFC were significantly higher after sucrose compared to after the other sugars solutions (**Figure 5.4e**).

5.15.6. Thirst

Change from baseline thirst scores were affected by treatment ($P<0.001$), time ($P<0.05$) and weight status ($P<0.05$), but there was no treatment x group x time ($P=0.98$) interaction. Although there was a treatment x group ($P<0.01$) interaction, there was no treatment x time ($P=0.98$) or time x group ($P=0.09$) interaction. Changes in thirst scores were significantly lower after sucrose compared to glucose and HFCS-55. Change from baseline thirst scores were significantly decreased for boys with a lower BMI compared to boys with a higher BMI. Thirst scores for boys with a lower BMI decreased more significantly following HFCS-55 compared to after all of the solutions for boys with a higher BMI. Thirst scores in boys with a lower BMI also decreased more significantly following the HFCS-55 preload in comparison to following the glucose and sucrose preload. Boys with a lower BMI were less thirsty after the control solution compared to sucrose (**Figure 5.4f**).

Figure 5.4 Change from Baseline Subjective Average Appetite 60 Min After Sugars Solutions by BMI Percentile



Change from baseline subjective average appetite ratings for a) average appetite, b) desire to eat, c) hunger, d) fullness and e) prospective food consumption at 0, 15, 30, 45 and 60 min. Values are means, n = 8 in BMI < 50th percentile group, n = 7 in BMI > 50th percentile group. Average and individual appetite scores changed over time.

Chapter 6

DISCUSSION

6.1. General Discussion

The results of this study support the hypothesis that sugars composition determines the effect on FI in children and that glucose increases mealtime satiation and decreases FI to a greater extent than after other sugars solutions in NW 9- to 14-year-old boys. Only glucose resulted in a statistically significant decrease in FI compared to the Sucralose® control. Cumulative FI (preload + meal) after sucrose and HFCS-55 was higher than after the control, suggesting that these sugars do not stimulate FI regulatory systems as well as glucose alone.

The effect of glucose on FI is consistent with previous reports in children (136) and adults (11, 12). Glucose was expected to have the strongest effect on FI for two reasons. First, glucose increases BG concentration more than sucrose or HFCS, which contributes to satiety (49, 59). Food intake following sugars solutions is inversely related to the effect of the sugars on BG (12, 200). It is hypothesized that foods that break down into glucose rapidly during digestion increase satiety (11). Second, the effect of glucose on FI suppression is related to the increased response of insulin secretion and decrease in plasma levels of ghrelin shown after solutions with a higher glucose: fructose ratio (12, 260, 261). This overall profile of increased elevations in BG (199, 200) and insulin (152) as a result of glucose consumption increases satiety (262). There is uncertainty, however, whether glucose or insulin is the primary signal regulating FI. Insulin is the likely regulator of FI based on euglycemic, hyperinsulinemic clamp studies showing that insulin, but not BG, was the primary regulator of FI (263). Twenty-four-hour endocrine and metabolic profiles after sugars solutions show larger responses in glucose and insulin induced by glucose compared to sucrose and HFCS, which are intermediate between the higher responses of glucose and lower responses after fructose (261). The intermediate responses in glucose and insulin induced by sucrose and HFCS-55 may help explain the weaker effect of these two sugars on FI compared to glucose. It

is unknown if the incretin hormones contribute to the stronger effect of glucose on FI as there is little research comparing the effect of various sugars on plasma levels of GIP and GLP-1. One study comparing the effect of oral glucose and fructose on FI concluded that although both sugars increase plasma GLP-1, the rise is greater after glucose (201). However, since there was no difference in FI following equicaloric preloads of glucose and fructose in their study, it was concluded that GLP-1 does not play the major role in regulating FI after all sugars (201).

Evidence in support of the hypothesis that HFCS causes overeating by disproportionally affecting FI compared to sucrose (8) is not supported. Mean FI following sucrose and HFCS-55 were similar in NW 9- to 14-year-old boys (1074 kcal vs. 1075 kcal, respectively). These results are similar to previous findings in adults where sucrose and HFCS-55 had similar effects on FI at a subsequent meal (12, 13, 115). A study by Akhavan and Anderson (12) demonstrated that sucrose and HFCS-55, as well as sucrose and G50:F50, had similar effects on FI in men. The effect of the solution on FI was dependent on the glucose: fructose ratio; a greater suppression of FI and increased caloric compensation was associated with an increased ratio of glucose in solution (12). Similar FI between sucrose and HFCS-55 was expected on the basis of their similar ratio of glucose: fructose (63) and their similar effect on BG and insulin secretion (12). Furthermore, sucrose and HFCS-55 are of similar relative sweetness (64, 65).

The weaker effect of sucrose and HFCS-55 relative to glucose may also be explained by use of a fixed dose (200 kcal) of sugars in the test solutions. There was an inverse association between the energy content of the sucrose and HFCS-55 preloads and subsequent FI. The boys at the higher end of the normal range received a lower dose relative to their BW, which resulted in greater FI after sucrose and HFCS-55. The bigger the boy, the lower the dose relative to BW and therefore the more they ate. In comparison, there was no association between the energy content of the glucose

preload, expressed as kcal/kg BW and subsequent FI. This suggests that the dose was less of a factor after glucose compared to after sucrose and HFCS-55, findings which are consistent with our FI data where only glucose resulted in a statistically significant decrease compared to the Sucralose® control. The larger incretin response to glucose may have overridden the weaker effect of BW based on the lack of statistical significance of BW/kg and FI after glucose compared with the other sugars.

It has been previously observed that FM inversely associates with FI and caloric compensation in children (104, 136, 264). To assess the impact of body composition within the NW range, subjects were grouped based on BMI percentile using a median split to determine if body composition was a factor of FI for boys within the normal range. When comparing boys with a BMI between the 5^{th} and 49^{th} percentile (n=8) to those with a BMI between the 52^{nd} and 83^{rd} percentile (n=7), treatment ($P<0.01$) and weight status ($P<0.01$) affected FI, but not caloric compensation, and there was no treatment x group interaction. When groups were individually assessed using a one-factor model, treatment affected FI in boys with a lower BMI ($P<0.05$) but not those with a BMI between the 52^{nd} and 83^{rd} percentile. Boys with a lower BMI ate significantly less after glucose compared to the control, whereas boys with a higher BMI ate more and did not compensate for the caloric content of the sugars solutions. Furthermore, with the exception of the glucose preload, FM positively associated with FI following the other solutions ($r=0.66$, $r=0.54$ and $r=0.75$ for the control, sucrose and HFCS-55 solutions, respectively). It is unknown how strongly body composition, and specifically FM, affected FI in this study because the preloads were not provided on a BW basis. As a result, although a larger body size resulted in a greater subsequent FI, it in unknown whether body composition or dose is the main driving factor affecting FI among subjects. However, differences in FI between the two groups support previous research suggesting that

differences in body composition affects physiological regulation of FI, with increased FM decreasing an individual's sensitivity to satiety hormones (136).

Caloric compensation, a measure of FI regulation to preload consumed energy, did not differ between sugars solutions or group. Caloric compensation scores for the glucose, sucrose and HFCS-55 preloads were 76%, 26% and 26%, respectively. In a previous study investigating the effect of 180 kcal of sucrose 25 min later in 9 and 10 year-old children, average compensation was 68% after sucrose (265). The weaker effect in older kids in the current study may be due to age, with compensation scores decreasing from childhood into adolescence, or use of a caloric sweetener as the control instead of water. Sweetness alone has been shown to decrease FI in previous studies in children (9, 104) and adults (119). When caloric compensation scores were compared based on BMI percentile, there was a trend (P=0.16) for lower compensation scores in boys with a higher BMI percentile compared to children in the lower BMI percentile range. Caloric compensation scores were significantly lower after sucrose compared to glucose, adding to the notion that treatment dose was a factor in the physiological response to the sugars solutions.

Power analysis indicates that a sample size of 38 and 29 subjects are needed to detect a significant difference in caloric compensation between glucose and sucrose or HFCS-55, respectively, with a power of 0.80. Although a larger sample size may have shown an effect on caloric compensation for the calories in the sugars solutions, the sample size of this study (n=15) was adequately powered to detect an effect of sugars on FI compared to the sweetened control. In addition, it is not uncommon for studies to use a smaller sample size to investigate the effect of macronutrients on FI using a preload design (11, 12, 96).

The weaker effect on FI after sucrose and HFCS-55 may also be explained by matching the solutions for sweetness. It has been proposed that sweet taste alone contributes to the suppression of

hunger and increased feelings of fullness (266) and satiety in children (104) and adults (9, 119). It was reported in children that aspartame-sweetened drinks suppress FI when compared with the effects of a water control (104). Therefore, use of a water control instead of a Sucralose® control in this study may have resulted in greater FI at the test meal after the control solution, increasing the effect of all sugars on the suppression of FI. Other reports, however, suggest that sweetness increases FI (127-129) or is not a factor affecting FI (12, 127). For example, a study by Akhavan et al. (12) did not find a significant relationship between solutions matched for sweetness and FI at a subsequent meal. In the present study, subjective sweetness did not differ among the four sugars solutions and because sweetness did not correlate with FI at the test meal, sweetness may not have been the major determinant of FI. However, it is important to note that all four sugars solutions in this study were rated as quite sweet compared to previous reports of SSB. For example, a study investigating the effect of commercial beverages on FI found average ratings of sweetness for cola and fruit drink to be 55.9 and 78.1 mm, respectively (267). At present, the role of sweetness on FI regulation is unclear as there is no agreement on whether sweetness stimulates or suppresses FI. It is therefore unknown how strongly sweetness affected FI in our study.

Previous research shows that enhancing the pleasantness of a food increases its intake within the meal (268, 269). As a result, pleasantness of the test meal and sugars solutions were measured by asking, 'How pleasant have you found the food/preload?' Pleasantness of the test meal was not affected by preload solution ($P=0.18$) and there was no association between pleasantness of the test meal and FI ($r=0.04$). Furthermore, although the glucose and sucrose solutions were rated as more pleasant than the control, only pleasantness of the glucose solution positively correlated with FI at the test meal. It is therefore unlikely that pleasantness of the test meal or preload had an effect on FI in this study because glucose was rated as the most pleasant and had the lowest FI.

Subjective appetite was measured at baseline (0 min) and again at 15, 30, 45, 60 and 90 min. Preload solution, but not weight status, affected absolute AA and AA expressed as the change from baseline. Although AA scores were significantly greater following the HFCS-55 solution in comparison to the glucose solution ($P<0.05$), changes in AA from baseline were significantly higher following the sucrose solution compared to the other three treatments ($P<0.01$). This suggests that sucrose and HFCS-55 differ in their effect on subjective measures of appetite, but not FI. Differences in AA reported as change from baseline after sucrose and HFCS-55 could be related to differences in osmolality. In animals, hyperosmolality stimulates leptin secretion (270), inhibits gastric emptying (271) and decreases FI (271, 272). Therefore, the enhanced gastric emptying associated with a lower osmolality could explain why changes in AA from baseline were significantly higher after sucrose. However, on days when children consumed the sucrose preload they arrived to the laboratory with lower subjective motivation-to-eat, which is the more likely explanation for a greater increase in AA after sucrose. When AA was assessed based on BMI percentile, weight status was not a factor ($P=0.17$), which suggests it is unlikely the boys with a higher BMI were driving this effect on appetite. Although subjects did not consistently report a decrease in subjective appetite following preload consumption, it appears they were able to quantify their appetite as consumption of the test meal decreased DTE, hunger and PFC and increased fullness, which has been reported by us in previous studies (86, 136).

Similar to AA, thirst was also measured at baseline and again at regular intervals throughout the study. Average thirst decreased at 15 min for all sugars, which suggests that all four solutions immediately quenched thirst. However, change in thirst scores were significantly lower after glucose and HFCS-55 compared to sucrose. Furthermore, although average thirst scores gradually increased after the initial decrease at 15 min, they remained decreased from baseline.

The DEBQ was used in this study to determine the presence of restrained, emotional or external eating behaviours, and their effect on FI (251, 256, 257). With the exception of one occasion, participant scores for the DEBQ did not correlate with FI or caloric compensation following the sugars solutions. Participants were unrestrained eaters, and measures of restraint did not correlate with FI. As a result, it is unlikely that restrained, emotional or external eating behaviours were major factors affecting FI in this study, as has been reported in previous studies in girls (252) and women (249).

The main finding of the present study is that glucose, in comparison to sucrose and HFCS-55, produces greater physiological effects on FI in NW 9- to 14-year-old boys. Although HFCS-55 did not significantly suppress FI compared to the control, it did not differ on its effect on FI, therefore concluding that HFCS-55 is not uniquely responsible for overeating despite a widely held belief that HFCS disproportionally affects FI compared to other sugars (8). In addition, previous studies show that use of HFCS in soft drinks results in decreased FI in both NW and OB children (267, 273). Consistent with our hypothesis, sucrose and HFCS-55 had similar effects on FI in NW boys, which can be related to their similar ratio of glucose: fructose, sweetness and endocrine and metabolic profile. Why FI was not significantly suppressed following the sucrose and HFCS-55 solutions requires further investigation, but could be a result of using a fixed dose and/or matching the solutions for sweetness. The main factor responsible for suppressing subsequent FI was sugars composition, but weight status was also a factor when subjects were grouped by BMI percentile. Therefore, use of glucose alone as the principal sweetener in beverages may be part of the solution to control appetite, reduce FI and promote healthier body weights in children.

6.2. Conclusion

In conclusion, the short-term regulation of FI in NW 9- to 14-year-old boys was affected by sugars source, treatment dose and body composition.

6.3. Methods and Limitations

Although the primary contribution of this thesis is support for the hypothesis that glucose decreases FI to a greater extent than sucrose and HFCS-55, the research contributed by advancing understanding of the nutritional and physiological determinants of childhood obesity and, specifically, the effect of sugars composition.

The use of visual analogue scales (VAS) as a measure of subjective appetite in children has received little investigation. Thirst scores decreased after consumption of the sugars solutions, therefore suggesting subjects were able to express their subjective thirst in a quantifiable manner. Furthermore, subjective appetite of all subjects decreased after the test meal, thus suggesting children understand and can quantify their subjective appetite through the use of VAS, but may also be an indication of the weaker effect of liquid to decrease subjective appetite compared to solid foods. However, subjective appetite scores did not consistently correlate with FI at the test meal.

This research focused on the effect of sugars solutions on FI in normal-weight boys, but to fully understand the interaction between sugars and physiological regulation of FI, the role of gender and BW must be addressed. Therefore, girls and subjects who are OW or OB should be included in future research. Additionally, this research used a fixed dose of 50g available carbohydrate for each sugars treatment. Subjects with a higher BMI percentile had higher FI at the test meal. This could be a result of using a fixed dose if 50g was less effective in heavier subjects. Future studies investigating the effect of sugar composition in children should give treatments based on gram per kilogram BW.

6.4. Future Directions

This research provides evidence for the role of physiological mechanisms on short-term FI and appetite regulation in NW 9- to 14-year-old boys, which differs depending on sugars and body composition. However, the effect of sugar composition and satiety hormones on FI regulation in children requires further investigation. The following issues should be examined in future studies:

1) Is sex a factor affecting short-term FI regulation in children?

Results from this study demonstrate that 9- to 14-year-old boys respond differently to treatments based on their composition. However, to fully understand the interaction between sugars and physiological regulation of FI, the role of gender should be explored. Girls around this age are entering the most active growth stage and are experiencing menarche, both of which may impact FI regulation. Future investigations should include girl subjects in order to determine whether gender has an impact on short-term FI in children.

2) Is body weight a factor affecting short-term FI regulation in children?

Although all subjects included in this study were NW, FI was affected by weight status when boys were grouped based on BMI percentile. Results from previous studies on FI suggest NW and OW or OB subjects respond differently to treatments. As a result, it is recommended future studies further investigate the role of body fatness on short-term regulation and subsequent FI in children.

3) What are the physiological mechanisms regulating short-term FI in children?

Although studies investigating physiological mechanisms in the regulation of short-term FI have been done in adults, little investigation exists in children. The measurement of satiety hormones in response to sugar composition would be an important first step to help develop an understanding of appetite control in children. This information will assist us in understanding how varying sugar composition affects appetite and FI.

4) Does sweetness affect short-term FI regulation in children?

Since all of the sugars solutions were matched for sweetness, this study left unknown the role of sweetness in short-term FI regulation in boys. This is of interest because previous studies on sweetness and FI have produced contrasting results. Therefore, it remains to be determined whether the hedonic value of sugars or the physiologic features is a stronger determinant of FI in children. Future studies should investigate the role of sweetness on short-term FI by using preload solutions of varying sweetness.

Chapter 7

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Chapter 8

APPENDIX

Appendix 8.1. Recruitment Letter for Parents

Effect of Sugars Solutions on Subjective Appetite and Short-Term Food Intake in Children

Dear Parent
Mount Saint Vincent University is leading a team of researchers investigating the physiological and environmental determinants of energy intake regulation on the health and cognitive functioning of children and young adolescents. In our current work we are conducting studies aimed at understanding the controls of food intake in children, with the ultimate goal of finding ways to address the problems of overeating and obesity that are becoming a concern among those people involved in improving the long term health of Canadians. Additionally we are interested in how different types of macronutrients and our ability to metabolize these nutrients might influence memory performance.

We are asking the parents of 9 to 14 year old girls and boys to allow their children to take part in a research study. Their participation is quite straightforward: on four separate weekend mornings, following a 12 hour fast, your child will consume a standard breakfast at home, and then consume a sweet beverage followed by a pizza lunch 60 min later in the Department of Applied Human Nutrition, Mount Saint Vincent University. Between the consumption of the beverage and eating lunch, your child will be presented with a list of common words and asked to recall them immediately and then after a 20 min delay. The study will take place on four weekend mornings at the Evaristus Building (Room 365), Department of Applied Human Nutrition.

There are criteria for participation that you need to be aware of, the child must:

- be between 9 and 14 years of age, and
- be healthy, and have been born at term, and
- not be taking medications.
- not have allergies to milk, wheat or nuts.

As a reward for taking part, at the end of each session the child will be given a gift certificate to Empire Theatres ($10 gift certificate).

If you would like your child to participate, or to get further information beyond that provided in this letter, please contact Ms. Marissa Van Engelen Student Investigator, at (902) 457-6378 or Dr. Nick Bellissimo, Principal Investigator, at (902) 457-6295.

If you have questions about how this study is being conducted and wish to speak with someone who is not directly involved in the study, you may contact the Chair of the University Research Ethics Board (UREB) c/o MSVU Research and International Office, at 457-6350 or via e-mail at research@msvu.ca
Thank you for your support in this important research.

Sincerely,
Dr. Nick Bellissimo, Department of Applied Human Nutrition, Mount Saint Vincent University.
Ms. Marissa Van Engelen, Department of Applied Human Nutrition, Mount Saint Vincent University.
Dr. Michelle Eskritt, Department of Psychology, Mount Saint Vincent University.

Appendix 8.2. Telephone Screening Questionnaire

Telephone Screening Questionnaire (with Parent)

Name: _____

Age: _____ yrs DOB (yy/mm/dd) : _____

Birth Weight: _____ Was your child born at full term? _____

Normal wt? Yes/No (>= 5.5 lbs <= 8.5 lbs) Full term? Yes/No (>= 37 weeks)

Has your child gained or lost weight recently? Yes/No

Does your child usually eat breakfast? Yes/No

Does your child like:
- Cheerios? Yes/No
- Skim Milk? Yes/No
- Orange Juice? Yes/No
- Pizza? Yes/No

Is your child following a special diet? Yes/No

Does your child have food allergies or sensitivities? Yes/No
- Milk, nut, wheat Yes/No

Health problems? Yes/No
If yes, explain: _____

Is your child on medication? Yes/No
If yes, which medication? _____

Education:
Grade: _____
Special Class? _____

Has your child skipped or repeated a grade? Yes/No

Does your child have learning or emotional difficulties? Yes/No

Include in study? Yes/No

If not, why? _____

First appointment date: _____

Investigator: _____

Date: _____

Appendix 8.3. Parental Consent Form

Department of Applied Human Nutrition

Effect of Sugars Solutions on Subjective Appetite and Short-Term Food Intake in Children
Study Information Sheet and Parent's Consent Form

Investigators:

Dr. Nick Bellissimo, PhD, BEd
Principal Investigator
Department of Applied Human Nutrition at Mount Saint Vincent University
Phone: (902) 457-6295
Email: nick.bellissimo@utoronto.ca

Ms. Marissa Van Engelen
Student Investigator
Phone: (902) 457-6378
Email: marissa.van.engelen@msvu.ca

Dr. Michelle Eskritt, PhD
Co-Investigator
Department of Psychology at Mount Saint Vincent University
Phone: (902) 457-6593
Email: michelle.eskritt@msvu.ca

Invitation:
Mount Saint Vincent University is leading a team of researchers investigating the physiological and environmental determinants of energy intake regulation on the health and cognitive functioning of children and young adolescents. In our current work we are conducting studies aimed at understanding the controls of food intake in children, with the ultimate goal of finding ways to address the problems of overeating and obesity that are becoming a concern among those people involved in improving the long term health of Canadians. Additionally we are interested in how different types of macronutrients and our ability to metabolize these nutrients might influence memory performance. We are asking the parents of 9-14 year old girls and boys to allow their children to take part in a research study.

Purpose of Research:
The purpose of this study is to determine the effects of sugars containing beverages on food intake regulation in normal weight 9-14 year-old girls and boys. This experiment is being conducted through the Departments of Applied Human Nutrition and Psychology at Mount Saint Vincent University by Marissa Van Engelen, Dr. Nick Bellissimo and Dr. Michelle Eskritt. Your child will be required to

attend four experimental sessions conducted over a 4-week period, for a total of 5 visits (4 food intake measurement sessions + 1 information/screening visit) to the Mount Saint Vincent University campus. Each visit will last approximately 90 min.

Procedure:
Appetite Assessment:
For those parents who express interest in having their child participate, some information about the child will be requested by telephone, by the investigator, Ms. Marissa Van Engelen. If the child was born at term, is healthy and does not receive any medications, an information/screening session will be arranged.

During the information/screening session, the researcher will explain the full details of the study. Parents that give consent to have their child participate will sign a consent form. The parent will receive copies of the consent form and of the study information sheet. If the child wishes to participate and signs a children's assent form, their weight, height, and body fat by skinfold caliper at 4-points (biceps, triceps, suprailiac, and subscapular), will be measured.

The children will then be asked to rank their preference for pizza that will be served as the lunch meal at each session.

The children who participate in this study will be requested to go to the Evaristus Building (Rm. 365), Department of Applied Human Nutrition, Mount Saint Vincent University, for four individual weekend morning sessions over a four week period.

On each of the four test days, the children will have a standardized breakfast of cereal, milk and orange juice at home, either at 8:00 am, 9:00 am or 10:00 am (the time will be consistent for each child). The children will arrive at the Evaristus Building, either at 10:00 am, 11:00 am or 12:00 pm (but consistent throughout for each child).

Children will fast for 12 hours before breakfast and after breakfast until their arrival, except for water (which will be allowed up to one hour before their arrival).

Each child will receive one glass of sweetened Kool-aid containing sugar or artificial sweetener. The amount of sugar in the drink will be similar to the amount found in common soft drinks.

McCain pizza and spring water (purchased at Sobey's or Atlantic Superstore) will be served 60 min after the children have consumed their beverage. Children will be told that they may eat as little or as much as they like. The amount of food eaten by each child will be measured.

The children will also be requested to complete scales on which they will place a pencil mark to describe their desire to eat ("Very weak" to "Very strong"), hunger ("Not hungry at all" to "As hungry as I've ever felt"), fullness ("Not full at all " to "Very full"), how much food they could eat ("A large amount" to "Nothing at all"), thirst ("Not thirsty at all" to "As thirsty as I ever felt") sweetness of the drinks ("Not sweet at all" to "Extremely sweet"), pleasantness of the preload and pizza ("Not at all Pleasant" to "Very Pleasant", and physical comfort ("Not well at all" to "Very well") . They will complete these scales during the information/screening session, in order to become familiar with the

test instruments.

The children will be fully supervised during the study sessions. The children will be engaged in age appropriate entertainment (as distraction) such as reading, playing puzzles or card games before lunch.

Memory test:
During each session between the consumption of the beverage and eating lunch, your child will be presented with a list of common words to remember. Your child will asked to recall the words both immediately and then after a 15, 30 and 45 min delay, and immediately after lunch. Your child will be given a chance to try the memory test during the information/screening session so they know what to expect.

Eating Behaviour Questionnaire:
If you consent to your child's participation in this experiment, he/she will also be asked to fill out a short questionnaire about their eating habits during the information/screening visit or after one of the food intake sessions. A trained examiner will help your child fill out the questionnaire. The answers will be strictly confidential and will only serve to assist in the analysis of the data collected. Your child may skip any questions of the questionnaire that make them feel uncomfortable.

Confidentiality:
Records relating to subjects will be kept confidential in a locked cabinet in the Department of Applied Human Nutrition and no disclosure of personal information of the children or parents will take place except where required by law. Subjects will have a code and a number that will identify them in all documents, records and files to keep their name confidential. All data will be entered into Microsoft Excel files, available only to investigators. Each participant will have a file, also only available for investigators. All forms and printouts will be stored in the individual files – and clearly labeled. All documents will be kept for a minimum of five years following completion of the study and then securely destroyed.

Benefits:
As the causes of obesity remains undefined, the potential benefits from this study will be a better understanding of the regulation of food intake in children and might contribute to the prevention of obesity in children.

Questions and further information:
If you have any questions or would like further information concerning this research project, please do not hesitate to call: Dr. Nick Bellissimo or Ms. Marissa Van Engelen at (902) 457-6378.

Dissemination of findings:
A summary of results will be made available to you to pick up, or if requested will be sent by mail or e-mail, after the study is completed.

Consent:
I acknowledge that the research procedures described above and of which I have a copy, have been explained to me and that any questions that I have asked have been answered to my satisfaction. I know that I may ask additional questions now or in the future. I am aware that participation in the

study will not involve any health risk to my child.

I understand that for purposes of the research project, if my child or I choose to withdraw from the study at any time, we may do so without prejudice.

Upon completion of each study session, my child will receive a $10 Empire Theatre gift certificate. I will also receive $5 to cover transportation costs following each study session. The final summary and results of the study will be available for me to pick up from the Department of Applied Human Nutrition, Mount Saint Vincent University. I am aware that the researchers may publish the study results in scientific journals, keeping confidential my child's identity.

If you have questions about how this study is being conducted and wish to speak with someone who is not directly involved in the study, you may contact the Chair of the University Research Ethics Board (UREB) c/o MSVU Research and International Office, at 457-6350 or via e-mail at research@msvu.ca

I hereby consent for my child, _____, to participate in this study.

_____ _____
(Name of parent or guardian) (Signature of parent or guardian)

_____ _____
(Name of witness) (Signature of witness)

Date: _____ (dd/mm/yy)

Appendix 8.4. Children's Assent Form

Department of Applied Human Nutrition

Effect of Sugars Solutions on Subjective Appetite and Short-Term Food Intake in Children

Children's Assent Form

Purpose of Research:
The purpose of this study is to determine the effects of sugar-sweetened beverages on appetite and memory in children. My weight, height, and body fat will be measured during the information/screening visit. I will also be required to drink a different beverage (within 5 min) each week, and complete special scales to show if I am hungry or full during each session. I will fill-out a short questionnaire about my eating behaviours, and know that I am allowed to skip any questions that may make me feel uncomfortable. The researchers will give me a quick memory test to see how many words I can remember. I will also be provided with a pizza lunch at the end of each study session (that I will eat in the Department of Applied Human Nutrition, Mount Saint Vincent University). All the experimental sessions will be on weekends, so I don't need to be absent from school.

I know that my participation in the study will not involve any health risk to me.

Also, if at any time I decide to stop participating, that will be O.K. I understand that information related to me will be kept confidential. I know that I will receive a $10 Empire Theatre gift certificate after completion of each study session, as a "thank you" for my participation.

"I was present when _____read this form and gave his/her

Signature

Name of the person who obtained assent:

_____

Date: _____ (dd/mm/yy)

Appendix 8.5. Screening Information Form

SCREENING INFORMATION SESSION – FOOD INTAKE IN CHILDREN

Subject Information

Name: _____ Phone #: _____

Age: _____ decimal years DOB (d/m/y): _____

Health Status

Weight: _____kg Height: _____cm IBW: _____kg

IBW: _____ kg

Skinfold Thickness

Biceps: _____mm Triceps: _____mm Skinfold Sum: _____mm

Suprailiac: _____mm Subscapular: _____mm Fat Mass: _____%

Include in study?

(Y/N) _____ If yes, subject #: _____ Subject code: _____

If not, why? _____

Forms Completed?

Food acceptability list completed? (Y/N) _____

Consent/assent forms signed? (Y/N) _____

Dutch Eating Behaviour Questionnaire? (Y/N) _____

Practice word recall (Y/N) _____

Standardized breakfast given for next session? (Y/N) _____

BEVERAGE

At all study sessions, your child will receive a sweet beverage. Please indicate whether your child will be able to drink a sweet beverage provided at each session. (Y/N) _____

LUNCH

The child will be provided with a pizza meal the day of the study. To enable us to provide your child with a meal that they will enjoy, which type of pizza should we serve? Pepperoni/Cheese?

Name of parent/guardian: _____

Investigator: _____

Date (d/m/y): _____

Start date and time: _____

Appendix 8.6. Dutch Eating Behaviour Questionnaire

Dutch Eating Behaviour Questionnaire

Please read each question and circle the appropriate response.

1. If you have put on weight, do you eat less than you usually do?

Never Seldom Sometimes Often Very often

2. Do you try to eat less at meal times than you would like to eat?

Never Seldom Sometimes Often Very often

3. How often do you refuse food or drink offered because you are concerned about your weight?

Never Seldom Sometimes Often Very often

4. Do you watch exactly what you eat?

Never Seldom Sometimes Often Very often

5. Do you deliberately eat foods that are slimming?

Never Seldom Sometimes Often Very often

6. When you have eaten too much, do you eat less than usual the following day?

Never Seldom Sometimes Often Very often

7. Do you deliberately eat less in order not to become heavier?

Never Seldom Sometimes Often Very often

8. How often do you try not to eat between meals because you are watching your weight?

Never Seldom Sometimes Often Very often

9. How often in the evenings do you try not to eat because you are watching your weight?

Never Seldom Sometimes Often Very often

10. When you eat, do you take into account what you weigh?

Never Seldom Sometimes Often Very often

11. Do you have the desire to eat when you are irritated?

Never Seldom Sometimes Often Very often

12. Do you have the desire to eat when you have nothing to do?

Never Seldom Sometimes Often Very often

13. Do you have the desire to eat when you are depressed or discouraged?

Never Seldom Sometimes Often Very often

14. Do you have a desire to eat when you are feeling lonely?

Never Seldom Sometimes Often Very often

15. Do you have a desire to eat when somebody lets you down?

Never Seldom Sometimes Often Very often

16. Do you have a desire to eat when you are angry?

Never Seldom Sometimes Often Very often

17. Do you have a desire to eat when you are expecting something unpleasant to happen?

Never Seldom Sometimes Often Very often

18. Do you get the desire to eat when you are anxious, worried or tense?

Never Seldom Sometimes Often Very often

19. Do you have a desire to eat when things are going against you or when things have gone wrong?

Never Seldom Sometimes Often Very often

20. Do you have a desire to eat when you are frightened?

Never Seldom Sometimes Often Very often

21. Do you have the desire to eat when you are disappointed?

Never Seldom Sometimes Often Very often

22. Do you have a desire to eat when you are bored or restless?

Never Seldom Sometimes Often Very often

23. Do you have a desire to eat when you are emotionally upset?

Never Seldom Sometimes Often Very often

24. If food tastes good to you, do you eat more than usual?

Never Seldom Sometimes Often Very often

25. If food smells and looks good to you, do you eat more than usual?

Never Seldom Sometimes Often Very often

26. If you see or smell something delicious, do you have the desire to eat it?

Never Seldom Sometimes Often Very often

27. If you have something delicious to eat, do you eat it straight away?

Never Seldom Sometimes Often Very often

28. If you walk past the baker, do you have the desire to buy something delicious?

Never Seldom Sometimes Often Very often

29. If you walk past a snack bar or a cafe, do you have the desire to buy something delicious?

Never Seldom Sometimes Often Very often

30. If you see others eating, do you also have the desire to eat?

Never Seldom Sometimes Often Very often

31. Can you resist eating delicious foods?

Never Seldom Sometimes Often Very often

32. Do you eat more than usual when you see others eating?

Never Seldom Sometimes Often Very often

33. When your mother or father is preparing a meal, are you inclined to eat something?

Never Seldom Sometimes Often Very often

Appendix 8.7. Feeding Session Cover Sheet

Feeding Session Cover Sheet
Department of Applied Human Nutrition, Mount Saint Vincent University

Food Intake Control in Children

Subject ID: _____ Session: ____

Date: _____

Baseline Questionnaire (to be asked by investigator)

1. Have you had the standardized breakfast this morning? YES/NO

2. At what time did you have the standardized breakfast? _____

3. Have you had anything to eat or drink for 10 - 12 hours before breakfast? YES/NO

If yes, please describe briefly _____

4. Have you had anything to eat or drink after breakfast before arriving here? YES/NO

If yes, please describe briefly _____

5. Are you taking any medication? YES/NO

If yes, please describe briefly _____

Comments/Notes:

Appendix 8.8. Study Day Test Package

STUDY DAY TEST PACKAGE

VAS – Motivation to Eat

VAS – Physical Comfort

VAS – Perceived Sweetness

VAS – Pleasantness (preload beverage)

VAS – Pleasantness (pizza lunch)

Appendix 8.8.1. Motivation to Eat Visual Analogue Scale

Time =

Visual Analogue Scale
Motivation to Eat

DATE: _____

ID: _____

These questions relate to your "motivation to eat" at this time. Please rate yourself by placing a small "**x**" across the horizontal line at the point which best reflects your present feelings.

1. How strong is your desire to eat?

Very WEAK _____ Very STRONG

2. How hungry do you feel?

NOT Hungry at all _____ As hungry as I have ever felt

3. How full do you feel?

NOT Full at all _____ VERY Full

4. How much food do you think you could eat?

NOTHING at all _____ A LARGE amount

5. How thirsty do you feel?

NOT thirsty at all _____ As thirsty as I have ever felt

Appendix 8.8.2. Physical Comfort Visual Analogue Scale

Time =

Visual Analogue Scale
Physical Comfort

DATE: _____

ID: _____

These questions relate to your "physical comfort" at this time. Please rate yourself by placing a small "x" across the horizontal line at the point which best reflects your present feelings.

How well do you feel?

NOT well at all _____ VERY Well

Appendix 8.8.3. Sweetness Visual Analogue Scale

Time =

Visual Analogue Scale
Sweetness

Subject ID: _____

Date: _____

Please rate the level of sweetness by placing a small "x" across the horizontal line at the point which best reflects your present feelings.

How sweet have you found the beverage?

NOT sweet at all _____ Extremely sweet

Appendix 8.8.4. Preload Pleasantness Visual Analogue Scale

Time =

Visual Analogue Scale
Pleasantness of Preload

DATE: _____

ID: _____

This question relates to the palatability of the drink you just consumed. Please rate the pleasantness of the beverage by placing a small "**x**" across the horizontal line at the point which best reflects your present feelings.

How pleasant have you found the preload?

NOT at all pleasant _____ Very pleasant

Appendix 8.8.5. Test Meal Pleasantness Visual Analogue Scale

Time =

Visual Analogue Scale
Pleasantness of Test Meal

DATE: _____

ID: _____

This question relates to the palatability of the food you just consumed. Please rate the pleasantness of the food by placing a small "x" across the horizontal line at the point which best reflects your present feelings.

How pleasant have you found the food?

NOT at all pleasant _____ Very pleasant