

The Influence of Weight Status on the Link between Television Viewing and Food Intake in Children

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Abstract

Recent research suggests that sedentary behaviours have detrimental effects on the health and well-being of children, including effects on obesity. Specifically, television viewing is consistently associated with childhood obesity. Two explanations have been proposed: 1) reduced energy expenditure, and 2) increased food intake. However, it has been suggested that the association between television viewing and childhood obesity may be better explained by an increase in energy intake than by a reduction in energy expenditure. To date, children of different weight status have not been compared in their dietary patterns in front of the television, and it is not known if total sedentary time is linked with food intake in children. The objectives of this thesis are: 1) to determine if obese children consume food more frequently while watching television than normal weight children, and 2) to examine which of television viewing or total sedentary time better predicts dietary patterns in children. Overall, our results re-affirm the notion that television viewing is associated with obesity, although physical activity plays a role in this association. Also, children who are obese consume fast food and fruits/vegetables more frequently during television watching than normal weight children. Furthermore, television viewing appears to be a better predictor of dietary patterns in children than overall sedentary time. Globally, these results provide evidence for the deleterious effects of television viewing on children's dietary patterns and justification for future intervention studies designed to reduce television viewing in children with obesity.

Contributions

The work in this thesis is my own, and I take full responsibility for its contents. I use data from the International Study of Childhood Obesity, Lifestyle and the Environment (ISCOLE), of which I was a key member of the data collection team during the entirety of data collection (September 2012 – May 2013). I was responsible for managing the accelerometry aspect of the study, which included initializing, administering, downloading, and managing over 1100 accelerometers. This is a manuscript-based thesis, which contains two papers. For each of these manuscripts I am the primary author and was responsible for the conceptual design of the paper, literature review, statistical analysis, writing the paper, preparing the tables and figures and submitting for publication. At the time of submission, manuscript #1 was under review in the *Journal of Nutritional Sciences* and manuscript #2 was in press in *Applied Physiology, Nutrition, and Metabolism*.

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I must also express my thanks to my co-supervisor Dr. Éric Doucet, and my committee members Drs. Gary Goldfield and Denis Prud’homme. Their comments and suggestions from my proposal can be seen throughout this thesis, and they have helped to guide me through this process. Gary has also provided me with opportunity to work on side projects throughout my degree, often helping me to answer research questions related to this thesis, and I am very thankful for this.

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With utmost sincerity,

Michael Borghese

Prelude to Thesis

In my thesis I use data from the International Study of Childhood Obesity, Lifestyle and the Environment (ISCOLE). Ethical approval for the study was provided by the Children's Hospital of Eastern Ontario Research Institute and the University of Ottawa research ethics boards, as well as the institutional review boards of the participating school boards (Appendix A). This is a manuscript-based thesis, which contains two papers using data from ISCOLE.

In chapter 1, I provide a general introduction to the topic of childhood obesity and sedentary behaviour/television viewing in children, briefly identify gaps in the literature, and outline the specific objectives and hypotheses of my thesis. In chapter 2, I provide a comprehensive review of the literature on childhood obesity, television viewing, and both energy expenditure and food intake explanations. Although the methods of data collection are described within each manuscript, in chapter 3, I provide a detailed description of the relevant materials and methods used in the ISCOLE study to improve clarity. Chapter 4 contains manuscript #1, which examines the role of weight status on variation in frequency of consumption of food items in front of the television in children. Chapter 5 contains manuscript #2, which examines the associations of both television viewing time and total sedentary time with food intake patterns in children. Chapter 6 discusses the implications of the findings in chapters 4-5, within the context of the literature described in chapters 1 and 2, as well as strengths and limitations of the thesis, public health implications, and opportunities for future research. The appendix contains supporting documentation as well as manuscripts, published abstracts, and conference presentations that I have authored or co-authored

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Chapter I – Introduction

1.1 General Introduction

Childhood obesity has become a major public health concern in recent decades in Canada (Roberts et al., 2012; Shields, 2006) and is associated with a myriad of health problems, including insulin resistance, type 2 diabetes, hypertension, poor emotional health, and diminished social well-being (Roberts et al., 2012). Childhood obesity is thought to be the result of an “obesogenic” environment (Chaput et al., 2012a), and is ultimately characterized by a positive energy balance. Recent research has begun to focus on sedentary behaviour, defined as any waking behaviour ≤ 1.5 METs while in a sitting or reclined posture (Sedentary Behaviour Research Network, 2012), and its relationship with childhood obesity. The results on the association between total sedentary time and obesity in children are mixed, with studies suggesting that each direction of association is independent of moderate-to-vigorous physical activity (MVPA) (Chaput et al., 2012c; Ekelund et al., 2012; Mitchell et al., 2013a). However, there is evidence to suggest that the type of sedentary behaviour, such as screen-based sedentary behaviours, may be more important than overall sedentary time for predicting cardio-metabolic health outcomes in children (Chaput et al., 2012b). For instance, television viewing has been shown to be positively associated with obesity in children (Dietz and Gortmaker, 1985; Mitchell et al., 2013a; Tremblay et al., 2011b), often independent of physical activity levels, while overall sedentary time is not consistently associated with obesity in children (Chaput et al., 2012c).

Television viewing has been referred to as the most important sedentary behaviour affecting overweight in children (Rey-López et al., 2008); this is not surprising considering it is estimated that children will spend more than 3 years watching television, not including

time spent watching videos, playing video games, or using a computer, before they are adults (Robinson, 1998). Previous literature has identified four possible explanations that may explain the relationship between television viewing and childhood obesity (Bryant et al., 2007; Robinson, 2001); although there are others which are discussed in the current thesis. The first proposed explanation is the ‘displacement hypothesis’, which suggests that television viewing, along with screen-based sedentary behaviours in general, displaces opportunities for children to engage in physical activity. The second explanation proposes that television watching decreases children’s energy expenditure during viewing. The third explanation suggests that television watching promotes between-meal snacking, thus increasing daily caloric intake. Finally, the fourth explanation suggests that television program content, specifically food advertisements, exerts a negative influence on children’s food choices/preferences and attitudes towards healthy lifestyles. However, it has recently been suggested that the relationship between television viewing and obesity may be more about “energy in” than “energy out” (Borghese and Chaput, 2013; Epstein et al., 2008).

In support of the “energy in” explanation, recent research has suggested that modern sedentary behaviours, such as television viewing, may promote an overconsumption of food in the current obesogenic environment (Chaput et al., 2011). Indeed, the association between television viewing and obesity in children is thought to be driven by increased food intake (Borghese and Chaput, 2013; Epstein et al., 2008; Robinson, 2001; Wiecha et al., 2006), as children’s dietary and television viewing patterns are related (Pearson and Biddle, 2011). Furthermore, this increased food intake may be seen even in the absence of hunger (Bellisle et al., 2004; Chaput et al., 2011), emphasizing the importance of hedonic mechanisms of food intake.

A recent review by Thivel et al. (2013) concluded that further studies are needed to delineate whether nutritional adaptations to modern sedentary behaviours, such as television viewing, are similar or different between children who are normal weight or overweight/obese(Thivel et al., 2013). Identifying differences in dietary habits with television viewing in children of varying weight status will provide much needed evidence for the explanations behind the relationship between television viewing and obesity. Furthermore, given that television viewing is highly prevalent in the pediatric population, targeting this behaviour at a population level has the potential to impact a large number of individuals.

Furthermore, while there is much evidence to suggest that television viewing and food intake are associated in children, this has not been the case for total sedentary time. A comparison of television viewing and total sedentary time, with respect to associations with food intake, has not been undertaken. It may be that the associations observed between television viewing, and lack thereof for sedentary time, and obesity may be explained by food intake.

1.2 Objectives

The general objective of this thesis is to improve our understanding of the associations between television viewing, food intake, and obesity in children. The focus of the objective is on the two aforementioned knowledge gaps:

- 1) To compare children of different weight status groups (i.e. normal weight, overweight, obese) in their food intake patterns while watching television;

2) To determine which of self-reported television viewing time or objectively measured total sedentary time is a better predictor of frequency of consumption of healthy and unhealthy foods in 9-11-year-old Canadian children.

1.3 Hypotheses

1) We hypothesized that children who are overweight or obese would a) watch more television; b) consume 'unhealthy' foods more frequently while watching television; and c) consume fruits/vegetables less frequently while watching television, as compared to their normal-weight counterparts.

2) We hypothesized that higher self-reported television viewing time would be positively associated with the frequency of consumption of unhealthy foods and negatively associated with the frequency of consumption of healthy foods. We also hypothesized that there would be no association between total sedentary time and healthy or unhealthy food intake patterns.

Chapter 2 - Literature Review

2.1 Childhood Obesity

Obesity is thought to be the result of an “obesogenic” environment – an environment which promotes a positive energy balance (Chaput et al., 2012a). There are a multitude of factors that contribute to the development of excess adiposity, especially in children. Obesity in children is defined using age- and sex-specific growth curves for height and weight in order to standardize variation in growth rates and biological maturity. Various percentile cut-points for body mass index (BMI) growth curves have been created, and their use is widespread throughout the literature. Growth curves generated by the Centers for Disease Control and Prevention (CDC) were derived from 5 nationally representative surveys conducted in the United States between 1963 and 1994 (Kuczmarski et al., 2002). Using these cut-points, normal weight, overweight, and obesity are defined as $>5^{\text{th}}$ but $<85^{\text{th}}$, $\geq 85^{\text{th}}$ but $<95^{\text{th}}$, and $\geq 95^{\text{th}}$ sex- and age-specific BMI percentiles, respectively (Krebs et al., 2007).

Weight status in school-aged children can also be defined using age- and sex-specific cut-offs provided by the World Health Organization (WHO) where overweight and obese are defined as +1 SD and +2 SD above the mean, or 84^{th} percentile and 97.7^{th} percentile, respectively (de Onis et al., 2007). The differences between CDC and WHO cut-offs are marginal for overweight (85^{th} percentile and 84^{th} percentile, respectively), and larger for obese (95^{th} percentile and 97.7^{th} percentile, respectively) (Shields and Tremblay, 2010). Children selected for inclusion into the creation of the WHO growth curves were those who were deliberately exposed to socio-economic conditions favourable for ideal growth and development. Thus, the WHO cut-offs are ‘prescriptive-based’, suggesting how

children *should* grow, while the CDC cut-offs are ‘descriptive-based’, illustrating how children *do* grow.

Finally, cut-offs developed by the International Obesity Task Force (IOTF) extrapolate backwards from the adult BMI cut-offs for overweight (25 kg/m²) and obesity (30 kg/m²) to generate curves in childhood that intersect these points upon adulthood (Cole et al., 2000). These cut-points tend to underestimate overweight and obesity, but are useful for population level surveillance of overweight and obesity and international comparisons (Shields and Tremblay, 2010).

Obesity in children has been shown to be associated with insulin resistance, type 2 diabetes, hypertension, poor emotional health, and diminished social well-being (Roberts et al., 2012). The prevalence of childhood obesity in Canada has been increasing since the late 1970s (Shields, 2006), and now nearly one-third of Canadian children are overweight or obese based on World Health Organization cut-offs (Roberts et al., 2012). Furthermore, obese children tend to maintain their obesity into adolescence (Nader et al., 2006) and into adulthood (Whitaker et al., 1997); the risk of becoming an obese adult is 2-6.5 times higher for obese children (Serdula et al., 1993). This further increases their risk of developing type 2 diabetes, cardiovascular disease, high blood pressure, osteoarthritis, some cancers, psychosocial problems, and disability (Janssen et al., 2005b; Tjepkema, 2006). The prevention of childhood obesity is therefore a major public health issue.

Beyond the health of any individual or population, there are economic effects associated with high rates of obesity. Obesity in adults is associated with higher direct medical costs (spending on diseases related to obesity), loss of productivity (through absenteeism, presenteeism [decreased productivity of employees at work], disability, and

premature mortality), and other economic costs such as transportation costs and human capital accumulation costs (Hammond and Levine, 2010). In 2004, the direct medical costs of obesity in Canada were estimated to be \$1.6 billion, while the indirect economic costs were even higher at \$2.7 billion (Katzmarzyk and Janssen, 2004); overall, representing 2.2% of total health care expenditure in Canada. The direct and indirect economic burden of obesity in Ontario alone in 2011 was as much as it was in Canada in 2004 - \$1.60 billion and \$2.87 billion, respectively (Katzmarzyk, 2011) – and has increased from \$647 million and \$905 million, respectively, since 2001 (Katzmarzyk and Janssen, 2004). The economic costs of obesity are rising and accelerating – this alone makes it crucial that we better understand this public health challenge. Although Canadian data are currently not available, data from the United States show that the annual direct costs of obesity in children specifically in the US are approximately \$14.3 billion (Cawley, 2010; Hammond and Levine, 2010; Trasande and Chatterjee, 2009). As mentioned above, children who are overweight or obese tend to carry this weight with them into adulthood (Whitaker et al., 1997; Serdula et al., 1993) and will thus have an increased length of exposure to this risk factor associated with the health complications seen in adults. It is estimated that the costs of adult obesity in today’s children over the next 10-40 years will be US\$ 254 billion (Lightwood et al., 2009). Large-scale reductions in childhood obesity may therefore function to reduce the individual and societal burden of obesity both now, and in the future.

Research aiming to better understand the development of childhood obesity on a population level must focus on the “causes of the cause” (Rose et al., 2008) or the factors that drive this positive energy gap seen as a result of the obesogenic environment. One of

the possible drivers is excess sedentary behaviour, specifically screen-based sedentary behaviours, such as television watching.

2.2 Sedentary Behaviour

Historically, research examining the ‘energy out’ side of the energy balance equation has focused on high-intensity physical activity, or lack thereof (Tremblay et al., 2011b); the quantification of time spent in sedentary pursuits has received far less attention (Dietz, 1996). This is despite the fact that Canadian children spend the majority of their time, 8.6 hours per day or 62% of their waking time, in sedentary pursuits (Colley et al., 2011). The relationship between sedentary behaviours and deleterious health consequences was noted as early as the 17th century by the occupational physician Bernardino Ramazzini (Franco and Fusetti, 2004). Only recently, several centuries later, has the field of sedentary physiology emerged as a legitimate field of study that is complementary to, but distinct from, the field of exercise physiology (Tremblay et al., 2010). There is now a growing body of evidence to suggest that there are negative physiological and health consequences of a sedentary lifestyle in children and youth, independent of physical activity level (Tremblay et al., 2011b, 2010).

In the past, the term ‘sedentary’ was constructed as conceptually being a lack of moderate-to-vigorous, or high-intensity, physical activity (Tremblay et al., 2010). However, sedentary behaviours are now defined as being any waking behaviour characterized by energy expenditure ≤ 1.5 METs while in a sitting or reclining posture (Sedentary Behaviour Research Network, 2012). It is now accepted that sedentary behaviours have independent and qualitatively different effects on human metabolism (specifically, fat and carbohydrate metabolism), physical function, and health outcomes

than simply a lack of MVPA (Tremblay et al., 2010). In adults, a sedentary lifestyle has been shown to be associated with increased cardiometabolic risk and all-cause mortality (Katzmarzyk et al., 2009). Sedentary lifestyles are deleterious in children as well - it has been shown that 1) a reduction in screen-based sedentary behaviours is associated with a reduction in health risk (Epstein et al., 2008), 2) lowering screen-based sedentary time leads to reductions in BMI, and 3) daily TV viewing in excess of 2 hours is associated with reduced fitness (overall fitness, musculoskeletal and cardiorespiratory fitness, and VO_2 max), physical health, and psychosocial health, including higher depressive symptoms, low self-esteem, and decreased perceptions of self-worth (Tremblay et al., 2011a, 2011b).

Thus, sedentary behaviours should be viewed as a separate construct from physical activity (Hamilton et al., 2008, 2007, 2004; Healy et al., 2008; Owen et al., 2010, 2000; Pate et al., 2008; Rosenberg et al., 2008), at least in their relationship to obesity (Tremblay and Willms, 2003), adiposity (Ekelund et al., 2006), and cardiometabolic risk. **Figure 2.1** illustrates how sedentary and exercise physiology can co-exist, while being conceptually distinct.

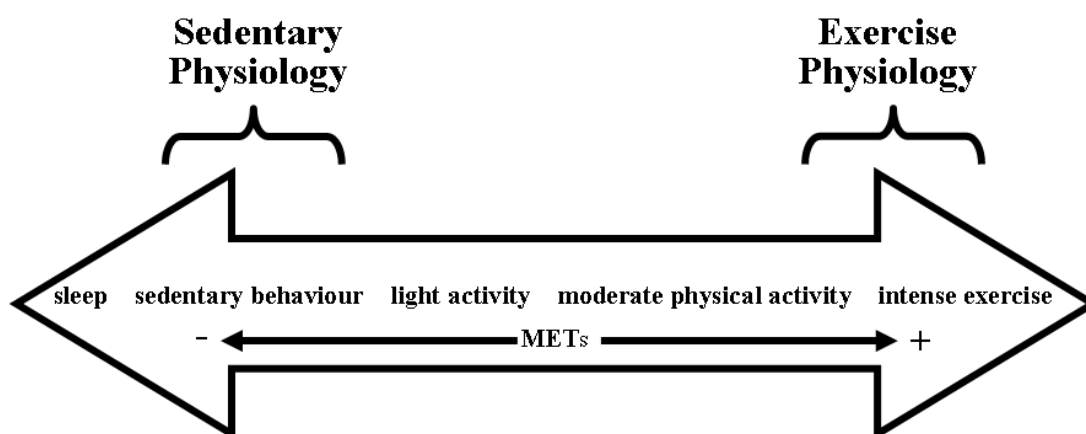


Figure 2.1: The movement continuum, illustrating the different focus of sedentary physiology and exercise physiology. METs: metabolic equivalent tasks. *Reproduced with permission from Tremblay et al, 2010.*

However, the literature is mixed with respect to the association between objectively measured sedentary behaviour and health risk in children (Saunders et al., In Press). Some studies have shown that overall sedentary time is associated with poor health outcomes in children (Cliff et al., 2013; Mitchell et al., 2013a), while other studies have shown no association (Chaput et al., 2013, 2012c; Ekelund et al., 2012). However, there is evidence to suggest that the type of sedentary behaviour may be more important in predicting health risk. For example, Carson and Janssen (2011) found, in a nationally representative sample of American children, that self-reported television viewing was independently associated with clustered cardiometabolic disease risk, while there was no association between objectively measured sedentary time and cardiometabolic disease risk (Carson and Janssen, 2011).

Indeed, screen-based sedentary behaviours may have differing metabolic and health effects than non-screen sedentary behaviours (Chaput et al., 2012b). Television viewing is by far the most studied screen-based sedentary behavior by virtue of its ubiquitous incorporation into modern lifestyles over several decades. Following the seminal paper linking television and obesity in children by Dietz and Gortmaker in 1985, research into television viewing and childhood obesity accelerated (Bryant et al., 2007). It is now known that television viewing in children is associated with cardiometabolic health risk (Carson and Janssen, 2011; Goldfield et al., 2013; Mark and Janssen, 2008; Staiano et al., 2013), psychological health risk (Tremblay et al., 2011b), as well as obesity (Ekelund et al., 2006; Must and Tybor, 2005; Tremblay et al., 2011b), independent of physical activity levels. Furthermore, television viewing in adults is associated with increased risk of all-cause and cardiovascular mortality (Dunstan et al., 2010) and has been shown to reduce life

expectancy – each hour of television viewing after age 25 reduces an individual's life expectancy by 21.8 minutes (Veerman et al., 2011).

2.3 Television Viewing and Childhood Obesity

Television viewing is the primary sedentary behaviour of children (Rideout et al., 2010) and is one of the most important factors affecting overweight in children (Hancox and Poulton, 2006; Robinson, 2001). The changing nature of television viewing makes this behavior difficult to accurately measure. Television viewing time continues to increase in children, despite the fact that traditional television viewing has decreased in recent years; this is largely due to increased time spent watching television using contemporary mediums, such as on computers, tablets, or smart-phones (Rideout et al., 2010). Canadian children spend an average of 14.1 hours/week watching television (Statistics Canada, 2006); however, when all media sources of television are considered, it is estimated that children aged 8-10 and 11-14 years watch 3.7 hours and 5.1 hours of television per day, respectively (Rideout et al., 2010). Television viewing time peaks at 9-12 years of age (Marshall et al., 2006), and children who are considered 'high' users of television (>4 hours per day) (American Academy of Pediatrics, 2001) are likely to remain high users as they age (Marshall et al., 2006). Boys tend to watch more television than girls (Rideout et al., 2010), but this trend is influenced by age (Marshall et al., 2006). The American Academy of Pediatrics (2013) continues to recognize the health risks associated with television viewing, including the development of childhood obesity, and recommends that parents limit their children's screen time to <2 hours per day and remove televisions from children's bedrooms, and that children <2 years of age do not engage in screen time (American Academy of Pediatrics, 2013).

As mentioned above, the link between television viewing and overweight and obesity in children was reported for the first time in the literature approximately 3 decades ago (Dietz and Gortmaker, 1985). This relationship has been echoed in cross-sectional (Andersen et al., 1998; Crespo et al., 2001; Grund et al., 2001; Hernández et al., 1999; Jackson et al., 2009; Maher et al., 2012), longitudinal (Gable et al., 2007; Gortmaker et al., 1996; Hancox and Poulton, 2006; Hancox et al., 2004; Henderson, 2007; Kaur et al., 2003; Mitchell et al., 2013b), and intervention studies (Epstein et al., 2008; Robinson, 1999), as well as reviews of the literature (Gorely et al., 2004; Marshall et al., 2004; Saunders et al., In Press; Tremblay et al., 2011b, 2010), throughout the past ~30 years. In summary, television viewing is associated with childhood obesity in a dose-response manner such that each additional hour of television viewing associated with a higher odds of being obese (Gortmaker et al., 1996). However, this dose-response relationship is may not be linear and the effect tends to accelerate over time; children's television viewing was found to be positively associated with both absolute increases in BMI and acceleration of a child's BMI trajectory over time (Danner, 2008). In Canada, children aged 6-11 years who report more than 2 hours of screen time are twice as likely to be overweight or obese than those who report less than 2 hours (Shields, 2006) independent of children's physical activity levels; this is similar to results from nationally representative US studies (Sisson et al., 2009), as well as results from Europe (Rey-López et al., 2012). In some studies, screen-based sedentary behaviours (i.e. screen time) have been shown to be more strongly associated with obesity and BMI (Hancox et al., 2004), as well as the risk of being overweight or obese (Maher et al., 2012; Rey-López et al., 2012), than MVPA.

Furthermore, watching more television as a child is predictive of BMI throughout the life course (Viner and Cole, 2005). It has been estimated that the risk of being overweight at age 15 increases by 22% for each hour of television viewing at age 13 (Van den Bulck and Hofman, 2009), and that 17% of the prevalence of overweight at age 26 can be attributed to watching >2 hours of television in childhood, independent of MVPA (Hancox et al., 2004). Finally, in their review of 137 593 youth from 34 countries, Janssen et al. (2005) noted that in most countries television viewing time was higher in children who were overweight, compared to children who were normal weight (Janssen et al., 2005a). Several explanations have been proposed to explain the relationship between television watching and obesity, and are discussed herein.

2.3.1 Reduced Energy Expenditure

The concept of time use displacement with television viewing was identified in the 1960s when television first emerged in mainstream society (Mutz et al., 1993). The displacement hypothesis of television viewing suggests that an increase in the amount of time spent in this sedentary pursuit directly decreases the amount of discretionary time available for physical activity (Mutz et al., 1993), thus decreasing daily energy expenditure and leading to a positive caloric balance. Television viewing has been shown to displace a number of activities in children (Hornik, 1981) including, but not limited to, homework, reading time, sleeping or playing with friends (American Academy of Pediatrics, 2001). While there is some evidence to suggest that television viewing and MVPA may be related (Herman et al., 2013; Parsons et al., 2005), the displacement hypothesis has been refuted theoretically on the basis that physical activity and television watching are not functionally

similar; displacement of one type of activity for another usually occurs when the two satisfy a common need (Mutz et al., 1993). There is an established body of evidence to suggest that television viewing time is not necessarily related to time spent in MVPA (Biddle et al., 2004; de Jong et al., 2013; Ekelund et al., 2006; Mutz et al., 1993) and that low levels of screen-based sedentary time do not necessarily predict high levels of MVPA (Fakhouri et al., 2013). Furthermore, it is possible for children to be “active couch potatoes”, i.e. to obtain high amounts of both sedentary time and MVPA (Katzmarzyk et al., 2009). In summary, the “displacement hypothesis” is not the most likely explanation driving the relationship between television viewing and obesity in children (Biddle et al., 2004; Ekelund et al., 2006; Grund et al., 2001; Jenvey, 2007; Marshall et al., 2004; Rey-López et al., 2008; Saunders et al., In Press; Van den Bulck and Hofman, 2009; Vandewater et al., 2006). This notion is further supported by evidence in adults (Cleland et al., 2008).

It is also said that television watching may decrease a child’s energy expenditure during viewing (Robinson, 2001), thus leading to a decrease in total energy expenditure and a positive caloric balance. The evidence to support this explanation is, however, limited. Klesges et al. (1993) found that the energy expenditure of children was lower when they were watching television than when they were at rest (Klesges et al., 1993). However, Dietz et al. (1994) found that resting energy expenditure did not change with television viewing, as compared to reading or sitting quietly (Dietz et al., 1994), which is consistent with findings in adults (Buchowski and Sun, 1996). Dietz et al. (1994) also found that children tended to fidget more when they were sitting quietly than when they were reading or watching television (Dietz et al., 1994). It is not yet known whether the reduction in

energy expenditure found by Klesges et al (1993) is simply a result of children's attentional allocation to the television set, and thus a reduction in fidgeting.

If television viewing does not promote a positive energy balance by modifying energy expenditure, then it stands to reason that it does so by modifying energy intake. In fact, studies have shown that reducing television viewing has an important role in preventing obesity and lowering BMI in children, and that this may be more related to changes in food intake than to changes in physical activity or energy expenditure (Epstein et al., 2008; Ludwig and Gortmaker, 2004; Robinson, 1999; Saunders et al., In Press; Swinburn and Shelly, 2008). Further, longitudinal studies have shown that the association between screen-based sedentary behaviours and change in BMI is independent of MVPA, supporting the notion that these changes are mediated by food intake (Falbe et al., 2013; Jackson et al., 2009; Rey-López et al., 2008).

2.3.2 Increased Energy Intake

A number of sedentary behaviours have been associated with an increase in food intake in our current obesogenic environment, including television viewing (Chaput et al., 2011; Thivel et al., 2013). Television viewing has been shown to have a stronger effect on food intake patterns and adiposity than other sedentary behaviours (Olafsdottir et al., 2013). For example, television viewing is associated with increased meal frequency and quantity (Coon et al., 2001; Crespo et al., 2001; Matheson et al., 2004; Sonnevile and Gortmaker, 2008). Total food intake has also been shown to increase for each additional hour of television watched (Crespo et al., 2001; Sonnevile and Gortmaker, 2008; Wiecha et al., 2006), and children who watch more television are more likely to consume

sweets (Vereecken et al., 2006) and less likely to consume fruits or vegetables (Barr-Anderson et al., 2009; Gebremariam et al., 2013; Santaliestra-Pasías et al., 2012; Vereecken et al., 2006) or to have healthy food habits (Hare-Bruun et al., 2011). Furthermore, longitudinal studies have shown that television viewing is associated with an increase in daily caloric intake, and that this increase is mediated by a higher consumption of calorie-dense foods (Gebremariam et al., 2013; Pearson et al., 2011), which are frequently advertised on television (Arcan et al., 2013; Wiecha et al., 2006), along with lower consumption of fruits (Pearson et al., 2011) and vegetables (Boynton-Jarrett et al., 2003; Gebremariam et al., 2013). Finally, a systematic review of 24 independent samples of children by Pearson and Biddle (2011) concluded that television viewing is consistently inversely associated with fruit and vegetable consumption, and positively associated with consumption of energy-dense snacks and drinks, total energy intake, and fast foods (Pearson and Biddle, 2011).

Sugar-sweetened beverage consumption is common in children and there is strong evidence to support the relationship between television viewing and sugar-sweetened beverage consumption (Barr-Anderson et al., 2009; Gebremariam et al., 2013; Giammattei et al., 2003; Santaliestra-Pasías et al., 2012), as the amount of sugar-sweetened beverages consumed increases in a dose-response manner with the number of hours of television watched (Olafsdottir et al., 2013). Sugar-sweetened beverage consumption has increased remarkably in the past half century (Popkin, 2010), and is associated with higher BMI in children (Giammattei et al., 2003).

Fast food consumption is also ubiquitous in society – 30% of US children consume fast food on a typical day (Bowman et al., 2004) – and high television viewing is associated

with increased consumption of fast food (French et al., 2001). In a nationally representative household survey, children who ate fast food, compared with those who did not, consumed more total energy, energy per gram of food, fat, carbohydrate, added sugars, sugar-sweetened beverages, along with less fiber, milk, fruits, and non-starchy vegetables (Bowman et al., 2004). Furthermore, when children consumed fast food they tended to eat more total energy and have poorer diet quality, as compared to days when they did not eat fast food (Bowman et al., 2004). Consumption of fast food is associated with television viewing, and has important implications for the development of obesity in children.

Few formal mediation analyses have been conducted to determine whether or not dietary patterns mediate the association between television viewing and obesity in children. One longitudinal mediation analysis showed that dietary patterns mediate the association between television viewing and BMI in children (Fuller-Tyszkiewicz et al., 2012). However, Carson and Janssen (2012) showed with the use of a large cross-sectional study that food intake did not mediate the relationship between television viewing and BMI (Carson and Janssen, 2012). However, these results should be interpreted with caution, as children's height and weight were parent-reported in their analysis instead of objectively measured as in the paper by Fuller-Tyszkiewicz et al. (2012). Also, Carson and Janssen (2012) merged responses from several food items to create a composite score of foods, which did not allow the authors to elucidate the effects of specific foods on BMI. Furthermore, television time was split into quartiles as opposed to being dichotomized into <2 and >4 hours per day, as recommended by the American Academy of Pediatrics (2001). Differences between the findings of these two formal mediation analyses may be related to

the use of different measures of obesity, television time, and study design (longitudinal vs. cross-sectional). Additionally, the lack of association between dietary patterns and overweight in children is often attributed to the difficulties in measuring food intake (Lissner, 2002), as well as the idea that differences in caloric intake required to lead to weight gain may be too small to detect (Reilly et al., 2007), and that individuals who are overweight may under-report food intake (Heymsfield et al., 1995; Trabulsi and Schoeller, 2001). Thus, more evidence is definitively needed before concluding that food intake does not mediate the relationship between television viewing and childhood obesity, especially given the limitations associated with observational evidence.

Television viewing differs from other sedentary behaviours in that it offers an avenue for food marketers to advertise their products to potential consumers. Food promotion is the most prevalent marketing category targeting children (Cairns et al., 2009), and the majority of food-product advertisements seen on television by children and adolescents are of poor nutritional content (Powell et al., 2007). In 1990, food advertisements constituted 9.6 minutes of programming time per hour in the United States (Story and Faulkner, 1990). In 2005, 83% of foods advertised during children's television programs were convenience/fast foods or sweets, and between-meal snacking was depicted more often than breakfast, lunch, and dinner combined (Harrison and Marske, 2005). The majority of foods and food products promoted on television to children are energy dense and high in fat, sugar, and salt, such as sugar-sweetened breakfast cereals, soft drinks, confectionary, and savoury snacks (Cairns et al., 2009) – collectively known as the ‘Big Four’ in the advertising industry (Hastings et al., 2003) – while the promotion of unprocessed foods, such as fruit and vegetables, whole grains and milk is very low (Cairns

et al., 2009). Furthermore, in 2006 in the United States, the food and beverage industry spent \$1.6 billion marketing foods and beverages to children and adolescents (Federal Trade Commission, 2008). In parts of Canada, the food and beverage industry self-regulates the marketing of foods to children; however, there is evidence to suggest that this self-regulation has no effect on children's marketing environments (Potvin Kent et al., 2011), and this does not appear to limit the amount of food or beverage advertising that children are exposed to (Potvin-Kent et al., 2011).

A systematic review in the UK concluded that food advertisements influence children's knowledge about food, their preference for foods, and their purchasing behaviors (Hastings et al., 2003). The results of this review were validated by an independent panel of experts for the UK government, who concluded that the systematic review by Hastings et al. (2003) "provided sufficient evidence to indicate a causal link between promotional activity and children's food knowledge, preferences and behaviours" (UK Food Standards Agency, 2003). Indeed, television advertisements have been shown to increase daily food intake by up to 45% in children (Harris et al., 2009), and are associated with obesity in children (Zimmerman and Bell, 2010). Internationally, there is a strong correlation between the proportion of children considered overweight or obese and the number of food advertisements that children are exposed to, especially those that encourage the consumption of energy-dense, micronutrient-poor foods (Lobstein and Dobb, 2005). The content of food advertisements appears to have an effect on childhood obesity, as advertisements for foods that are high in sugar or fat are particularly strongly linked with childhood obesity, while advertisements for healthy foods may have a mild protective effect against obesity (Lobstein and Dobb, 2005). It may be that children who are obese

have a heightened alertness to food-related cues in that they recognize more food-related television advertisements than their normal-weight counterparts (Halford et al., 2007, 2004). Further, the same authors found an association between the ability to recognize a food advertisement and the quantity of food eaten after viewing the advertisement.

While television watching has been shown to increase food intake throughout the whole day, food intake has also been shown to increase while children are watching television, even in the absence of television advertisements (Marsh et al., 2013). It has been reported that 18-26% of total energy intake may be consumed in front of the television in children and adolescents (Matheson et al., 2004; Van den Bulck and Van Mierlo, 2004). Snacking during television viewing may also mediate other food patterns, such as consumption of energy-dense snacks and drinks (Pearson et al., 2011). Also, eating in front of the television has been shown to be associated with obesity, independent of MVPA (Rey-López et al., 2012). These results are echoed in studies in adults as well, as meals, snacks, soft drinks and alcohol partially mediate the association between television viewing and waist circumference (Cleland et al., 2008).

Indeed, overconsumption of food is associated with a number of sedentary behaviours in children (Chaput et al., 2011), such as television viewing. Unfortunately, there is very little evidence examining the driving factors of this association in children; in lieu of this, the literature has adopted research from the field of adult obesity to describe what may happen in children. Increased food intake while watching television is thought to be driven by several factors, including an attentional allocation to TV stimulus (Bellisle et al., 2004; Stroebele and de Castro, 2004), which can lead to delayed and reduced mealtime satiety signals (Bellisle et al., 2004; Bellissimo et al., 2007), as well as satiety signals from

previous meals (Bellissimo et al., 2007). Results from a recent meta-analysis indicate that eating in the presence of distractions (such as watching television, listening to music, or reading) moderately increases immediate intake (Robinson et al., 2013). There is evidence to suggest that these factors are not within an individual's control, as enhancing the awareness of food being eaten may not affect immediate intake (Robinson et al., 2013).

Beyond the physiological effects of television on satiety, the meta-analysis by Robinson et al. (2013) also suggests that eating in the presence of distractions substantially increases later intake, and that these effects may be related to cognition (Robinson et al., 2013). Drawing one's attention away from food may serve to impair memory formation about how much food is being eaten and may lead to overconsumption, for both immediate and later intake. For example, if a meal is remembered as being satiating, this may have an inhibitory effect on later food intake. The ability to create episodic food memories provides an individual with the means to use information about the physiologic effects of food eaten at a prior meal to inform future consumption. Distraction may also disrupt habituation to rewarding qualities of food (Temple et al., 2007), through alterations in the creation of associative or episodic food memories (Epstein et al., 2011). This is supported by the finding that enhancing an individual's memory of food consumed at a prior meal can reduce later food intake (Robinson et al., 2013).

Not only does television viewing alter an individual's inhibitory control, as mentioned above through distraction, habituation, and episodic memory mechanisms, but it may also increase the reward saliency of food through classical conditioning mechanisms (Chapman et al., 2012; Rodin and Marcus, 1982). Repeated pairing of television with food may result in the formation of linked memories that condition an individual to anticipate

food intake when they watch television; this learned response is especially important in human feeding behaviour (Bellisle, 1979). Thus, eating in front of the television, when performed repeatedly, may strengthen linked memories and this association may be integrated into children's lifestyle. Furthermore, television viewing itself may become a conditioned cue to eat (Chapman et al., 2012), and in children this has the potential to increase the frequency of consumption of specific foods, as well as total caloric intake.

2.4 Gaps in the Literature

The evidence supporting the link between television viewing and obesity in children is strong. In reality, both the 'energy out' and 'energy in' explanations influence these associations; although, there is much stronger evidence for the role of food intake in the association between television viewing and childhood obesity. However, few studies have measured food intake in children during television watching (Matheson et al., 2004; Rey-López et al., 2012; Van den Bulck and Van Mierlo, 2004); the majority of studies have only assessed daily food intake over a 24-hour period. As noted by Thivel et al. (2013), there is currently a lack of evidence on how children who are overweight/obese or of normal weight may differ in their food intake patterns in front of the television (Thivel et al., 2013). The third chapter of this thesis aims to address this gap in the literature.

While the association between television viewing and food intake has been unequivocally demonstrated in the literature, there is no evidence to date to suggest that total sedentary time is associated with food intake in children. This represents a gap in the literature, as associations with food intake may explain the mixed findings observed between total sedentary time and television viewing, with obesity and adiposity in children

(Chaput et al., 2012c; Ekelund et al., 2012; Mitchell et al., 2013a). The fourth chapter of this thesis aims to address this gap in the literature.

Chapter 3 – ISCOLE Study Design and Methodology

3.1 Overview of the ISCOLE Project

The International Study of Childhood Obesity, Lifestyle, and the Environment (ISCOLE) is a multi-national, cross-sectional study based out of Baton Rouge, Louisiana, USA (Coordinating Center). The primary purpose of ISCOLE is to construct a statistical model which can predict adiposity in children based on dietary habits and physical activity, as well as other environmental variables. A more detailed description of ISCOLE study design and methods can be found elsewhere (Katzmarzyk et al., 2013). Data from the NHANES 2005/2006 study informed an *a priori* power calculation which indicated that a sample size of 500 participants from each of the 12 international sites would allow for statistical power of 97%, when $\alpha=0.05$ and variance in adiposity (R^2) explained by either dietary habits or physical activity =3%. The targeted overall sample included 6000 10-year-old children from 12 countries in five major geographic regions of the world (Europe, Africa, the Americas, South-East Asia, and the Western Pacific). All analyses in this thesis are secondary data analyses; the power calculation for the ISCOLE study is based on primary outcomes other than those used in this thesis.

A standard study protocol was developed for implementation in all regions of the world. A rigorous system of training and certification of study personnel was developed and implemented, including web-based training modules and regional in-person training meetings. Data from the Canadian site of the ISCOLE project (PIs: Mark Tremblay and Jean-Philippe Chaput) will be used for the proposed analyses outlined herein. Inclusion and exclusion criteria for the Canadian site of the ISCOLE project are as follows:

The inclusion criteria are such that participants must:

- Assent and have parental consent to participate in the study;
- Reside in one of the four school districts nearest to the data collection site (Ottawa, Ontario);
- Be enrolled in an urban or sub-urban school within one of the four Ottawa school boards.

The exclusion criteria of the study are such that participants were excluded if:

- They do not provide consent or assent for their participation;
- They were enrolled in an elementary school in a rural location, as defined by the boundaries set out by the four Ottawa school boards;
- Participants with a pacemaker or other internal medical device were precluded from participating in the bioelectric impedance analysis portion of the study, because weak currents from the equipment may cause these devices to malfunction. These participants were still eligible for, and are included in, all other aspects of the study.

Data were collected in school, during school hours, with 597 children who provided assent and parental consent for participation in ISCOLE Canada, and who met inclusion/exclusion criteria. After inclusion/exclusion criteria, and absences from school, data were collected on 567 (57.1% female; 9-11 years of age) children in the 5th grade from the Ottawa Region between September 2012 and May 2013. Schools were stratified into four groups based on Ottawa school boards: English Public (n=393; 69.3%), French Public (n=60; 10.6%), English Catholic (n=75; 13.2%), and French Catholic (n=39; 6.8%). All schools within each stratum were invited to participate and the first to respond were

included into the study, until data were collected on 500 children as per the above power calculation. (NB: Recruitment ceased once the sample size of 500 children was met, but data were collected on an additional 67 children who had already provided consent and assent). Complete data, defined as participants providing all primary study endpoints, were obtained from 541 children, representing 91% (541/597) of children who provided consent/assent and 95% (541/567) of children who participated in data collection. Ethical approval from the Research Ethics Board at the Children's Hospital of Eastern Ontario Research Institute was granted in June of 2011 and from the four Ottawa district school boards in September of 2012. Ethical approval for the inclusion of ISCOLE Canada data in the current thesis was obtained in August of 2013. See Appendix A for ethics approval documents.

3.2 Relevant Materials and Methods

3.2.1 Anthropometry

This study uses measured height and weight to derive BMI instead of proxy- or self-reports because of the potential for misclassification of children into BMI categories with proxy or self-reports (Shields et al., 2011). Anthropometric data were collected at the schools on the primary day of testing and were collected by the same study personnel, whenever possible. In this thesis childhood obesity is defined according to CDC age- and sex-specific growth curves to allow for comparison with much of the published literature and since these descriptive-based cut-offs may better reflect the current sample of Canadian children who may or may not be exposed to conditions ideal for growth and development. Using these cut-points, normal weight, overweight, and obesity are defined as $>5^{\text{th}}$ but

<85th, ≥85th but <95th, and ≥95th sex- and age-specific BMI percentile, respectively (Krebs et al., 2007).

Standing height was measured to the nearest 0.1cm using a SECA 213 portable stadiometer. Participants were asked to remove footwear and hair accessories, place their hands at their sides with their feet together, while maintaining contact with the stadiometer at 4 locations: their heels, buttocks, back and head. Participants were also asked to inhale and hold their breath, and keep their head in the Frankfort Plane, where the horizontal line from the ear canal to the lower border of the orbit of the eye is parallel to the floor and perpendicular to the vertical backboard. Study personnel then lowered the slide to the vertex of the head, recorded the measurement, and repeated this process. Two measurements were averaged, unless they were greater than 0.5 cm apart where a third measurement was taken and the closest two values were averaged.

The participant's weight to the nearest 0.1kg and impedance were measured using the portable Tanita Body Composition Analyzer (SC-240). The Tanita SC-240 was chosen because it allows data to be downloaded directly to a laptop during data collection, thus reducing the potential for data entry errors. Participants removed outer clothing, heavy pocket items, footwear, and socks. Participants' weight, body fat percentage, and impedance were recorded both into the connected computer, and on a backup data collection form. Two measurements were taken and averaged, unless the difference was greater than 2.0 kg for weight or 2.0% for percent body fat apart, in which case a third measurement was taken and the closest two values were averaged. Measurements were typically done in the morning; however, due to scheduling difficulties some measurements were taken during the afternoon.

3.2.2 Measures of Food Intake: The Food Frequency Questionnaire

The food frequency questionnaire (FFQ) was adapted from the Health Behaviour in School-aged Children Survey (HBSC) (Currie et al., 2008), and asked the participants how often they consumed 23 different types of food in a “usual” week. There were 7 response options ranging from ‘never’ to ‘every day, more than once’. Children in this study were also asked how often they consume 6 food items while watching television, a tool which was adapted from Van den Bulck and Van Mierlo (2004):

- Potato chips or peanuts
- Fried foods such as chicken wings, chicken fingers, French fries, etc.
- Cookies, biscuits, chocolate or candy bars
- Ice cream
- Fast foods such as pizza, hamburgers, etc.
- Fruits or vegetables

There is evidence to suggest that children aged 8 years and over can reliably recall foods eaten in the recent past provided that the time period under investigation is not subject to irregular events and/or eating patterns (Livingstone and Robson, 2000). There appears to be an inverted U-shaped curve with ability to recall foods eaten and age, with children aged 8-12 completing food recall questionnaires more reliability than those younger and older than them (Livingstone and Robson, 2000). Food recall methods may be beyond the intellectual capacity of children younger than 8, who may not have the cognitive maturity to complete such questionnaires. Furthermore, food recall methods completed by children older than 12 may be hindered because of a lack of motivation and issues with social desirability bias and perception of body image, in addition to ever-

present recall bias. Indeed, in adults the validity of the food recall methods is generally poor (Archer et al., 2013; Heymsfield et al., 1995; Schoeller et al., 2013); however, it has been suggested that intake data obtained from children are more valid than data from adults (Bellisle, 2001). As children in the ISCOLE study are between the ages of 8 and 12, this may increase the reliability of this tool.

The underlying principle of the FFQ method is that average long-term diet is the conceptually important exposure, rather than food intake on specific days (Willett, 2012). Other measures of food intake, such as diet recall interviews and diet records, may not be as feasible as they rely on an individual's episodic memory as opposed to their generic memory; the former of which is more difficult to describe. These methods are also generally expensive, significantly increase participant burden, may be under-representative of usual intake if only a few days are assessed, and may be inappropriate to assess past diet (Willett, 2012). Furthermore, these methods suffer from the same social desirability bias as FFQ methods, which is thought to drive under-reporting (Heymsfield et al., 1995). However, one major advantage to methods that quantify total caloric intake is the ability to identify individuals who under-report caloric intake based on comparisons with objectively measured energy expenditure (Poslusna et al., 2009) – this method has identified considerable flaws in previous research methodologies using 24-hour food recalls (Archer et al., 2013).

FFQ methods of dietary assessment are advantageous in large, epidemiological studies because they are inexpensive, easy to complete, and assess long-term dietary patterns, which is the relevant exposure of interest for such studies (Willett, 2012). Furthermore, a recent review of the literature by Mattes (in press) suggests that frequency

of consumption may play a larger role in the weight gain than portion size (Mattes, 2014). The FFQ method was selected for use in ISCOLE for the aforementioned reasons, and in order to reduce participant burden and to improve retention and compliance.

3.2.3 Measures of Sedentary Behavior: Accelerometry and Self-Report

There are a variety of methods to measure sedentary behaviours in children, including both objective and subjective ones. Objective measures include motion devices, such as accelerometry, and direct observation, such as video taping and using television time recorders (Hardy et al., 2013). Due to the invasiveness of direct observation, accelerometers have been primarily used as an objective measure of total sedentary time in children (Colley et al., 2012a; Hardy et al., 2013) and have been shown to accurately classify children's behaviour as being sedentary (Lubans et al., 2011). The primary disadvantage of using accelerometers to measure sedentary behaviour is that they do not provide contextual information (Hardy et al., 2013). Despite their improved feasibility over direct observation, accelerometers may still be invasive enough to reduce participant compliance, especially in children.

Subjective measures, such as proxy- or self-report measures, overcome these limitations as they provide contextual information of specific behaviours and are non-invasive, but they are subject to substantially more measurement error, including recall and social desirability biases, as well as variation in interpretation of questions (Hardy et al., 2013). Furthermore, these methods quantify sedentary behaviours as distinct from time spent standing or not wearing a device. Self-report measures of specific sedentary behaviours, such as television viewing, have been shown to be reliable, but their validity remains largely untested (Lubans et al., 2011). Despite being influenced by recall and

social desirability biases, it has been suggested that self-report measures of television viewing are appropriate to determine the health effects of these behaviours in children (Bryant et al., 2007). As suggested by the literature (Hardy et al., 2013; Lubans et al., 2011), ISCOLE has incorporated both objective and subjective measures of sedentary behaviours to measure sedentary behaviours in children.

The Canadian site of ISCOLE study uses the ActiGraph GT3X+ accelerometer to objectively measure the movement behaviours in children. Total sedentary time was measured using the ActiGraph GT3X+ accelerometer. The ActiGraph GT3X+ was chosen as the objective measure of movement behaviours because of recent advances in the objective measurement of total sleep time using this device (Tudor-Locke et al., 2014). Sedentary time was defined as all minutes showing <100 counts per minute, which is a widely used cut-point in the literature (Wong et al., 2011). Devices were given to the children during classroom time and qualified research staff gave instructions. Children were asked to wear the devices 24 hours per day for at least 7 consecutive days (worn at the waist on an elasticized belt), to wear it as often as possible, and to only remove it for aquatic activities. Compliance calls were conducted on one weekday and one weekend day during the week the child was wearing the device by trained research staff to ensure that children wore the device as often as possible. Also, an in-person compliance audit was conducted on the day following the school visit to ensure that the children were wearing the devices properly. The devices were retrieved from the schools and data were downloaded and stored at the Children's Hospital of Eastern Ontario Research Institute.

Data reduction conformed to the approach outlined by Colley et al. (2010), which suggests that children are included in analyses only if we have 4 valid days of data, where a

valid day is defined as greater than 10 hours of wear time (Colley et al., 2010). Data were collected at sampling rate of 80 Hz, downloaded in 1-second epochs, and were aggregated to 15-second epochs (Evenson et al., 2008).

A screen time questionnaire, adapted from the HBSC study (Currie et al., 2008), was used to measure the amount of time spent in various screen-based sedentary behaviours. Children were asked how many hours of television they watch on a typical school day as well as on a typical weekend day. The response options included: no television watching, <1 hour, 1 hour, 2 hours, 3 hours, 4 hours, and 5 or more hours of television per day. Self-report methods of quantifying screen time have been shown to have acceptable reliability in children (Lubans et al., 2011). As mentioned above, direct methods of quantifying television viewing exist (Bryant et al., 2007), such as videotaping or using television time recorders; however, these methods can reduce external validity because of their invasiveness. ISCOLE aimed to assess the amount of television that children watch during a typical week with the highest possible external validity in order to draw meaningful conclusions about this sample of Canadian children. The weighted-average method of determining television viewing per day based on self-report of television viewing time on weekdays and weekends has been used in the literature (Herman et al., 2013), and is used herein.

3.2.4 Physical Activity Assessment

Physical activity assessment is a primary outcome of ISCOLE and the ActiGraph GT3X+ accelerometer was used as a measure of physical activity in children. MVPA is used as a covariate in the analyses herein. Cut-points for moderate (>574 counts/15 sec, or

>2296 counts/min) and vigorous (>1003 counts/15 sec, or >4012 counts/min) were adopted from Evenson et al. (2008).

3.2.5 Covariates

Demographic questionnaires completed by parents were used to determine children's age (from date of birth reported by the parents), sex and ethnicity (White/Caucasian, African American, Asian, First Nations, East Indian, "don't know", or "other"). These are important covariates to consider because age (Marshall et al., 2006), sex, and ethnicity (Gorely et al., 2004) have been shown to be associated with television viewing in children. Parents were also asked to identify their combined total household income before taxes from 8 options ranging from less than \$14,999 to \$140,000 and above and to identify the highest level of education completed by the child's mother and father from 6 options (less than high school, some high school, high school diploma/GED, diploma or 1-3 years of college, bachelor's degree, graduate [master's or PhD/professional] degree). Parental income and education level have consistently been shown to be associated with television viewing (Cameron et al., 2012; Gorely et al., 2004) and consumption of some foods (Cameron et al., 2012); thus these variables are also important to consider in such analyses. For the analyses in this thesis, the highest level of education completed by either parent will be used; in cases where there is missing data for either parent, the available datum is used.

Somatic maturity is an important variable to consider in analyses of obesity in children, as children of similar age can vary greatly in their degree of maturation (Malina et al., 2004). The ISCOLE study uses two methods to assess somatic maturation: (1) percentage of predicted adult stature attained, using the Khamis-Roche method (Khamis and

Roche, 1994) to predict adult stature, and (2) the maturity offset method (Mirwald et al., 2002), which estimates age from an individual's peak height velocity. The maturity offset method is used to represent somatic maturation in the proposed analyses. This method of assessment of somatic maturity has been validated using a longitudinal sample of Canadian children (Mirwald et al., 2002).

Sleep time has been shown to impact obesity in children (Chaput et al., 2011). Total sleep period time was assessed using the ActiGraph GT3X+ and was included as a covariate in most analyses. Furthermore, fat mass is an important variable to consider in the associations between sedentary behaviours and food intake, and obese children generally have higher energy requirements (Institute of Medicine of the National Academies, 2005). Fat mass was determined by bioelectric impedance analysis using a Tanita SC-240 Body Composition Analyzer (Arlington Heights, IL), which is a valid measure of fat mass in children (Barreira et al., 2013).

Chapter 4 – Manuscript I: Television Viewing and Food Intake
Patterns of Lean and Overweight/Obese 10-year-old Canadian

Children

This article has been submitted for publication to the Journal of Nutrition Sciences and is presented in the format required for publication.

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Running Title: TV viewing, food intake and childhood obesity

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4.1 Abstract

It is unclear if children of different weight status differ in their nutritional habits while watching television. The objective of this paper is to determine if children who are overweight or obese differ in their frequency of consumption of six food items while watching television compared to their normal-weight counterparts. A cross-sectional study of 550, 5th grade children (57.1% female; mean age = 10 years) from Ottawa, Canada was conducted. Children's weight status was categorized using the Centers for Disease Control and Prevention cut points. Questionnaires were used to determine the number of hours of television watching per week and the frequency of consumption of six types of foods while watching television. Overweight/obese children watched more television per day than normal-weight children (3.3 hours vs. 2.7 hours, respectively, $p=0.001$). Children who watched more than 4 hours of television/day had higher odds [OR (95% CI): 3.21 (1.14-9.03); $p=0.03$] of being obese, independent of several covariates, but not independent of moderate-to-vigorous physical activity (MVPA). Obese children consumed fast food and fruits/vegetables more frequently while watching television than normal weight or overweight children ($p<0.05$). In conclusion, high television watching was associated with obesity in children aged 9-11 years independent of covariates, but not independent of MVPA. Obese children consumed fast food more frequently while watching television than normal-weight and overweight children; this association may be driven by the nutritional habits of obese children. Obese children also consumed fruits/vegetables more frequently, which is contrary to the literature and will require validation in future studies.

Abbreviations

MVPA – Moderate-to-vigorous physical activity

ISCOLE – International Study of Childhood Obesity, Lifestyle and the Environment

CDC – Centers for Disease Control and Prevention

IQR – Inter-quartile range

4.2 Introduction

Childhood obesity is an important public health concern and nearly one-third of Canadian children are considered overweight or obese ⁽¹⁾. Television viewing has been identified as an important behaviour associated with overweight and obesity in children ^(2,3). High television viewing time (>4 hours/day) ⁽⁴⁾ has been shown to be positively associated with childhood obesity ⁽⁵⁻⁷⁾. Historically, the association between television viewing and obesity in children has been thought to be driven by the displacement of moderate-to-vigorous physical activity (MVPA) with increased television viewing. However, there is evidence to suggest that the displacement hypothesis may not be the most likely explanation for this relationship ⁽⁸⁻¹¹⁾.

Another potential explanation for the association between television viewing and obesity is the role of food intake. Television viewing is associated with an overconsumption of food in the current obesogenic environment ⁽¹²⁾. Specifically, high television viewing time has been reported to be inversely associated with fruit and vegetable consumption, and positively associated with consumption of energy-dense snacks and drinks, fast food and total energy intake ⁽¹³⁾. However, the evidence for the role of food intake, specifically while watching television, in the association between television viewing and obesity is limited. The observation of increased food intake while watching television is thought to be driven by several distraction-related factor and habituation to satiety cues ⁽¹⁴⁻¹⁸⁾. Furthermore, television advertising can prompt consumption during viewing and may lead to unhealthy food choices ⁽³⁾. Van den Bulck and Van Mierlo ⁽¹⁹⁾ showed that each hour of television viewing was associated with the consumption of an additional ~156 kcal/day in youth. However, the authors examined only absolute energy

intake, not food types. A better understanding of the types of foods that children eat in front of the television is crucial to the development television and dietary intervention studies designed to reduce overconsumption in children. As children can consume 19-26% of their daily energy intake in front of the television^(19,20), further research into the types of food children consume in front of the television is needed. Furthermore, the authors above did not differentiate between children of different weight status. It is not known if children who are normal weight, overweight or obese differ in their food intake patterns in front of the television.

Thus, the aim of this paper is to compare children of different weight status groups in their food intake patterns while watching television. This analysis is novel as it considers the consumption of food items specifically while watching television. It is hypothesized that children who are overweight or obese would 1) watch more television; 2) consume ‘unhealthy’ foods more frequently while watching television; and 3) consume fruits/vegetables less frequently while watching television than their normal-weight counterparts.

4.3 Methods

4.3.1 Participants

The International Study of Childhood Obesity, Lifestyle and the Environment (ISCOLE) is a multi-national, cross-sectional study conducted in 12 countries; details pertaining to the study design and methods, including sample size justification, can be found elsewhere⁽²¹⁾. Analyses herein include data from the Canadian site of ISCOLE. Data were collected in schools on 567 children in the 5th grade (57.1% female; 9-11 years of age) from the Ottawa area between September 2012 and May 2013. Schools were

stratified into four groups: English Public (n=393; 69.3%), French Public (n=60; 10.6%), English Catholic (n=75; 13.2%), and French Catholic (n=39; 6.8%). This project was approved by the research ethics boards at the Children's Hospital of Eastern Ontario and the University of Ottawa, as well as by the participating school boards.

4.3.2 Anthropometric Measurements

Trained study staff collected anthropometric data and administered questionnaires in schools during school hours. Weight was measured to the nearest 0.1 kg using a portable Tanita Body Composition Analyzer (SC-240). Standing height was measured to the nearest 0.1 cm using a SECA 213 portable stadiometer. Normal weight, overweight, and obesity were defined as $>5^{\text{th}}$ but $<85^{\text{th}}$, $\geq 85^{\text{th}}$ but $<95^{\text{th}}$, and $\geq 95^{\text{th}}$ sex-specific body mass index (BMI) percentile, respectively, as defined by the Centers for Disease Control and Prevention (CDC) ⁽²²⁾. CDC cut points were used to define overweight and obesity to allow for comparison with much of the published literature. Children who were underweight (n=15), as well as children who did not provide a valid measure of weight (n=2), were excluded from the analysis; thus, data were analyzed with 550 children.

4.3.3 Television Viewing and Food Frequency Questionnaire

During the school visit participants completed a diet and lifestyle questionnaire which included a self-reported measure of television viewing as well as a food frequency questionnaire (FFQ) to assess the frequency of consumption of six food items while watching television ⁽²¹⁾.

The screen time questionnaire, obtained from the U.S. Youth Risk Behavior Surveillance System ⁽²³⁾, asked children how many hours of television they watch on a typical school day as well as on a typical weekend day. The response options included: no

television watching, <1 hour, 1 hour, 2 hours, 3 hours, 4 hours, and 5 or more hours of television per day. A weighted mean number of hours of television watching per week was calculated as follows: [(hours of television on weekdays x 5) + (hours of television on weekend days x 2)]/7. Self-report methods of quantifying screen time have been shown to have acceptable reliability and validity in children ⁽²⁴⁾.

The FFQ during television viewing was adapted from Van den Bulck and Van Mierlo⁽¹⁹⁾, and asked the participants how often they consumed five ‘unhealthy’ food items and one ‘healthy’ food item while watching television in a usual week. Unhealthy foods included 1) potato chips or peanuts; 2) fried foods such as chicken wings, chicken fingers, French fries, etc.; 3) cookies, biscuits, chocolate or candy bars; 4) ice cream; and 5) fast foods such as pizza, hamburgers, etc. Healthy foods included fruits or vegetables. There were 7 response options ranging from ‘never’ to ‘every day, more than once’.

4.3.4 Covariates

Demographic questionnaires completed by parents were used to determine children’s age (from date of birth reported by the parents), gender and ethnicity (White/Caucasian, African American, Asian, First Nations, East Indian, “don’t know”, or “other”), along with total annual family income (8 options ranging from less than \$14 999 to \$140 000 or more), and the highest level of parental education (less than high school, some high school, high school diploma/GED, diploma or 1-3 years of college, bachelor’s degree, graduate [Master’s or PhD]/professional degree). Biological maturity was estimated using the maturity offset method, which estimates an individual’s age from peak height velocity ⁽²⁵⁾. Nightly sleep duration was assessed using the ActiGraph GT3X+; a detailed description of this novel algorithm developed for the ISCOLE study is available

elsewhere⁽²¹⁾. MVPA was also assessed using the ActiGraph GT3X+ with cut points developed by Evenson et al. (>2296 counts per minute)⁽²⁶⁾. Further details with respect to accelerometry data reduction procedures are available elsewhere⁽²¹⁾. These covariates were chosen because of their association with television viewing and/or food intake patterns in the literature.

4.3.5 Statistical Analysis

Non-parametric tests for significant differences were performed given the nominal or ordinal nature of the data. Kruskal-Wallis analysis of variance (ANOVA) was used to determine significant differences between weight status groups in their television watching and the frequency of consumption of food items while watching television. When Kruskal-Wallis ANOVA was significant, Mann-Whitney U tests were used *post-hoc* to determine specifically which weight status groups differed in television viewing time or frequency of consumption of food items. Logistic regression was used to compute odds ratios (and 95% confidence intervals) and adjusted odds ratios (after adjustment for covariates) for the odds of being overweight or obese with high television viewing or high consumption of food items found to be significantly different in the Kruskal-Wallis ANOVA. Children who watched more than 4 hours of television per day were compared with children who watched ≤ 2 hours of television per day; this is consistent with definitions of high and low television viewing in the literature^(4, 27). Children who watched 3 hours of television were excluded from this analysis. High and low frequency of consumption while watching television was defined as above or below the median response for each food item. For fast foods, responses ‘never’ and ‘less than once/week’ were merged to represent low frequency of consumption, while responses ‘once a week’ up to ‘every day, more than once’ were

merged to represent high frequency of consumption. For fruits/vegetables, responses from ‘never’ to ‘2-4 days/week’ were merged to represent low frequency of consumption, while responses ‘5-6 days/week’ to ‘every day, more than once’ were merged to represent high frequency of consumption. Finally, the ‘frequency rate’ of consumption of food items during television watching by weight status was computed by dividing the frequency of consumption of the food item by the number of hours of television watched; only those foods found to be significantly different between weight status groups in the Kruskal-Wallis ANOVA were included in this analysis. A 2-tailed p-value of less than 0.05 was the threshold to indicate statistical significance. All statistical analyses were performed using SPSS version 21 (IBM, Armonk, NY, USA).

4.4 Results

Participant and parent demographic information is provided in Table 1. A total of 550 participants (57.1% girls) provided complete data for the variables of interest and were included in analysis. There were no statistically significant sex interactions between television viewing and the outcome variables; thus, data for both sexes were merged to maintain statistical power. The prevalence of overweight and obesity was 12.4% and 10.9%, respectively, using CDC cut points.

Results observed for the weighted-mean number of hours of television watched per day and the mean number of hours television watched on weekdays were similar; however, results were not significant with television watching on weekend days. In all analyses the weighted mean number of hours of television viewing per day is reported to improve clarity. There was a significant main effect of weight status on television viewing, and children who were overweight or obese watched more television per week than those who

were normal weight (Table 2). Logistic regression analyses showed that children who watched more than 4 hours of television per day had higher odds of being obese, but did not have higher odds of being overweight (Table 4). This association remained statistically significant with the addition of age, sex, ethnicity, biological maturity, total annual family income, highest parental education level, and nightly sleep duration into the model. However, this association became non-significant with the addition of MVPA.

There was a significant main effect of weight status on the consumption of fast foods as well as fruits/vegetables while watching television. Obese children reported to consume fast food and fruits/vegetables more frequently while watching television than those who were normal weight or overweight (Table 3), but there were no differences in any of the other food items between weight status groups. Children who consumed fast food while watching television once or more per week did not have higher odds of being overweight or obese than those eating fast food less than once per week (Table 4); different cut-points around the median for high/low frequency of consumption of fast food did not yield different results. Children who consumed fruits/vegetables while watching television on more than 4 days per week had higher odds of being obese, but not of being overweight as compared to children consuming fruits/vegetables less than 3 days per week (Table 4). This association did not hold with the addition of covariates. Once again, the choice of cut-point around the median for high/low frequency of consumption of fruits/vegetables had no effect on the results.

Finally, children who were normal weight ate fast food at a higher ‘frequency rate’ while watching television than those who were overweight; however, normal weight children did not differ from obese children in their ‘frequency rate’ of fast food

consumption during television watching (Figure 1). There were no differences between weight status groups for the ‘frequency rate’ of consumption of fruits/vegetables while watching television (data not shown).

4.5 Discussion

In the current sample of 550 5th graders, overweight/obese children watched more television than their normal weight peers. Children who watched more than 4 hours of television per day had higher odds of being obese, independent of several covariates; however, this relationship did not hold with the addition of MVPA. Finally, obese children consumed fast food and fruits/vegetables more frequently while watching television than those who are normal weight or overweight.

The finding that children who are overweight or obese watch more television than their normal-weight counterparts is consistent with the literature^(5,7). This finding is a cause for concern as children who are high users of television are likely to be high users as they age⁽²⁸⁾, and television viewing in adults is associated in a dose-response manner with type 2 diabetes, cardiovascular events, and all-cause mortality⁽²⁹⁾.

Children who watched high amounts of television were found to have higher odds of being obese, independent of many covariates, but not independent of MVPA. This finding suggests that physical activity plays an important role in this association, and is contrary to some studies using objective measures of physical activity in adolescents. Rey-Lopez et al.⁽³⁰⁾ found that boys, but not girls, who watched >4 hours of television per day had higher odds of being overweight, independent of MVPA. However, the study by Rey-Lopez et al.⁽³⁰⁾ did not adjust for any of the covariates considered in the analyses herein and residual confounding is a possibility. The same finding as that of Rey-Lopez et al.

⁽³⁰⁾was observed in the current analysis when only adjusting for MVPA (data not shown), illustrating the importance of controlling for a larger panel of potential confounders (if the study is sufficiently powered) when examining the relationship between television viewing and obesity in children.

Few studies have considered the role of food intake while watching television on overweight and obesity in children. No study to date has done so with a large sample size while also considering many potentially confounding variables, factors that have led to mixed results in previous studies. Rey-Lopez et al. ⁽³⁰⁾ found that adolescents who eat in front of the television once a week are at higher odds of being overweight after adjusting for MVPA ⁽³⁰⁾; however, the authors did not consider the role of other confounding variables. Matheson et al. ⁽²⁰⁾ found that food intake while watching television was not associated with BMI in children ⁽²⁰⁾; however, the sample size was too small and heterogeneous (pooled from two studies, n=90 and n=124) to perform between-groups analyses or to adjust for several confounders.

Consumption of fast food is consistently associated with obesity ⁽¹³⁾, and high amounts of television viewing are associated with obesity ⁽⁵⁻⁷⁾ and increased fast food consumption ⁽³¹⁾. Thus, the current finding that children who are obese consume more fast food while watching television may not come as a surprise, given the state of the literature. However, the finding that a high frequency of fast food consumption while watching television is not associated with higher odds of being overweight or obese in both unadjusted and adjusted models is intriguing. The relationship between fast food and obesity, at least as it relates to fast food eaten while watching television, may be better explained by reverse causality - obese children may consume more fast food, but

consuming more fast food may not predict obesity. The cross-sectional nature of this analysis does not allow for the determination of causality, but future research should better delineate the association between fast food consumption during television viewing and obesity. Furthermore, as this analysis only considers the frequency of consumption of fast food during television watching, the absolute quantity and variation in quality cannot be determined.

Normal-weight children consumed fast food at a higher ‘frequency rate’ while watching television than overweight children, but not obese children; there were also no differences between overweight and obese children. Given the descriptive results of this study, this finding is not surprising – normal weight and overweight children consume fast food in front of the television with a similar frequency, however, overweight children watch more television. Likewise, the magnitude of the difference in frequency of consumption of fast food while watching television between overweight and obese children is small, and they watch similar amount of television. Thus, any differences in the ‘frequency rate’ of consumption of fast food during television viewing between overweight and obese children may be too small to detect⁽³²⁾. This is a novel analysis in the consideration of food intake during television viewing, as the frequency of consumption may be higher in obese children, but this is explained by higher television watching, not a higher ‘frequency rate’ of fast food consumption. There is some evidence to suggest that obese children may have a heightened alertness to food-related cues associated with television viewing^(33, 34); however, the present findings suggest that, at least in front of the television, obese children do not consume foods at a higher ‘frequency rate’.

The finding that children who are obese consume fruits/vegetables more frequently while watching television than their overweight and normal weight counterparts is contrary to our hypothesis and most of the available evidence^(13, 31, 35,36). The median [inter-quartile range (IQR)] of the frequency of consumption of fruits/vegetables is considerably higher than the other food items in the FFQ, especially for children who are obese. This may indicate a positive response or social desirability bias, as this differs from what is generally seen in the literature; however, this cannot be known with certainty. Children who are obese have higher daily energy requirements⁽³⁷⁾ and so may consume many different types of foods more frequently than children who are overweight or normal weight; however, the absolute quantity and variation in quality of food intake cannot be determined from the FFQ. As this analysis does not consider the food that children eat in the absence of television watching, it is possible that obese children do not consume fruits/vegetables more frequently over the course of the entire day, but due to increased television watching more of this consumption might occur while watching television.

Furthermore, the co-consumption of other foods while consuming fruits/vegetables cannot be ruled out; if children who are obese consume more meals, which include fruits/vegetables, in front of the television this may lead to overconsumption of many food types which can promote a positive caloric balance. In the current analysis, there was no effect of weight status on the ‘frequency rate’ of consumption of fruits/vegetables while watching television, which suggests that obese children consume fruits/vegetables more frequently in front of the television simply because they watch more television. Also, the finding that fruit and vegetable consumption while watching television was associated with higher odds of being obese in the unadjusted model may provide evidence for this

hypothesis. However, that the association became non-significant with the addition of covariates should remind us of the confounded nature of the association between food intake, television watching, and obesity in children and of the many factors at play. Indeed, there are many factors that may explain the finding above and researchers in this field may wish to further examine the role of food intake while watching television and its impact on obesity, specifically considering the co-consumption of foods with fruits/vegetables, and evaluating the impact of eating in front of the television in the context of whole-day food intake.

There are several strengths of this study, including the large sample of Canadian children, the robust data quality assurance procedures⁽²¹⁾ and the inclusion of many confounding variables, which were not typically included in past research. Unique to this analysis is a novel covariate, total sleep time as measured by accelerometry, as well as biological maturity, which is an important consideration in such analyses. Finally, the use of an objective measure for the measurement of MVPA is an asset.

There are also several limitations to the current analysis. First, the direction of causality cannot be determined from cross-sectional data. Second, although we used a large sample of Canadian children, it is not known if the sample is nationally representative and therefore results may not be generalizable. Third, the current study did not differentiate between watching television alone or with peers, as well as the placement of televisions (i.e. in the bedroom), which has been associated with unfavourable body composition in itself⁽³⁸⁾. Fourth, television viewing is notoriously difficult to measure, and better measures other than self-report exist⁽³⁹⁾; however, the screen time frequency questionnaire used in the current analysis maximized feasibility for the given sample size and reduced participant

burden. Fifth, this analysis does not take into account the effect of television watching on absolute food intake, or the effect of television advertisements on whole-day food intake; however, this was outside of the scope of the current research question. Finally, the FFQ is limited in its ability to assess food intake as it does not account for quantity or quality; however, that frequency alone may differ between weight status groups in children is an important finding.

4.6 Conclusion

High television watching was associated with obesity in the current sample of children aged 9-11 years independent of covariates, but not independent of MVPA. This finding suggests that physical activity plays a role in the association between television viewing and obesity. Obese children consumed fast food more frequently while watching television than normal-weight children; however, higher frequency of consumption of fast food was not associated with higher odds of being obese, which suggests that the association may be driven by the nutritional habits of obese children. Also, obese children consumed fruits/vegetables more frequently while watching television than normal-weight children. This finding is contrary to most of the literature and should be validated in future studies which examine the quantity and quality of food eaten, as well as the co-consumption of food eaten alongside fruits/vegetables while watching television.

Conflicts of Interest

The authors have no conflicts of interest to declare.

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MB participated in study coordination, data collection and was primarily responsible for the analyses, writing of the manuscript and generation of tables and figures. MST conceived of the study design and oversaw its coordination, and contributed to interpretation of the study results. GL was primarily responsible for the management of the study, and was involved in data collection and data cleaning. CB, PB, AGL, and CF participated in study coordination and management, data collection and data cleaning. JPC conceived of the study design and oversaw its coordination, contributed to data analysis and interpretation of the study results. All authors reviewed and provided critical input into this manuscript. We would like to thank Jessica McNeil and Nina Azoug-Boneault for their role in data collection for the Canadian site of ISCOLE, and the following members of the Coordinating Center for ISCOLE in Baton Rouge, Louisiana for their support throughout the study: Peter Katzmarzyk (PI), Timothy Church (Co-PI), Denise Lambert (Project Manager), Ben Butitta, Shannon Cocreham, Kara Dentre, Katy Drazba, Deirdre Harrington, Dione Milauskas, Emily Mire, Allison Tohme, Ruben Rodarte, as well as the members of the Data Management Center at Wake Forest University: Bobby Amoroso, John Luopa, Rebecca Neiberg, Scott Rushing. We would also like to thank the study participants along with their parents, teachers and school principals for their involvement in the study. ISCOLE was funded by the Coca-Cola Company. The funder had no role in study design, data collection and analysis, decision to publish, or preparation of manuscript.

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4.8 Tables and Figures

Table 4.1: Descriptive characteristics of participants.

Age (mean years, SD)	10.0 (0.38)
Gender (n,%)	
Male	236 (42.9)
Female	314 (57.1)
Ethnicity (n,%)	
White/Caucasian	360 (66.3)
African American	15 (2.8)
Asian	56 (10.3)
First Nations	2 (0.4)
East Indian	5 (0.9)
Don't know	1 (0.2)
Other	104 (19.2)
Maturity Offset (median, IQR)	-1.88 (-2.74,-1.20)
BMI Category – CDC^a(n,%)	
Normal weight	422 (76.7)
Overweight	68 (12.4)
Obese	60 (10.9)
Television Watching (n,%)	
<2 hours	456 (82.9)
>4 hours	40 (7.3)
Annual Household Income (n ,%)	
Less than \$14,999	16 (3)
\$15,000 - \$29,999	32 (6.1)
\$30,000 - \$39,999	15 (2.8)
\$40,000 - \$59,999	36 (6.8)
\$60,000 - \$89,999	72 (13.6)
\$90,000 - \$109,999	77 (14.6)
\$110,000 - \$139,999	78 (14.8)
\$140,000 and above	202 (38.3)
Highest Level of Parental Education (n,%)	
Less than high school	2 (0.4)
Some high school	9 (1.7)
High school diploma/GED	35 (6.4)
Diploma or 1-3 years of college	110 (20.3)
Bachelor's degree	169 (31.1)
Graduate (Master's or PhD)/professional degree	218 (40.1)
Daily minutes of MVPA (mean, SD)	58.9 (19.2)
Nightly minutes of sleep (mean, SD)	544.4 (50.8)

^aBMI – Body Mass Index [National Center for Chronic Disease Prevention and Health Promotion (CDC): Body mass index for age percentiles] (22).
MVPA, moderate-to-vigorous physical activity; Standard deviation, SD; interquartile range, IQR

Table 4.2: Hours of television viewing (median [range]) on both weekdays and weekends by body mass index category, and differences between weight status categories.

Hours of television viewing ^a	BMI Category ^b			Kruskal Wallis ANOVA	
	Normal weight (n=422) (median [IQR])	Overweight (n=68) (median [IQR])	Obese (n=60) (median [IQR])	χ^2	p-value
Weekdays	2.5 [2.0-4.0]	3.0 [2.0-4.0] [†]	3.0 [2.0-5.0] [†]	17.48	<0.01 [*]
Weekends	4.0 [3.0-4.3]	4.0 [4.0-5.0]	4.0 [2.3-6.0]	4.29	0.12
Total week ^c	2.7 [2.0-3.9]	3.3 [2.4-4.3] [†]	3.3 [2.3-5.2] [†]	14.78	0.01 [*]

* Significant main effect (p<0.05) [Kruskal Wallis ANOVA]

[†] Significantly different from normal weight (p<0.05) [Mann-Whitney U post-hoc test]

^a Response categories: 1= no television watching, 2= <1 hour, 3= 1 hour, 4= 2 hours, 5= 3 hours, 6= 4 hours, and 7= 5 or more hours of television per day

^b National Center for Chronic Disease Prevention and Health Promotion (CDC): Body mass index for age percentiles. Available from: [http://www.cdc.gov/growthcharts/\(22\)](http://www.cdc.gov/growthcharts/(22))

^c Weighted mean – [(number of hours on weekdays x 5) + (number of hours on weekends x 2)]/7

BMI, body mass index; IQR, interquartile range; analysis of variance, ANOVA

Table 4.3: Frequency of foods consumed while watching television per week by body mass index category.

Food items ^a	BMI Category ^b			Kruskal Wallis ANOVA	
	Normal weight (n=422) (median [IQR])	Overweight (n=68) (median [IQR])	Obese (n=60) (median [IQR])	χ^2	p-value
Potato chips or peanuts	2 [1-3]	2 [1-2.75]	2 [2-3]	4.74	0.09
Fried foods ^c	2 [1-2]	2 [1-2.75]	2 [1-3]	4.30	0.12
Snack foods ^d	2 [1-3]	2 [1.25-3]	2 [2-3]	0.14	0.94
Ice cream	2 [1-3]	2 [1-2.75]	2 [1-3]	1.14	0.57
Fast foods ^e	2 [1-2]	2 [1-2.75]	2 [2-3] ^{Δ, †}	6.14	0.04 [*]
Fruits or vegetables	4 [2-6]	4 [2-6]	5.5 [4-7] ^{Δ, †}	10.95	<0.01 [*]

* Significant main effect [Kruskal Wallis ANOVA]

^ΔSignificantly different from normal weight (p<0.05) [Mann-Whitney U post-hoc test]

[†]Significantly different from overweight (p<0.05) [Mann-Whitney U post-hoc test]

^a Response categories: 1= Never; 2= Less than once a week; 3= Once a week; 4= 2-4 days a week; 5= 5-6 days a week; 6= Once a day, every day; 7= Every day, more than once

^b National Center for Chronic Disease Prevention and Health Promotion (CDC): Body mass index for age percentiles. Available from: [http://www.cdc.gov/growthcharts/\(22\)](http://www.cdc.gov/growthcharts/(22))

^c Fried food such as chicken wings, chicken fingers, french fries, etc

^d Snack foods such as Cookies, biscuits, chocolate or candy bars

^e Fast foods such as pizza, hamburgers, etc.

BMI, body mass index; IQR, interquartile range; analysis of variance, ANOVA

Table 4.4: Odds ratio (OR) of being obese if a child watches high amounts of television or eats fast food or fruits/vegetables more frequently while watching television.

	Odds ratio of being obese		
	OR	95% CI	p-value
Watching >4 hours of television per day ^a			
Model 1	6.00	(2.83-12.72)	p<0.01*
Model 2	3.21	(1.14-9.03)	p=0.03*
Model 3	2.40	(0.79-7.01)	p=0.12
Eating fast food while watching television ≥ 1 day per week ^b			
Model 1	1.40	(0.78-2.53)	p=0.25
Model 2	1.45	(0.65-3.20)	p=0.36
Model 3	1.39	(0.61-3.20)	p=0.44
Eating fruits/vegetables while watching television ≥ 4 days per week ^c			
Model 1	2.20	(1.26-3.83)	p<0.01*
Model 2	1.58	(0.77-3.21)	p=0.21
Model 3	2.02	(0.95-4.27)	p=0.07

Model 1: unadjusted.

Model 2: adjusted for age, sex, ethnicity, biological maturity, total annual family income, highest parental education level, and nightly sleep duration

Model 3: additionally adjusted for MVPA

^a – Reference group: watching ≤ 2 hours of television per day

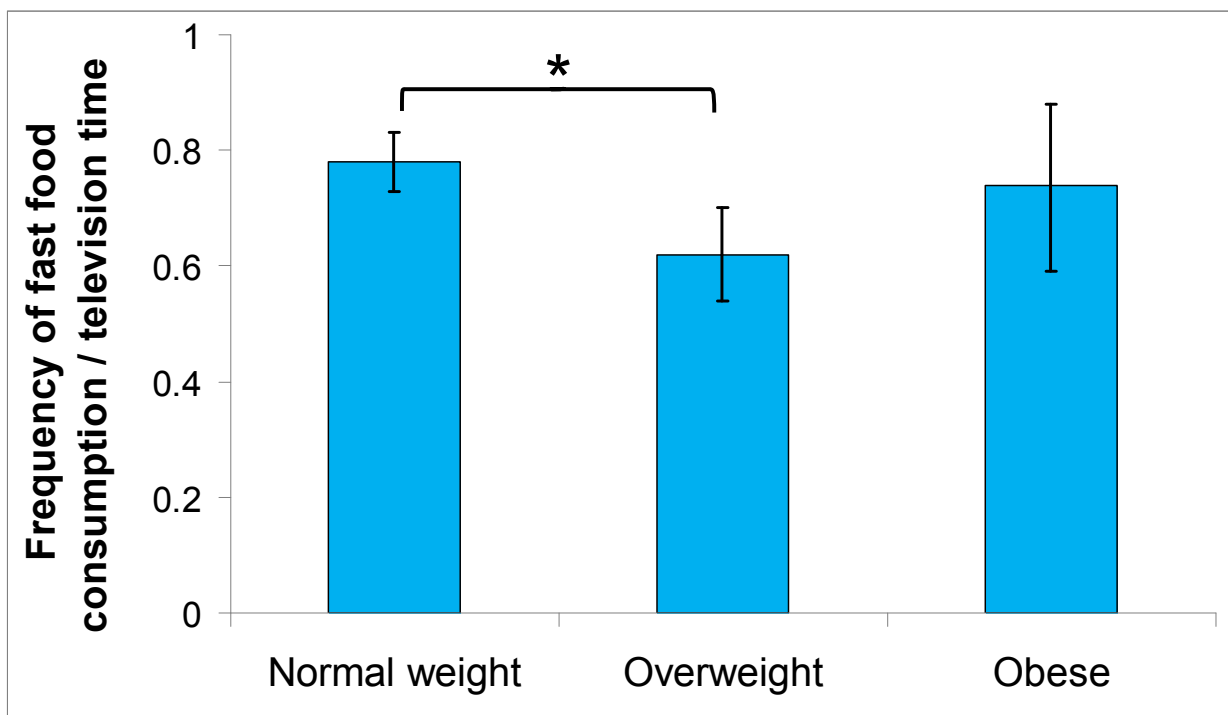
^b – Reference group: Eating fast food while watching television < 1 day per week

^c – Reference group: Eating fruits/vegetables while watching television < 3 days per week

*<0.05, n=550

Odds ratio, OR; 95% confidence interval, 95% CI

Figure 4.1: Frequency of fast food consumption while watching television per day divided by the number of hours of television watched per day by weight status groups. Error bars represent 95% confidence intervals. *p<0.05.



**Chapter 5 - Manuscript II: Independent and combined
associations of total sedentary time and screen time with food
intake patterns of 10-year- old Canadian children**

This article is in press for in Applied Physiology, Nutrition, and Metabolism and is presented in the format required for publication.

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Running Title: Sedentary time, television viewing time, and food intake in children

Keywords: sedentary behaviour, television watching, screen time, energy intake, food intake, childhood obesity, observational study

5.1 Abstract

The relationships between sedentary time, television viewing time and dietary patterns in children are not fully understood. The aim of this paper is to determine which of self-reported television viewing time or objectively measured sedentary time is a better correlate of frequency of consumption of healthy and unhealthy foods. A cross-sectional study of 9-11 year old children (n=523; 57.1% female) from Ottawa, Canada was conducted. Accelerometers were used to determine total sedentary time. Questionnaires were used to determine the number of hours of television watching and the frequency of consumption of foods per week. Television viewing was negatively associated with frequency of consumption of fruits, vegetables and green vegetables, and positively associated with frequency of consumption of sweets, soft drinks, diet soft drinks, pastries, potato chips, fries, fruit juices, ice cream, fried foods, and fast food. Except for diet soft drinks and fruit juices, these associations were independent of covariates, including sedentary time. Total sedentary time was negatively associated with frequency of consumption of sports drinks, independent of covariates, including television viewing. In combined sedentary time/television viewing analyses, children watching >2 hours of television per day consumed several unhealthy food items more frequently than children watching ≤ 2 hours of television, regardless of sedentary time. In conclusion, this paper provides evidence to suggest that television viewing time is more strongly associated with unhealthy dietary patterns than total sedentary time. Future research should focus on reducing television viewing time as a means of improving dietary patterns and potentially reducing childhood obesity.

5.2 Introduction

Sedentary lifestyles in children are associated with negative physiological and health consequences, including reduced fitness, physical and psychosocial health, and obesity (Tremblay et al. 2011a, 2010). However, the associations between overall sedentary time and obesity in children is mixed, with studies suggesting that both positive and negative associations are independent of moderate-to-vigorous physical activity (MVPA) (Chaput et al. 2012b; Mitchell et al. 2013a). Interestingly, there is evidence to suggest that the type of sedentary behaviour, such as screen-based sedentary behaviour (e.g., television, video games), may be more important than overall sedentary time in predicting obesity in children (Chaput et al. 2012a). For instance, television viewing has been shown to be positively associated with obesity in children (Dietz and Gortmaker 1985; Mitchell et al. 2013a; Tremblay et al. 2011a), often independent of physical activity levels. The association between television viewing and obesity in children is thought to be driven by increased food intake (Borghese and Chaput 2013; Epstein et al. 2008; Robinson 2001; Wiecha et al. 2006). One longitudinal mediation analysis showed that dietary patterns mediate the association between television viewing and BMI in children (Fuller-Tyszkiewicz et al. 2012).

Television viewing is inversely associated with fruit and vegetable consumption, and positively associated with consumption of energy-dense snacks and drinks, total energy intake, and fast foods (Pearson and Biddle 2011). However, the association between overall sedentary time and food intake patterns in children has not been documented. Furthermore, a comparison of self-reported television viewing time vs. objectively measured total sedentary time, with respect to associations with food intake, has not been undertaken. If

the associations between sedentary behaviours and obesity are independent of MVPA, as is suggested by the literature (Chaput et al. 2013, 2012b; Cliff et al. 2013; Ekelund et al. 2012; Mitchell et al. 2013b; Tremblay et al. 2011a), then understanding the role of dietary patterns is paramount.

The aim of this paper was to determine which of self-reported television viewing time or objectively measured total sedentary time is a better predictor of frequency of consumption of healthy and unhealthy foods in 9-11 year-old Canadian children. We hypothesized that higher self-reported television viewing time would be positively associated with the frequency of consumption of unhealthy foods and negatively associated with the frequency of consumption of healthy foods. It was also hypothesized that there would be no association between total sedentary time and healthy or unhealthy food intake patterns. This study is the first to examine this issue and will provide much needed evidence for the role of food intake in the link between both television viewing and sedentary time with childhood obesity.

5.3 Materials and Methods

5.3.1 Participants

The International Study of Childhood Obesity, Lifestyle and the Environment (ISCOLE) is a multi-national, cross-sectional study conducted in 12 countries; details pertaining to the study design and methods can be found elsewhere (Katzmarzyk et al. 2013). Analyses herein include data from the Canadian ISCOLE site. Data were collected in 26 schools on 567 children in the 5th grade (57.1% female; 9-11 years of age) from Ottawa between September 2012 and May 2013. The city of Ottawa is predominately Anglophone with a Francophone minority (Statistics Canada 2012); thus schools were

stratified into four groups with proportional representation to reflect the demographic composition of Ottawa: English Public (n=393; 69.3%), French Public (n=60; 10.6%), English Catholic (n=75; 13.2%), and French Catholic (n=39; 6.8%). All schools were invited to participate and were included until each stratum was filled. This project was approved by the research ethics boards at the Children's Hospital of Eastern Ontario, the University of Ottawa, and the participating school boards. Written informed parental consent and child assent were obtained for all participants.

5.3.2 Accelerometry

Sedentary time was measured using the ActiGraph GT3X+ accelerometer (ActiGraph LLC, Pensacola, FL, USA) (Katzmarzyk et al. 2013). Children wore the device on a belt around the waist at the right mid-axillary line 24 hours/day for 7 consecutive days; children were asked to remove the device for aquatic activities and showering/bathing. Study staff instructed children how to wear the device. To increase wear time compliance, study staff conducted an in-person check 2-4 days after initialization to ensure the child was following the accelerometer wear protocol. Two compliance phone calls were also made to the parents/guardians (one weekday call and one weekend call) to ensure that the device was being worn properly. A valid recording required at least 4 days (including at least one weekend day) of at least 10 hours of wear time per day. Data were collected at sampling rate of 80 Hz, downloaded in 1-second epochs, and were aggregated to 15 second epochs (Evenson et al. 2008). Sedentary time was defined as all minutes showing <100 counts per minute, which is a widely used cut-point in the literature (Wong et al. 2011). Forty-four children did not provide complete accelerometry data and were excluded from the analysis; thus data from 523 children (58.3% female) were analyzed.

5.3.3 Television Viewing and Food Frequency Questionnaire

During the school visit, participants completed a diet and lifestyle questionnaire which included a self-reported measure of television viewing and a food frequency questionnaire (FFQ). To assess television viewing children were asked how many hours of television they watch on a typical school day and on a typical weekend day, based on a question adapted from the U.S. Youth Risk Behavior Surveillance System (YRBSS). The television viewing time question derived from the YRBSS was originally designed for use in population level surveillance of television viewing patterns, not hypothesis testing; however, this item was shown to have adequate reliability (spearman correlation=0.55-0.68) and validity (spearman correlation=0.47) (Schmitz et al. 2004). Self-report methods of quantifying screen time have been shown to have acceptable reliability and validity in children (Lubans et al. 2011). The response options included: no television watching, <1 hour, 1 hour, 2 hours, 3 hours, 4 hours, and 5 or more hours of television per day. A weighted mean number of hours of television watching per week was calculated as follows: $[(\text{hours of television on weekdays} \times 5) + (\text{hours of television on weekend days} \times 2)]/7$; this method of determining daily amount of television viewing has been used elsewhere (Herman et al. 2013).

The FFQ was adapted from the Health Behaviours in School-age Children (HBSC) study (Currie et al. 2008), and is a reliable (spearman correlation= 0.52-0.82) questionnaire that can be used for ranking the frequency of consumption of most food items (Vereecken and Maes 2003). The FFQ asked the participants how often they consumed 23 food items in a usual week. There were 7 response options ranging from ‘never’ to ‘every day, more than once’.

5.3.4 Covariates

Demographic questionnaires completed by parents were used to determine children's age (from date of birth), gender, ethnicity (White/Caucasian, African American, Asian, First Nations, East Indian, "don't know", or "other"), total annual family income (8 options ranging from less than \$14 999 to \$140 000 or more), and the highest level of parental education (less than high school, some high school, high school diploma/GED, diploma or 1-3 years of college, bachelor's degree, or graduate degree [master's or PhD]/professional degree). Fat mass was determined by bioelectric impedance analysis using a Tanita SC-240 Body Composition Analyzer (Arlington Heights, IL) and is a valid measure of fat mass in field studies (Barreira et al. 2013). Biological maturity was estimated using the maturity offset method, which estimates an individual's age from peak height velocity (Mirwald et al. 2002). Maturation is an important variable to consider in such analyses as children's energy needs are a determinant of their growth (Rogol et al. 2002), and maturation is associated with increased energy needs (Stang and Story 2005). Total sleep period time was assessed using the ActiGraph GT3X+; a detailed description of this novel algorithm developed for the ISCOLE study is available elsewhere (Tudor-Locke et al. 2014). Television viewing time is negatively associated with sleep duration in children (Cain and Gradisar 2010). Sleep duration has also been linked with diet in children (Chen et al. 2008) – a recent randomized cross-over intervention comparing increased and decreased sleep durations showed that children consumed 138 fewer calories/day when they slept 1.5 hours more than their baseline, as compared to 1.5 hours below baseline sleep time (Hart et al. 2013). Thus, sleep period time is an important covariate to consider in analyses of sedentary behaviour and food intake in children. Finally, MVPA was

assessed using the ActiGraph GT3X+ and was derived using cut points of >2296 counts per minute (Evenson et al. 2008). These covariates were chosen because of their association with the exposures and/or outcomes.

5.3.5 Statistical Analysis

The correlation between frequency of consumption of each of the 23 food items and both television viewing time and sedentary time were computed using Spearman's rho and Pearson's r, respectively. Bonferroni correction for multiplicity was used to reduce the family-wise error rate; the critical p-value for the univariate correlations was set at $0.05/23$, or $p < 0.002$. Multivariate linear regression and simple linear regression were used to determine the independent associations between both television viewing time, and total sedentary time, respectively, with the individual food items that were significantly correlated with each variable.

Models are presented as: 1) unadjusted; 2) adjusted for age, gender, ethnicity, biological maturity, fat mass (kg), total family annual income, highest level of parental education attained, total sleep period time, and MVPA; and 3) sedentary time and television viewing time were both mutually adjusted for one another. The variance inflation factors between all variables entered into the model were < 5 , suggesting that multicollinearity was not a problem in the models. Types of foods were compared with groups of both high/low sedentary time and television viewing time using multivariate analysis of variance (MANOVA). High/low sedentary time was defined as above/below the median (510.9 minutes/day) and high/low television viewing time was defined as > 2 hours/ ≤ 2 hours per day, as per the Canadian Sedentary Behaviour Guidelines (Tremblay et al. 2011b). Multivariate analysis of covariance (MANCOVA) was performed, adjusting for age,

gender, ethnicity, biological maturity, and MVPA. Due to the small sample size of some of the groups, further adjustment was not possible. Bonferroni post-hoc tests were used to determine significant differences between groups where the main effects were significant. All statistical analyses were performed using SPSS version 21 (IBM, Armonk, NY, USA).

5.4 Results

Participant demographic information is available in Table 1. A total of 436 (83.4%) of children watched ≤ 2 hours of television per day, while 87 (16.6%) of children watched > 2 hours of television per day. The median number of minutes of total sedentary time was 511 minutes per day. There were no statistically significant gender interactions between television viewing time or sedentary time and the outcome variables of food items; thus, data for both genders were merged to maintain statistical power. Further, there were no differences in age, gender, ethnicity, biological maturity, fat mass, household annual income or highest level of parental education between children who provided valid accelerometry data ($n=523$) and those who did not ($n=44$) (data not shown).

After Bonferroni correction for multiplicity, television viewing time was negatively correlated with frequency of consumption of fruits, vegetables, and green vegetables (Table 2), and was positively correlated with frequency of consumption of sweets, soft drinks, pastries, diet soft drinks, potato chips, French fries, fruit juices, ice cream, fried foods, and fast food. Sedentary time was negatively associated with frequency of consumption of sports drinks after Bonferroni correction, but was not significantly correlated with other food items. In unadjusted multivariate linear regression, television viewing time was associated with all of the food items in the directions seen in the univariate analysis (Table 3, model 1). After adjusting for covariates (Table 3, model 2), the food items remained

significantly associated with television viewing time, except for diet soft drinks and fruit juices. Further adjustment for total sedentary time yielded the same results (Table 3, model 3). The proportion of variance in frequency of consumption of food items explained by television viewing time ranged from 1% to 14%. In linear regression, sedentary time explained a significant proportion of variance in frequency of sports drink consumption in unadjusted (3%), partially adjusted (15%), and fully adjusted models (14%) (Table 4, models 1-3).

Frequency of consumption of food items was compared between groups of high and low sedentary time and television viewing time. Children with >2 hours of television time consumed soft drinks, diet soft drinks and fast foods more frequently than children with ≤ 2 hours of television time, regardless of whether or not they had high or low sedentary time (Table 5). However, after adjustment for age, gender, ethnicity, biological maturity, and MVPA, the high sedentary/high television time group no longer consumed soft drinks, diet soft drinks, or fast food more frequently than the low sedentary/low television time group. Children with high sedentary time and high television viewing time consumed sweets and ice cream more frequently; however, after adjustment for covariates, the high sedentary/high television time group also consumed sweets more frequently than the low sedentary/low television group. In both unadjusted and adjusted models, children with low sedentary/high television time consumed pastries more frequently and green vegetables less frequently than children with low television time and either high or low sedentary time. Finally, in both unadjusted and adjusted models, children who had low sedentary/high television time consumed fruit juices more frequently than those with high sedentary/low

television time. A main effect of consumption of sports drinks between sedentary time/television viewing time groups was not observed.

5.5 Discussion

In the current sample of 9-11 year old Canadian children, television viewing was more strongly associated with dietary patterns in children than was sedentary time. Specifically, television viewing was negatively associated with frequency of consumption of a number of healthy food items and positively associated with frequency of consumption of a number of unhealthy food items. This is the first study to compare television time and sedentary time in their respective associations with food intake in children. These findings provide evidence to suggest that the discrepancies seen between television viewing time and sedentary time in children, with respect to health outcomes, may be influenced by dietary patterns.

Except for diet soft drinks and fruit juices, these associations were independent of several covariates, including total sedentary time. In combined sedentary time/television viewing time analysis, higher television viewing was associated with higher consumption of several unhealthy food items, regardless of sedentary time. Sedentary time was negatively associated with consumption of sports drinks, independent of covariates and television viewing, but was not associated with any other food items. The majority of the explained proportion of variance in frequency of consumption of food items was less than 10%; however, television viewing and sedentary time each explained 14% of the variance in frequency of consumption of fruits and sports drinks, respectively. In the literature, models tend to predict <30% of the variance in fruit intake, with studies in children predicting as little as 3% (Baranowski et al. 1999). Neumark-Sztainer et al. (2003) were

able to predict 13% of the variance in fruit and vegetable intake using data on food availability and taste preferences in adolescents (Neumark-Sztainer et al. 2003). Likewise, Reynolds et al. (1999) found that availability and preferences for fruit explained 11% of the variance in fruit consumption in grade 3 children (Reynolds et al. 1999). The proportion of variance in frequency of consumption of food items with television time is consistent with the magnitude of effect size seen in the literature.

The current finding that television viewing in children is positively associated with energy-dense foods and drinks as well as fast foods, and negatively associated with consumption of fruits and vegetables, has been shown consistently in the literature (Pearson and Biddle 2011). Previous work has shown hightelevision viewing to be associated with higher consumption of sweets and soft drinks (Santaliestra-Pasías et al.2012), fast food (French et al. 2001), meat, pizza, and salty snacks (Coon et al. 2001), and lower consumption of fruits and vegetables (Boynton-Jarrett et al. 2003; Santaliestra-Pasías et al. 2012; Vereecken et al. 2006). Intriguingly, the present study showed that the known associations between television viewing and food intake were maintained, even independent of covariates and total sedentary time. These results suggest that the type of sedentary behaviour in children is more important in predicting dietary patterns than total sedentary time. Furthermore, the food items that were associated with television viewing were not associated with overall sedentary time. This is likely because sedentary time in children encompasses a variety of behaviours that may or may not be associated with frequency of consumption of food items. This may suggest that mixed findings seen in the literature with respect to sedentary time and childhood obesity may be explained by food intake. Furthermore, these results may explain why both total sedentary time and bouts of

sedentary time are not associated with health risk in children (Colley et al. 2013). Future intervention studies which aim to reduce the health impact of sedentary behaviours in children should thus focus on reducing the amount of time spent in specific sedentary behaviours, such as television viewing, as opposed to overall sedentary time.

The finding that sedentary time is negatively associated with frequency of consumption of sports drinks, even after adjustment for covariates (including MVPA), is somewhat contrary to our hypothesis. The increase in the proportion of variance in frequency of consumption of sports drinks from 3% to 14% with the addition of covariates suggests that factors, such as MVPA or socio-economic status, play an important role in this association. Each additional hour of sedentary time was associated with a reduction in the frequency of consumption of sports drinks of ~1-2 sports drinks/week. This is an interesting finding because sports drinks have been criticized for their high-sugar content and their potential to increase a child's risk of obesity (Committee on Nutrition and the Council on Sports Medicine and Fitness 2011); that children consume these drinks more frequently the less time they spend sedentary is intriguing. Future research should examine how children who frequently consume these drinks displace their sedentary time (i.e. with sport participation, independent of MVPA) and should also examine the contexts within which sports drinks are consumed.

There are several strengths of this study, including the large sample of Canadian children, the robust data quality assurance procedures (Katzmarzyk et al. 2013) and the inclusion of many confounding variables. Unique to this analysis is the mutual adjustment of television viewing time and sedentary time as a means of comparing the associations between these two measures of sedentary behaviour and food intake patterns. Finally, the

use of both self-report and objective measures of sedentary behaviour was an asset. There are also several limitations to the current analysis. First, the direction of causality cannot be determined from cross-sectional data. Second, although we used a large sample of Canadian children, this sample is not nationally representative and therefore results may not be generalizable. Third, the FFQ is limited in its ability to assess food intake as it does not account for food quantity; although the finding that frequency alone may differ between groups of varying sedentary time/television time is intriguing. Fourth, as with all self-report measures, the FFQ and screen time questionnaire are subject to recall and social desirability biases; however, these measures maximize feasibility for studies with large sample sizes and reduce participant burden.

5.6 Conclusion

Television viewing was negatively associated with frequency of consumption of healthy food items and positively associated with frequency of consumption of unhealthy food items, independent of covariates, MVPA, and total sedentary time. Sedentary time was negatively associated with consumption of sport drinks, independent of confounders, MVPA, and television viewing time. It is thought that the association between sedentary behaviours and obesity in children may be driven by variations in dietary patterns – this paper provides evidence to suggest that television viewing better explains variation in dietary patterns than total sedentary time. Future intervention research should focus on reductions in television time, independent of total sedentary time, as a means of improving dietary patterns and potentially reducing childhood obesity.

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5.8 Tables

Table 5.1: Descriptive characteristics of participants (n=523)

Age [years, mean (SD)]	10.0 (0.37)
Gender [n (%)]	
Male	218 (41.7)
Female	305 (58.3)
Ethnicity [n (%)]	
White/Caucasian	345 (66.7)
African American	13 (2.5)
Asian	53 (10.3)
First Nations	2 (0.4)
East Indian	5 (1.0)
Don't know	1 (0.2)
Other	98 (19.0)
Maturity Offset [median,(IQR)]	-1.87 (-2.74,-1.20)
Fat mass [kg, mean (SD)]	8.4 (5.4)
Television Watching [n (%)]	
No television watching	55 (10.5)
<1 hour	156 (29.8)
1 hour	138 (26.4)
2 hours	87 (16.6)
3 hours	51 (9.8)
4 hours	22 (4.2)
5 or more hours	14 (2.7)
Television Watching Groups [n (%)]	
≤2 hours	436 (83.4)
>2 hours	87 (16.6)
Annual Household Income [n (%)]	
Less than \$14,999	14 (2.8)
\$15,000 - \$29,999	27 (5.4)
\$30,000 - \$39,999	15 (3.0)
\$40,000 - \$59,999	35 (7.0)
\$60,000 - \$89,999	67 (13.3)
\$90,000 - \$109,999	75 (14.9)
\$110,000 - \$139,999	73 (14.5)
\$140,000 and above	196 (39.0)
Highest Level of Parental Education [n (%)]	
Less than high school	2 (0.4)
Some high school	8 (1.5)
High school diploma/GED	36 (7.0)
Diploma or 1-3 years of college	100 (19.3)
Bachelor's degree	159 (30.8)
Graduate (Master's or PhD)/professional degree	212 (41.0)

Daily minutes of MVPA [mean (SD)]	58.7 (19.3)
Daily minutes of sedentary time [mean (SD); median]	511.4 (63); 510.9
Total sleep period time[mean (SD)]	544.4 (50.7)
Sedentary Time and Television Viewing Time Groups [n (%)]	
Low sedentary/Low television	210 (40.2)
Low sedentary/High television	52 (9.9)
High sedentary/Low television	197 (37.7)
High sedentary/High television	64 (12.2)

MVPA – moderate-to-vigorous physical activity

SD – standard deviation

IQR – interquartile range

GED – General Educational Development (high school equivalent)

Table 5.2: Correlations between television viewing time (hours per day), total sedentary time (minutes per day) and frequency of consumption of food items in children.

	Television viewing time (hours/day)		Total sedentary time (min/day)	
	<i>Spearman R</i>	<i>p-value</i>	<i>Pearson R</i>	<i>p-value</i>
Sport drinks	-	-	-0.14	<0.0022
Fruits	-0.22	<0.002	-	-
Vegetables	-0.14	<0.002	-	-
Green vegetables	-0.21	<0.002	-	-
Sweets	0.15	<0.002	-	-
Soft drinks	0.20	<0.002	-	-
Pastries	0.17	<0.002	-	-
Diet Soft drinks	0.19	<0.002	-	-
Potato chips	0.20	<0.002	-	-
Fries	0.20	<0.002	-	-
Fruit juices	0.14	<0.002	-	-
Ice cream	0.22	<0.002	-	-
Fried foods	0.16	<0.002	-	-
Fast foods	0.22	<0.002	-	-

n=523

Critical p value = 0.05/23 comparisons = 0.002

Note: Only food items significantly associated with either television viewing time or sedentary time are shown.

Table 5.3: Independent associations between television viewing time and food items in children.

	Television Viewing Time								
	Model 1		Model 2		Model 3				
	β (95% CI)	R ²	p-value	β (95% CI)	R ²	p-value	β (95% CI)	R ²	p-value
Fruits	-0.21 (-0.29,-0.13)	.05	< 0.001	-0.18 (-0.27, -0.09)	.14	< 0.001	-0.18 (-0.27, -0.09)	.14	< 0.001
Vegetables	-0.16 (-0.25,-0.08)	.02	< 0.001	-0.10 (-0.20, -0.001)	.07	0.047	-0.10 (-0.20,-0.001)	.06	0.047
Green vegetables	-0.23 (-0.33,-0.13)	.04	< 0.001	-0.24 (-0.35, -0.12)	.05	< 0.001	-0.23 (-0.35, -0.12)	.05	< 0.001
Sweets	0.15 (0.07, 0.24)	.02	0.001	0.24 (0.14, 0.34)	.05	< 0.001	0.24 (0.14, 0.34)	.05	< 0.001
Soft drinks	0.17 (0.10, 0.24)	.04	< 0.001	0.09 (0.02, 0.17)	.07	0.020	0.09 (0.01, 0.17)	.07	0.026
Pastries	0.11 (0.04, 0.18)	.02	0.001	0.10 (0.02, 0.18)	.02	0.010	0.09 (0.02, 0.17)	.02	0.015
Diet Soft drinks	0.13 (0.07, 0.19)	.03	< 0.001	-	-	0.078	-	-	0.079
Potato chips	0.13 (0.07, 0.20)	.03	< 0.001	0.13 (0.06, 0.21)	.05	< 0.001	0.13 (0.05, 0.20)	.06	0.001
Fries	0.12 (0.06, 0.17)	.03	< 0.001	0.09 (0.02, 0.15)	.07	0.010	0.08 (0.01, 0.14)	.09	0.021
Fruit juices	0.15 (0.04, 0.26)	.01	0.009	-	-	0.062	-	-	0.09
Ice cream	0.18 (0.11, 0.25)	.04	< 0.001	0.18 (0.09, 0.26)	.05	< 0.001	0.17 (0.09, 0.25)	.05	< 0.001
Fried foods	0.15 (0.07, 0.23)	.02	< 0.001	0.10 (0.01, 0.19)	.07	0.032	0.10 (0.01, 0.19)	.07	0.036
Fast foods	0.16 (0.10, 0.22)	.05	< 0.001	0.15 (0.09, 0.22)	.07	< 0.001	0.15 (0.08, 0.22)	.08	< 0.001

n=523

Model 1: unadjusted

Model 2: adjusted for age, gender, ethnicity, maturity offset, fat mass, income, education, total sleep period time, and moderate-to-vigorous physical activity

Model 3: additionally adjusted for total sedentary time (min/day)

R² – adjusted R²

95% CI – 95% confidence interval

Note: Only food items significantly associated with television viewing time are shown.

Table 5.4: Independent associations between total sedentary time and food items in children.

	Sedentary time (min/day)		
	Model 1 (R ² =.03) β (95% CI)	Model 2 (R ² =.15) β (95% CI)	Model 3 (R ² =.14) β (95% CI)
Sport drinks	-0.004 (-0.006, -0.002)	-0.003 (-0.005, 0.00007)	-0.03 (-0.005, -0.00008)
	p-value < 0.001	p-value 0.04	p-value 0.04

n=523

Model 1: unadjusted

Model 2: adjusted for age, gender, ethnicity, maturity offset, fat mass, income, education, total sleep period time, and moderate-to-vigorous physical activity

Model 3: additionally adjusted for television time (hours/day)

R² – adjusted R²

95% CI – 95% confidence interval

Note: Only food items significantly associated with total sedentary time are show

Table 5.5: Combined associations of total sedentary time and television viewing time with food items (reported frequency of consumption in days per week) in children.

Food items [median (IQR)]	Low sedentary/ Low television	Low sedentary/ High television	High sedentary/ Low television	High sedentary/ High television	F-value	p-value
Green vegetables	4 (3-6) ^b	3 (2-4)	4 (3-6) ^b	4 (2-5)	46.6	0.001
Sweets	4 (3-5)	4 (3-5)	3 (2-4)	4 (3-5) ^{a,c}	34.2	0.001
Soft drinks	2 (1-3)	2 (2-3) ^{a,c}	2 (1-3)	2 (2-4) ^c	24.6	<0.001
Pastries	2 (2-3)	3 (2-4) ^{a,c}	2 (2-3)	2 (2-3)	14.1	0.008
Diet soft drinks	1 (1-2)	2 (1-3) ^a	1 (1-2)	2 (1-3) ^c	20.9	<0.001
Fruit juices	5 (3-6)	6 (3.25-7) ^c	4 (3-6)	5 (3-6)	40.3	0.007
Ice cream	2 (2-3)	2 (2-4)	2 (2-3)	3 (2-4) ^c	25.1	0.001
Fast foods	2 (2-3)	3 (2-3) ^{a,c}	2 (2-3)	3 (2-3) ^c	20.6	<0.001

n=523

Adjusted for age, sex, ethnicity, maturity offset, and moderate-to-vigorous physical activity

Corrected model: F=2.25, p<0.001

F-value – Wilk's Lambda

IQR- interquartile range

^a Significantly higher than low sedentary/low television

^b Significantly higher than low sedentary/high television

^c Significantly higher than high sedentary/low television

High/Low sedentary time was defined as above or below the median (511 minutes per day)

High/Low television time was defined as >2 hours and ≤2 hours per day, respectively.

Bonferroni post hoc tests were used to determine significant differences between groups.

Note: Only food items that were significant different between groups of total sedentary time and television viewing time are shown.

Chapter 6 – Global Discussion

Television viewing has been shown to be associated with obesity in children and there is evidence to suggest that this may be mediated by food intake patterns. To reiterate, the objectives of the current thesis were:

- 1) To compare children of different weight status groups (i.e. normal weight, overweight, obese) in their food intake patterns while watching television;
- 2) To determine which of self-reported television viewing time or objectively measured total sedentary time is a better predictor of frequency of consumption of healthy and unhealthy foods in 9-11 year-old Canadian children.

The studies chapters 4 and 5 have made important contributions to our understanding of the associations between television viewing, food intake, and obesity in children. Table 6.1 provides a summary of the findings from chapters 4 and 5.

Table 6.1: Summary of thesis key findings

Study 1 – Chapter 4	<ul style="list-style-type: none"> • Children who are overweight or obese watch more television than those who are normal weight • Children who watch >4 hours of television/day are at higher odds of being obese, but not independent of MVPA • Obese children consumed fast food and fruits/vegetables more frequently during television watching than overweight or normal weight children • Eating fast food or fruits/vegetables in higher frequency is not associated with increased odds of being obese
Study 2 – Chapter 5	<ul style="list-style-type: none"> • Higher television viewing time is associated with lower frequency of consumption of healthy foods, and higher frequency of consumption of unhealthy foods, independent of covariates and total sedentary time • Total sedentary time is negatively associated with frequency of consumption of sports drinks

6.1 Television viewing, obesity, and the displacement hypothesis

In chapter 4 we showed that children of different weight status differ in their food intake patterns while watching television. This is the first study to examine these potential differences in a large sample of children and was largely derived from suggestions for future research from Thivel et al. (2013). We found that children who are obese watch more television than those who are overweight/normal weight in this cross-sectional sample of 10-year-old children. As mentioned in previous chapters, the association between television watching and obesity has consistently been reported in previous studies. Contrary to our hypothesis, we showed that MVPA plays a role in the association between television viewing and obesity, as children who watch >4 hours of television/day are at higher odds of being obese, but not independent of MVPA. With respect to television viewing and obesity, while the evidence for the role of food intake is much stronger and more consistent than the evidence for that of energy expenditure (Chaput et al., 2011; Robinson, 2001; Thivel et al., 2013), our results suggest that it is not appropriate to abandon the idea of displacement of MVPA with television viewing just yet.

However, as researchers, we must approach these displacement effects with caution. Displacement effects are difficult to measure as the very nature of the concept necessitates a longitudinal study design with repeated measures over time; simply identifying lower/higher time spent in various activities as in Chapter 4, along with other cross-sectional studies, does not imply that any one activity is displaced for another. One longitudinal study investigated this issue and found that changes in television viewing time and MVPA were unrelated over time, suggesting that these two are separate constructs rather than opposite activities (Taveras et al., 2007). It is certainly logical to suggest that as television viewing time increases, time spent in MVPA has the potential to decrease – indeed, there are only 24 hours in a day. However, as

Mutz et al. (1993) have pointed out, daily activities tend to be displaced by other functionally similar activities, or activities that fulfill a similar need for an individual. This is not the case with television viewing and physical activity in children, and is consistent with the findings by Taveras et al. (2007). As television viewing is contextually unrelated to physical activity, the most likely scenario for displacement in the case of television viewing and physical activity is the “marginal activities hypothesis”. This hypothesis suggests that a desirable activity in children will displace marginal, or fringe, activities (Mutz et al., 1993), which historically have been referred to as any activity that is difficult to measure. With advances in our ability to objectively measure these marginal activities collectively using accelerometry, it may be that increased time spent watching television is associated with a reduction in time spent engaging in activities that are functionally similar and that children deem to be marginal. Mutz et al. (1993) showed that increases in children’s television viewing time, as television became available in South Africa, reduced time spent in other activities that are similar and deemed less important or marginal, such as listening to radio or attending movies. Even among activities that are both functionally similar and marginal, these effects may not be uniform or consistent, may be asymmetric, and are subject to inter-individual variability.

The concept of functional reorganization (Mutz et al., 1993) may play a role in the displacement of activities with television time, as some of the reasons that children would engage in physical activity, such as social interaction, may be reorganized and incorporated into television viewing. This can be seen through the work done by Mutz et al. (1993), as they showed that subsequent reductions in children’s television viewing time following the initial increase in South Africa did not lead to parallel increases in time spent in activities which were previously displaced. Thus, these activities were functionally reorganized to fulfill needs in a

different way and in the absence of television watching the amount of time required to spend in these activities to fulfill the reorganized needs was not the same. Evidence of an effect such as this can be seen in the literature with television viewing and physical activity. For example, Epstein et al. (2008) showed that a reduction in television viewing in children did not have an effect on their level of physical activity. There are two explanations for this finding: 1) television viewing and physical activity are truly unrelated, and changes in one do not lead to changes in another, or 2) television viewing does not displace time spent in physical activity, but instead alters the function that physical activity serves for children such that a reduction in television viewing would not lead to an increase in physical activity. Longitudinal studies using accelerometry and self-report measures of television viewing time are needed to better understand how television viewing affects physical activity levels in children.

6.2 Food intake patterns of obese, overweight, and normal weight children while watching television

In chapter 4, we showed that obese children consume fast food more frequently during television watching than overweight or normal weight children, but that eating fast food in higher frequency is not associated with increased odds of being obese. As mentioned in chapter 4, these findings provide justification for future research to evaluate a reverse-causal effect and for further examining the dietary patterns of children who are obese, rather than intervening to prevent obesity in those children who may have unhealthy diets. The increased frequency of consumption of fast food is concerning as this provides more frequent opportunities for children who are obese to over-consume in front of the television. The increased potential for overconsumption is even more worrisome considering that obese children may be more responsive to environmental food cues (Braet et al., 2008), such as television viewing (Halford et

al., 2007, 2004), and thus may experience an increase in food intake when exposed to these cues (Chapman et al., 2012). It cannot be known from this study if children who are obese consume a higher quantity of kilocalories from fast food than other children; however, as shown in chapter 4, they have a higher frequency of opportunities to do so. However, as mentioned above, the literature suggests that the frequency of consumption may have a stronger effect on weight gain than portion size (Mattes, 2014).

We also showed that children who are obese consume fruits/vegetables more frequently during TV watching than normal weight children, but again that those who consumed fruits/vegetables more frequently were not at higher odds of being obese. As the analysis in chapter 4 used specific food items only, it is quite possible that fruits/vegetables are co-consumed with a variety of foods with similar compositions to one another, which would not be evident in this type of analysis. For example, if fruits/vegetables are consumed alongside foods that are all high in fat or sugar, this may still have detrimental effects on dietary patterns and energy balance, but would not be evident in an analysis of specific food items.

The increased frequency of fast food and fruit/vegetable consumption in obese children in front of the television may be the result of linked memory formation in a classical model of conditioning (Chapman et al., 2012; Rodin and Marcus, 1982). A repeated pairing of specific foods and television watching may promote consumption in response to television watching; in other words, watching television becomes a conditioned cue to eat. A higher frequency of consumption of fast food has the potential to impact energy balance. While perhaps less likely with fruits/vegetables, if other food items are co-consumed as part of a complete or balanced meal alongside fruits/vegetables this could lead to children being conditioned to consume these foods as well.

It is possible that the pairing of food and television has more to do with a child's home environment, as 10 year old children are often not capable of being, or expected to be, involved with food preparation at home. For instance, it may be that children who are obese are also more likely to live in an environment more conducive to repeated pairing of television and fast food or fruits/vegetables. Children are, however, capable of influencing purchasing decisions by their parents – this is indeed the effect that food advertising companies depend on when marketing their products to children (Hastings et al., 2003). If children alter their parents purchasing decision in response to viewing television advertisements, children can then experience repeated pairing of specific foods and television watching through their own free will. However, this scenario would be affected by parenting style, post-purchase food availability, and household rules surrounding the child's ability to exercise free choice in deciding what they eat.

Contrary to this, increased frequency of fast food and fruit/vegetable consumption in obese children was explained by the increase in frequency of television watching, as the 'frequency rate' of consumption was not higher in obese children than in normal weight children. In fact, we showed that normal weight children consumed fast food in front of the television more frequently per hour of television time than children who were obese. This suggests that there are opportunities for obese children to watch television without consuming fast food; however, these results are subject to social desirability bias and should be replicated in other samples of children. This analysis could not consider foods that obese children were consuming when not eating fast foods, as this may still contribute to a positive energy balance over time.

6.3 Sedentary time, television time and frequency of consumption of food items

In chapter 5, we presented results suggesting that higher TV time is associated with lower frequency of consumption of healthy foods, and higher frequency of consumption of unhealthy

foods, even independent of total sedentary time, and that total sedentary time is negatively associated with sports drinks only. The finding that objectively measured sedentary time is very weakly associated with frequency of consumption of food items, as compared to television time, is not surprising and was hypothesized by the authors herein. There are several explanations for the differences seen between television viewing and sedentary time with respect to food intake. Firstly, these two types of measures are assessing different behaviours; one is a specific behaviour known to be linked to food intake, while the other encompasses any behaviour that is undertaken in a seated or reclining posture while awake. Furthermore, the lack of association observed with sedentary time and food intake may be due to a lack of inter-individual variability in sedentary time (Colley et al., 2012b) given the sedentary nature of modern Canadian lifestyles (Colley et al., 2011).

The results of this study provide evidence for the aforementioned role of television advertisements on dietary patterns in children. The majority of food marketing occurs on television (Federal Trade Commission, 2008), largely due to the ubiquitous nature of television and children's attentional allocation to television viewing. As mentioned previously, the food and beverage industry in parts of Canada has engaged in a self-regulatory marketing initiative to reduce the advertising of unhealthy foods to children, especially those under 12 years old; however, there is evidence to suggest that this self-regulation has no effect on children's marketing environments (Potvin Kent et al., 2011). Even when bans on advertising to children are put in place, this may not limit the amount of food or beverage advertising that children are exposed to (Potvin-Kent et al., 2011). This represents a major cause for concern as the self-regulatory marketing initiatives may be providing a false sense of empowerment to both parents

and health policy makers if they believe that self-regulation is reducing the number of advertisements that children are exposed to.

As mentioned in chapter 2, there is a growing body of evidence to suggest that in children sedentary behaviours lead to deleterious health consequences (Tremblay et al., 2011b, 2010) and that different types of sedentary behaviours have different health consequences (Chaput et al., 2012b). While self-reported screen time, such as television viewing, has been consistently associated with food intake (Chaput et al., 2011; Thivel et al., 2013), the association between objectively measured sedentary behaviour and food intake in children is largely unknown. In chapter 5 we showed that children's objectively measured sedentary time is associated only, and inversely, with frequency of consumption of sports drinks while their self-reported television viewing time is associated with frequency of consumption of a number of healthy and unhealthy foods. The results with overall sedentary time represent a novel finding, as this type of analysis had not been undertaken previously, and are strengthened by the companion results with self-reported television time, which replicate the consistent findings from previous literature. It is worth noting here that while self-reported screen time is consistently associated with obesity (Dietz and Gortmaker, 1985; Robinson, 2001) and other health outcomes (Saunders et al., In Press) in children, the literature is mixed with respect to the association between objectively measured sedentary time and health outcomes in children (Saunders et al., In Press). The results presented in chapter 5 may provide an explanation for the mixed results observed in the literature with respect to overall sedentary time and health consequences in children. An assessment of health outcomes or health risk in children is beyond the scope of this thesis.

6.4 Strengths and Limitations

Many of the strengths and limitations of this thesis have been identified in chapters 4 and 5 as part of the manuscripts. However, there are outstanding strengths, which should be addressed. One major strength of this thesis that has not been mentioned is the availability of data for both habitual frequency of consumption of foods items as well as for frequency of consumption of food items in front of the television. Analyses which examine food intake in the context of television viewing usually include only one of these measures. Likewise, the use of both objectively measured sedentary time and self-reported television viewing time is also an asset as these two measures of sedentarism capture unique behaviours in children.

There are also outstanding limitations that should be discussed. Firstly, one limitation is the use of a food frequency questionnaire to measure children's dietary patterns as this tool cannot determine total caloric intake. While the frequency of consumption of specific food types uniquely captures dietary information in its own right, it does not allow for the assessment of energy balance. An estimate of the typical portion size of the food eaten by children would have been useful in lieu of measures of caloric intake; however, this would have added significant burden to participation for children and their families.

Secondly, the food frequency questionnaire cannot exclude any children who may have under-reported their food intake. The phenomenon of under-reporting food intake has been known for over 30 years (Hallfrisch et al., 1982), and the degree of underreporting is positively related to BMI in children (Champagne et al., 1998), at least partially under volitional control, and is likely motivated by social desirability (Heymsfield et al., 1995). However, while obese adolescents have been shown to under-report caloric intake by up to 40%, this figure is significantly reduced in children (~25%) (Livingstone and Robson, 2000). In fact, obese children

in the ISCOLE study reported consuming fast foods, fruits/vegetables more frequently than their normal weight counterparts. It cannot be known to what degree, if any, children in the current thesis under-reported the frequency of consumption of any foods.

Thirdly, it has been suggested that the time and the amplitude of human meals are not under the direct control of metabolic signals of hunger and satiety and are essentially determined by socio-cultural factors (Bellisle, 1979). ISCOLE does not have information on the socio-cultural aspects of eating or meal times within the families of children; thus, this was not included in the analyses. As other variables, such as ethnicity, total annual family income, and parental education level, were routinely accounted for in the analyses, this may reduce the residual effect of any additional information regarding the socio-cultural influences of children's dietary patterns. Parents' food purchasing habits can also impact children's diets; data on food purchases were not available in the current study, but should be strongly considered in future studies. Parental intake and household availability have been shown to be moderate predictors of fruit and vegetable intake in children (Rasmussen et al., 2006). Studies using data on household availability have explained 11-13% of the variance in fruit and vegetable consumption (Neumark-Sztainer et al., 2003; Reynolds et al., 1999); similar in magnitude to the results seen in Chapter 5. The current study did not measure parental intake, and provided only a crude estimate of household availability of some foods. These variables are important to consider in future studies which aim to explain variance in the consumption of these foods.

Fourthly, there are several known factors within the home and family environment that are known correlates of children meeting or not meeting the Canadian Sedentary Behaviour Guidelines (<2 hours of screen time per day) (Tremblay et al., 2011a) which could have been included in the analyses. Some of these factors were either not measured, such as parental

television habits (Gorely et al., 2004; Hardy et al., 2006) or co-viewing television with parents (Hardy et al., 2006; Krosnick et al., 2003), while others were not included because they were outside of the scope of the research question, such as the presence of a sibling in the household (Hardy et al., 2006) or the presence of a television in the bedroom (Gorely et al., 2004). The covariates used were chosen because they were associated with the exposure or outcome variables (or both), and were relevant potential confounders given the context of the research question. The number of covariates was also considered within the context of the statistical power of models through this thesis. For example, in the combined total sedentary time/television watching time in Table 5.5, power was limited due to the small sample size of one of the groups; thus, the five most relevant confounding variables were used as covariates in the model.

Finally, screen time in children is difficult to measure due to multi-tasking, where children's actual exposure can differ from their self-reported exposure. Rideout et al. (2010) determined that the discrepancy between self-reported screen time and total screen time, due to multi-tasking, can be up to 3 hours; American children are exposed to 7 and a half hours of screen time per day, but this figure increases to 10 and a half hours after multi-tasking is considered. Television viewing is uniquely difficult to measure because of the use of contemporary mediums of watching, such as on computers, tablets or smart-phones. For example, children may record watching television on the computer as computer or television time.

6.5 Public Health Implications: eat less during television or watch less television?

It is important to consider the implications of the current findings from a public health perspective; that is, should we suggest that children modify their dietary habits during television

viewing and/or attempt to reduce the influence of television advertisements on their food preferences and choices, or should we encourage children to watch less television altogether?

As suggested by the review of potential explanations in this thesis, increased consumption of food in front of the television may not be under an individual's volitional control and is due, at least in part, to external factors. If overconsumption is driven by distraction and classical conditioning mechanisms, as well as inhibited episodic memory formation and habituation to food cues, behaviour changes may be difficult to attain for most children.

Secondly, television advertisements, specifically those for food, influence children's nutritional habits throughout the day (Harris et al., 2009) as well as their food preferences and choices (Federal Trade Commission, 2008), and are associated with obesity in children (Zimmerman and Bell, 2010). As mentioned above, even when public health interventions in Canada are designed to reduce the impact of these advertisements on children, these efforts are largely unsuccessful (Potvin Kent et al., 2011; Potvin-Kent et al., 2011).

Thus, in order to reduce the impact of television viewing on children's dietary habits and their risk of developing obesity, the take-home message here is ultimately to watch less television as well as to increase children's levels of MVPA. At least on a small scale, this is an achievable goal which produces results: children enrolled in a 6-month classroom-based curriculum to reduce television viewing and other screen-based sedentary behaviours saw reductions in the amount of television they watched and meals eaten in front of television, as well as reductions in BMI, triceps skinfold, waist circumference, and waist-to-hip ratio (Robinson, 1999). Watching less television can reduce the risk of overconsumption through hedonic mechanisms and reduce children's exposure to television advertisements that are associated with aberrant alterations in dietary patterns (Swinburn and Shelly, 2008). It is

important to acknowledge that reducing television viewing implies an increase in some type of other behaviours. As noted by Jordan and Robinson (2008), if researchers are successful in reducing television viewing time, it is of utmost importance to understand what types of activities children replace this time with to address any potential compensation effects of reducing television viewing (Jordan and Robinson, 2008). Of course, efforts to reduce television viewing may be futile if children replace this time with television viewing using contemporary mediums of viewing (i.e. computers or tablets), or other screen-based sedentary behaviours which may also impact children's health (Goldfield et al., 2011; Saunders et al., 2013).

Various effect sizes of the variance in BMI explained by television viewing have been observed; specifically, observational studies typically show small effect sizes and intervention studies show larger effect sizes (Swinburn and Shelly, 2008). It is thought that the smaller effect sizes of BMI and television viewing observed in observational studies between individuals or within-individuals over time is reflective of children's relatively high, but stable, television viewing habits. Historically, the trend has been towards an increase in the exposure to television viewing; however, in recent years traditional television viewing (i.e. viewing from a television set) has declined, only to be replaced with television viewing over the internet and on smart phones and tablets (Kaiser Family Foundation, 2007). Despite shifting trends in the medium of viewing, overall television exposure in children has increased. The push for reducing screen-based sedentary behaviors is stronger now than ever, as emphasized by the growing number of medical and public health recommendations surrounding these behaviours (American Academy of Pediatrics, 2013; Tremblay et al., 2011a). This support for reducing television viewing, and other screen-based sedentary behaviours, is necessary to combat the growing problem of

sedentarism in children, and research suggests that this could have a significant impact on reducing obesity prevalence (Swinburn and Shelly, 2008).

While reducing screen-based sedentary behaviours is beneficial for children (Epstein et al., 2008; Tremblay et al., 2011b, 2010), it may not be enough to combat the health effects of screen-based sedentary behaviours in a modern-day, technology-savvy society. Researchers and policy makers should also focus on regulations to reduce the heavy marketing of energy dense foods and beverages on television as this may be an effective public health measure in order to minimize the impact of television viewing on obesity in children (Swinburn and Shelly, 2008).

6.6 Direction for Future Research

While this thesis has identified gaps in the literature, and provided data to some previously unanswered questions in the field, several questions remain.

Firstly, the role of MVPA in the association between television viewing and obesity has not been truly delineated in the context of a displacement effect. As mentioned above, longitudinal studies will be needed to accomplish this. The longitudinal study by Taveras et al. (2007) conducted with American adolescents, provides a foundation for future research in Canadian children; these studies should consider the use of objective methods of physical activity assessment, as opposed to the self-report methods employed by Taveras et al. (2007). Secondly, the findings of this thesis are limited in that they can only be generalized to Canadian children approximately 10 years of age living in the Ottawa area and attending school in one of the four Ottawa school boards. The impacts of different socio-political environments on screen time and food intake in children should be expanded upon on a global scale. Thirdly, there is a need for mechanistic studies in children to determine the driving factors behind increased food intake with higher screen time, as the vast majority of these studies have been conducted in

adults. It is not truly known if these explanatory factors exist in children, or how they may operate in children. Fourthly, manuscript #1 identified a unique metric of frequency of consumption of food during television viewing – the ‘frequency rate’ of consumption, defined by the frequency of consumption during television viewing divided by the number of hours of television viewing. Further studies are needed to investigate the frequency rate of consumption of foods, including fast food, in children who are obese vs. normal weight. If children who are obese are watching television without eating specific foods, such as fast food, it would be crucial to know if they are eating any other types of food instead. Fifthly, the changing nature of television viewing makes this behaviour more difficult to measure now than ever, and there has been little research in the area of contemporary television watching in children. Research is needed to identify if dietary and/or physical activity patterns are consistently and uniformly affected by different mediums of television watching. For example, it is plausible that mediums with fewer food advertisements may have a diminished effect on dietary patterns. Furthermore, it is currently unknown if the cumulative intensity exposure to screens due to multi-tasking (i.e. simultaneously watching television and using a computer/tablet) is associated with higher food intake or risk of developing obesity. Future research should examine the dose-response effect of screen time intensity on food intake in children. Finally, the literature on the effect of different television advertising environments on children’s food preferences is relatively weak (Potvin-Kent et al., 2011), and further examination into these potential differences is warranted.

Chapter 7 – Bibliography

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Chapter 8 - Appendices

Appendix A: Ethics Approval

File Number: H08-13-04

Date (mm/dd/yyyy): 08/01/2013



Université d'Ottawa **University of Ottawa**
Bureau d'éthique et d'intégrité de la recherche Office of Research Ethics and Integrity

Ethics Approval Notice Health Sciences and Science REB

Principal Investigator / Supervisor / Co-investigator(s) / Student(s)

<u>First Name</u>	<u>Last Name</u>	<u>Affiliation</u>	<u>Role</u>
Jean-Philippe	Chaput	Medicine / Medicine	Supervisor
Michael	Borghese	Health Sciences / Human Kinetics	Student Researcher

File Number: H08-13-04

Type of Project: Master's Thesis

Title: International Study of Childhood Obesity, Lifestyle and the Environment

<u>Approval Date (mm/dd/yyyy)</u>	<u>Expiry Date (mm/dd/yyyy)</u>	<u>Approval Type</u>
08/01/2013	07/31/2014	Is

(Is: Approval, Ib: Approval for initial stage only)

Special Conditions / Comments:

Research based on secondary use of data.





Université d'Ottawa **University of Ottawa**
Bureau d'éthique et d'intégrité de la recherche Office of Research Ethics and Integrity

This is to confirm that the University of Ottawa Research Ethics Board identified above, which operates in accordance with the Tri-Council Policy Statement and other applicable laws and regulations in Ontario, has examined and approved the application for ethical approval for the above named research project as of the Ethics Approval Date indicated for the period above and subject to the conditions listed the section above entitled "Special Conditions / Comments".

During the course of the study the protocol may not be modified without prior written approval from the REB except when necessary to remove subjects from immediate endangerment or when the modification(s) pertain to only administrative or logistical components of the study (e.g. change of telephone number). Investigators must also promptly alert the REB of any changes which increase the risk to participant(s), any changes which considerably affect the conduct of the project, all unanticipated and harmful events that occur, and new information that may negatively affect the conduct of the project and safety of the participant(s). Modifications to the project, information/consent documentation, and/or recruitment documentation, should be submitted to this office for approval using the "Modification to research project" form available at: <http://www.research.uottawa.ca/ethics/consent.html>.

Please submit an annual status report to the Ethics Office four weeks before the above-referenced expiry date to either close the file or request a renewal of ethics approval. This document can be found at: <http://www.research.uottawa.ca/ethics/consent.html>.

If you have any questions, please do not hesitate to contact the Ethics Office at extension 5387 or by e-mail at: ethics@uOttawa.ca.

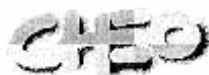
Signature:



Kim Thompson

Protocol Officer for Ethics in Research
For Daniel Lagarec, Chair of the Health Sciences and Sciences REB





CHEO RESEARCH ETHICS BOARD APPROVAL – DELEGATED REVIEW

Principal Investigator: Dr. Jean-Philippe Chaput / Charles Boyer

Proposal Number: #1144X

Protocol Title: International Study of Childhood Obesity, Lifestyle and the Environment (ISCOLE)

Department or PSU: HALO

Approval date: June 23, 2011

Valid Until: June 22, 2012

Documents reviewed and approved: No version date or number specified on the Application for Funding (revised documents received by the REB on March 30, 2011), the following documents were received:

1. ISCOLE Protocol, Version 2.0, Field Site: 10 Canada
2. Appendix A: Investigators and Coordinating Center Personnel Biographies
3. Appendix B: Investigators and Study Personnel Contacts
4. Appendix C: ISCOLE Investigator Sampling Questionnaire
5. Appendix D: Statistical Power and Sample Size
6. Appendix E: ISCOLE Demographic and Family Health Questionnaire
7. Appendix F: Tracing Questionnaire
8. Appendix G: Detailed Anthropometric & Bioelectric Impedance Measurement Procedures
9. Appendix H: Anthropometric Data Collection Form
10. Appendix I: Instruction Manual for Tanita Body Composition Analyzer SC-240
11. Appendix J: Accelerometer Instructions
12. Appendix K: Accelerometer Compliance Verification Checklist
13. Appendix L: Accelerometer Tracking Log
14. Appendix M: Diet and Lifestyle Questionnaire
15. Appendix N: Parent Questionnaire
16. Appendix O: School Environmental Questionnaire
17. Appendix P: School Audit Tool
18. Consent Form – Parents, June 21, 2011, Version #3
19. Consent Form – School, June 21, 2011, Version #3
20. Assent Form - June 21, 2011, Version #3
21. ISCOLE Subcontract agreement 10 Canada_Tremblay

This is to notify you that the Children's Hospital of Eastern Ontario Research Ethics Board has granted approval to the above named research study on the date noted above. Your project was reviewed under the delegated review stream, which is reserved for projects that involve no more than minimal risk to human subjects.

Final approval is granted for the above noted study, with the understanding that the investigator agrees to comply with the following requirements:

- The investigator must conduct the study in compliance with the protocol and any additional conditions set out by the Board.
- The investigator must not implement any deviation from, or changes to, the protocol without the approval of the REB, or when the change involves only logistical or administrative aspects of the study (e.g., change of telephone number or research staff).
- The investigator must, prior to use, submit to the Board changes to the study documentation, e.g., changes to the informed consent letters, recruitment materials.

.../2



Letter – Dr. JP Chaput – Protocol #1144X

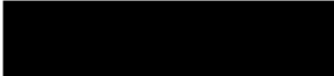
June 23, 2011

Page 1

- For all other research studies, investigators must promptly report to the REB all unexpected and untoward occurrences (including the loss or theft of study data and other such privacy breaches).
- Investigators must submit an annual renewal report to the REB 30 days prior to the expiration date stated above.
- Investigators must submit a final report at the conclusion of the study.
- Investigators must provide the Board with French versions of the consent form, unless a waiver has been granted.

For complete procedures relating to these modifications, please refer to the RLB website at http://www.cheo.on.ca/about_ethics.htm or contact Sharon Haig, Ethics Coordinator at shaig@cheo.on.ca or 613-737-7600 ext. 2128.

Regards,



Dr. Carole Gentile, C.Psych.
Chair, Research Ethics Board

CG/smeh 23/06/2011
c.c. CHEO RI Administration
Dr. Mark Tremblay, H/ALO

This is an official document. Please retain the original for your file

2010 version



CONSEIL DES
ÉCOLES CATHOLIQUES
DU CENTRE-EST
*Le meilleur conseil
où on passez votre journée*

December 7, 2012

Dr. Jean-Philippe Chaput
Junior Research Chair



Dear Dr. Chaput:

Re: International Study of Childhood Obesity, Lifestyle and the Environment (ISCOLE)

On behalf of the Conseil des écoles catholiques du Centre-Est (CECCE), I am pleased to inform you that the ISCOLE research project has been approved for the 2012-2013 school year. The names of our participating schools have been provided to Mrs. Geneviève Leduc.

Thank you for considering our school board for your research project.

Sincerely yours,



Micheline Bercier-Larivière
Head of Accountability

/ac



Conseil des
écoles publiques
de l'Est de l'Ontario

September 19, 2012

Dr. Jean-Philippe Chaput
Junior Research Chair



Re: International Study of Childhood Obesity, Lifestyle, and the Environment (ISCOLE)

Dear Dr. Chaput,

On behalf of the *Conseil des écoles publiques de l'Est de l'Ontario* (CEPEO) Research Advisory Committee, I am pleased to inform you that the ISCOLE research project was approved for the 2012-2013 school year.

Thank you for considering the *Conseil des écoles publiques de l'Est de l'Ontario* (CEPEO) for your research project.

Sincerely,



Rachid El Keurti
Executive Director

ÉCOLES DE CHOIX, CONSEIL DE CHOIX

ENVIRONNEMENT
D'APPRENTISSAGE
DE CHOIX

ÉCOLES ET SERVICES
PERFORMANTS ET
IMPUTABLES

ENVIRONNEMENT
DE TRAVAIL DE
CHOIX



Ottawa-Carleton Research Advisory Committee

August 24, 2012

Dr. Jean-Philippe Chaput
Junior Research Chair



Re: International Study of Childhood Obesity, Lifestyle, and the Environment (ISCOLE)

Dear Dr. Chaput,

On behalf of the Ottawa-Carleton Research Advisory Committee, I am pleased to inform you that you have satisfactorily responded to the suggested revisions to your research proposal that were communicated to you on the letter dated June 13, 2012. You may start contacting the schools and begin collecting data.

Thank you for considering the Ottawa-Carleton area school boards for your research project. We look forward to your report at the end of the research study. Good luck with your research project.

Sincerely,

Botsalano Tsala Mosimakoko, Ph.D (Chair, OCRAC)
Research Officer, Quality Assurance
Ottawa Carleton District School Board



On behalf of the Ottawa-Carleton Research Advisory Committee

Appendix B: Permissions

Permission to reproduce Figure 1 from Tremblay et al. was obtained via personal communication on Tuesday, November 26th, 2013. The figure is reproduced from a publication in *Applied Physiology, Nutrition, and Metabolism* in 2010. Reproductions of content do not require permissions from the publisher, as long as they are used in good faith and per the original intention of the author.

Appendix C: Publications during my MSc. Studies

Peer-reviewed Publications (including those under review)

Larouche R, Chaput JP, Leduc G, Boyer C, Bélanger P, LeBlanc AG, **Borghese MM**, Tremblay MS. A cross-sectional examination of socio-demographic and school-level correlates of children's school travel mode in Ottawa, Canada. *BMC Public Health*, *accepted*.

Saunders TJ, Gray CE, **BorgheseMM**, McFarlane A, Mbonu A, Ferraro ZM, Tremblay MS. Validity of pedometer-derived moderate and vigorous physical activity during treadmill walking and running in a heterogeneous group sample of children and youth. *BMC Public Health*, *accepted*.

Borghese MM, Tremblay MS, Leduc G, Boyer C, Belanger P, LeBlanc AG, Francis C, Chaput JP. Independent and Combined Associations of Total Sedentary Time and Television Viewing Time with Food Intake Patterns of 9-11 year-old Canadian Children. *Applied Physiology, Nutrition and Metabolism*, *in press*.

Borghese MM, Tremblay MS, Leduc G, Boyer C, Belanger P, LeBlanc AG, Francis C, Chaput JP. Television Viewing and Food Intake Patterns of Normal Weight, Overweight and Obese 9-11 year-old Canadian Children. *Journal of Nutritional Science*, *under review*.

Borghese MM, Boyer C, McClelland K, Hay J, Tremblay MS, Longmuir PL. Higher Peer Support and Lower Sedentary Behaviour are Associated with Higher Physical Activity Self-Efficacy in Children 8 to 12 Years of Age. *Research Quarterly for Exercise and Sport*, *under review*.

Gow RM, **Borghese MM**, Honeywell C, Colley RC. Activity intensity during free-living activities in children and adolescents with Inherited Arrhythmia Syndromes: assessment by combined accelerometer and heart rate monitor - a proof-of-principle study. *Circulation: Arrhythmia and Electrophysiology*, *epub August 30th, 2013*, doi:10.1161/CIRCEP.113.000514.

Boyer C, Tremblay MS, Saunders TJ, McFarlane A, **Borghese M**, Lloyd M, Longmuir P (2013). Validity and reliability of the plank isometric hold as a field-based assessment of muscular endurance for children 8 to 12 years of age. *Pediatric Exercise Science*, 25:407-422.

Borghese M, Chaput JP (2013). Television viewing promoting obesity in children: Do we really know the mechanism? *Bioenergetics: Open Access*, 2:1

Colley RC, Barnes J, Leblanc A, **Borghese M**, Boyer C, Tremblay MS. (2013) Validity of the SC-StepMX pedometer during treadmill walking and running. *Applied Physiology, Nutrition and Metabolism*, 38: 520-524.

Barnes JD, Colley RC, **Borghese M**, Janson K, Fink A, Tremblay MS. (2013) Results from the Active Healthy Kids Canada 2012 Report Card on Physical Activity for Children and Youth. *Paediatrics & Child Health*. June/July 2013, 18(6): 301-304

Jelley W, Larocque N, **Borghese M** (2013) Essential Competencies for Intraprofessional Practice. *Physiotherapy Canada*, 65(2): 148-151.

Non-Peer Reviewed Publications

Borghese MM & LeBlanc AG (2014). Healthy active living in a modern world. *Ottawa Parenting Times*, February/March 2014, 66. <http://www.parentingtimes.ca/healthy-active-living-in-a-modern-world/>

Active Healthy Kids Canada (2013). Are we driving our kids to unhealthy habits? – The Active Healthy Kids Canada Report Card on Physical Activity for Children and Youth. Toronto: *Active Healthy Kids Canada*, 2013.

Active Healthy Kids Canada (2012). Is Active Play Extinct? – The Active Healthy Kids Canada Report Card on Physical Activity for Children and Youth. Toronto: *Active Healthy Kids Canada*, 2012.

Active Healthy Kids Canada (2011). Don't let this be the most physical activity our kids get after school – The Active Healthy Kids Canada Report Card on Physical Activity for Children and Youth. Toronto: *Active Healthy Kids Canada*, 2011.

Appendix D: Abstracts and Conference Presentations during my MSc Studies

Published Abstracts

Borghese MM, Tremblay M, Leduc G, Boyer C, Belanger P, LeBlanc A, Francis C, Chaput JP (2014). Television viewing and food intake pattern of normal weight, overweight, and obese 9-11 year-old Canadian children. *Obesity Reviews* 15(suppl.2):232.

Chaput JP, **Borghese M**, Saunders TJ, Mathieu ME, Henderson M, Tremblay MS, O'Loughlin J, Tremblay A, on behalf of the QUALITY cohort research group (2013). Combined associations between moderate to vigorous physical activity and sedentary behaviour with cardiometabolic risk factors in children. *Canadian Journal of Diabetes*, 37(2): S262

Barnes JD, Colley RC, **Borghese M**, Janson K, Fink A, Tremblay MS, on behalf of the Active Healthy Kids Canada Research Work Group 2012. Results from the Active Healthy Kids Canada 2012 Report Card on Physical Activity for Children and Youth. *Applied Physiology, Nutrition, and Metabolism* 37(S1): S2

Conference Presentations

Oral - **Borghese MM**, Tremblay MS, Leduc G, Boyer C, Belanger P, LeBlanc AG, Francis C, Chaput JP (2013). Television Viewing and Food Intake Patterns of Normal Weight, Overweight and Obese 9-11 year-old Canadian Children. *Human Kinetics Graduate Student conference, University of Ottawa, Ottawa, Canada.*

Oral - **Borghese MM**, Tremblay MS, Leduc G, Boyer C, Belanger P, LeBlanc AG, Francis C, Chaput JP (2013). Television Viewing and Food Intake Patterns of Normal Weight, Overweight and Obese 9-11 year-old Canadian Children. *12th International Congress on Obesity, Kuala Lumpur, Malaysia.*

Oral - **Borghese MM**, Tremblay MS, Leduc G, Boyer C, Belanger P, LeBlanc AG, Francis C, Chaput JP (2013). Television Viewing and Food Intake Patterns of Normal Weight, Overweight and Obese 9-11 year-old Canadian Children. *Children's Hospital of Eastern Ontario Research Day.*

Chaput JP, **Borghese M**, Saunders TJ, Mathieu ME, Henderson M, Tremblay MS, O'Loughlin J, Tremblay A, on behalf of the QUALITY cohort research group (2013). Combined associations between moderate to vigorous physical activity and sedentary behaviour with cardiometabolic risk factors in children. *Canadian Obesity Summit, Vancouver, Canada.*