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Examining the Association Between Sleep Duration, Diet and Body Mass Index in Québec Children

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Examining the association between sleep duration, diet and body mass index in Québec children.

By

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Thesis submitted to the Faculty of Graduate and Postdoctoral Studies in partial fulfillment of the requirements for the MSc degree in Epidemiology

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Abstract

The prevalence of obesity in young children is increasing. Sleep duration is suggested to affect the regulation of body weight through changes in metabolic hormones that regulate appetite, food selection, and energy expenditure.

Using data obtained from the *Québec Longitudinal Study of Child Development*, this study prospectively examined: 1) the association between longitudinal sleep duration pattern (LSDP) (age 2.5 to 6 years) and overweight/obesity at age 6 and 7 years; and, 2) whether such an association may be mediated by dietary intake and/or eating behaviour at the population level. Associations were examined using multivariate logistic regression methods, with adjustments for potential confounders.

Boys with a '*short persistent* or *short increasing*' LSDP had significantly greater odds of being overweight/obese at age 6 and 7 years, in comparison to boys with an '*11-hour persistent*' LSDP. This association was partially mediated by problematic eating behaviours. LSDP did not associate with overweight/obesity in girls.

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CHAPTER 1: Introduction

The prevalence of overweight and obesity in young children is not only increasing, but accelerating across the globe, particularly in industrialized societies (Janssen et al., 2005; Lobstein, Baur, & Uauy, 2004; Lobstein & Leach, 2007; Ogden et al., 2002; Rennie & Jebb. 2005; Shields, 2005; World Health Organization, 1998). Of greatest concern is that overweight and obesity in childhood is likely to track into later adolescent and adult years (Johannson et al., 2006; Magarey et al., 2003) and is associated with numerous physical and psychological negative health outcomes (Ebbeling, Pawlak, & Ludwig, 2002; Lobstein et al., 2004; Must & Strauss, 1999; Visscher & Seidell, 2001). These negative outcomes place an economic burden on society through increased direct and indirect medical costs (Wolf & Colditz, 1998; Wolf, 1998). Due to its rising prevalence and serious negative effects, childhood overweight and obesity is recognized as an epidemic and public health crisis (Ebbeling et al., 2002; Kopelman et al., 2005).

This chapter reviews: 1) The definition of childhood overweight and obesity, its prevalence estimates, adverse health effects, and complex aetiology; and, 2) provides a rational for examining the relationship between sleep duration, dietary intake/eating behaviour and body mass index in young children.

1.1 *Background*

1.1.1 Definition & Classification

Overweight and obesity is defined as a condition of excessive body fat and body weight that is greater than what is considered healthy for a given age, sex, and a given height, increasing the risk of morbidity (Division of Nutrition, Physical Activity and Obesity, National Center for Chronic Disease Prevention and Health Promotion, 2009; Reilly & Wilson, 2006).

Ideally, the most precise estimates of total body fat are taken through direct measures of body composition through methods such as underwater weighing (hydro-densitometry), air-displacement plethysmography, magnetic resonance imaging (MRI), computerized tomography (CT), dual-energy X-ray absorptiometry (DEXA), or bioelectrical impedance analysis (BIA); however, these methods are often costly, unsuitable for young children, and not appropriate for large, epidemiological studies (Lobstein et al., 2004; Lobstein & Leach, 2007). Rather, more practical, inexpensive, and indirect estimates of body fatness are more commonly used for population-based research, the most common of these being: Body Mass Index (BMI), calculated by dividing weight (in kilograms) by height squared (in meters). BMI is widely used as a measure of relative adiposity and as a weight classification system for overweight and obesity in Canada (Health Canada, 2003) and by the World Health Organization (WHO) (WHO, 2006). At an individual level, BMI may not accurately measure body fatness in people that are particularly muscular, or especially short or tall (Lobstein et al., 2004); however, at a population level, BMI is recognized by the WHO as the most useful measure to estimate the prevalence of obesity and its associated health risks (WHO, 2000).

Using BMI as an index of body fatness, two classification systems are most commonly used to categorize children as overweight or obese in epidemiological research, although, other methods have been used. One of these methods, developed by the International Obesity Task Force (IOTF) in the year 2000, uses age- and gender- specific cut-off points for children aged 2 to 18 years that were extrapolated backwards from adult cut-off points for adverse health effects associated with overweight (a BMI=25 kg/m^2 in adults) and obesity (a BMI=30 kg/m^2 in adults) at age 18 years (Cole et al., 2000). These age- and gender- specific cut-offs were derived using data from six different reference populations, making them useful for epidemiological research in children and adolescents and for making comparisons with populations world-wide. However, the IOTF acknowledges that these cut-offs may not be adequate for use in Asian populations.

The second method commonly used as a classification system for childhood obesity uses BMI-for-age and gender-specific reference charts to classify overweight and obesity by BMI percentiles. With this method, care must be given to choose a BMI-for-age reference chart based on the most appropriate reference population. To date, several countries have used local data to develop BMI-for-age and gender-specific reference charts appropriate to their study population. Using this method, children with BMI's between the 85th and 95th centile are commonly classified as 'overweight' and those at or above the 95th centile are classified as 'obese'. More recently, growth charts developed in the USA by the Centers for Disease Control and Prevention (CDC) and the US National Center for Health Statistics (NCHS) recommend that children with BMI's between the 85th and 95th centile be classified as 'at risk of overweight' and those at or above the 95th centile as 'overweight' to avoid the stigma associated with classifying children as 'obese' (Kuczmarski et al., 2000). Using age- and gender- specific reference charts is a method that is useful both in a clinical setting and for epidemiological research; however, caution is necessary to ensure that centiles are not interpreted as coming from an ideal population if it is the case that they come from a reference population that may have a high prevalence of obesity (as is in the USA NCHS data). Additionally, when this method is used in a clinical setting, it is important that individuals be comparable to the reference population in order to be appropriately classified as overweight or obese.

Generally, out of these two classification methods, several studies have shown that the IOTF method produces more conservative estimates for the prevalence of overweight and obesity in pediatric populations, in comparison to prevalence estimates produced using the 85^{th} and 95^{th} centiles using a US-based reference population; however, the two methods produce similar estimates when applied to an adolescent population (Flegal et al., 2001; Wang & Wang, 2002).

1.1.2 Prevalence Estimates in Canada & Around the Globe

From the years 1981 to 2001, the prevalence of overweight and obesity in Canadian children aged 7 to 13 years increased by 200% to 300%, with overweight (including obesity) increasing from a prevalence of approximately 11% (2.0% strictly obese) to 29% (10% strictly obese) in boys from 1981 to 2000-2001 respectively, and from 13% (1.7% strictly obese) to 27% (10% strictly obese) in girls over those same years (Tremblay, Katzmarzyk, & Willms, 2002; Statistics Canada, 2003). These prevalence estimates are based on the IOTF age- and sex-specific BMI cut-off points, with BMI estimates based on measured heights and weights in 1981 (*1981 Canada Fitness Survey*) and parental- or self-reported data in 2000-2001 (*2000-2001 National Longitudinal Survey of Children and Youth*).

More resent results from the 2004 Canadian Community Health Survey (CCHS), which used measured indices for height and weight, showed that 26% of children aged 2 to 17 years were overweight or obese in the year 2004, with 8% of these being strictly obese, according to the IOTF age- and sex-specific BMI cut-off points for overweight and obesity (Shields, 2005).

From 1970 to the year 2000, similar high increases in the prevalence of childhood overweight and obesity were found in the USA and Brazil with year-on-year increases of approximately 0.5%, and also in Australia and the United Kingdom where increases per annum more closely resembled those found in Canada of around 1.0% increase per annum (Lobstein et al., 2004). In these four countries, according to the IOTF age- and sex-specific BMI cut-off points for overweight (including obesity), the prevalence of overweight and obesity was reported as: 35% in boys and 36% in girls aged 6 to 17 years in the USA during 2003-2004 (IASO, 2008); 23% and 21% in boys and girls, respectively, aged 7 to 10 years in southern Brazil in the year 2002 (De Assis et al., 2005); 25% and 30% in boys and girls, respectively, aged 9 to 13 years in Australia in 2007 (IASO, 2008); and 29% and 29% in boys and girls, respectively, aged 5 to 17 years in England in 2004 (IASO, 2008).

1.1.3 Adverse Health Effects

Childhood overweight and obesity is associated with numerous negative physiological and psychological health outcomes and economic consequences. These consequences include: 1) Immediate, short-term risks (e.g. orthopedic abnormalities such as Blount's disease; asthma; poor self-esteem; etc.); 2) intermediate (mid-range) risks that persist into adolescence and adulthood, but that do not necessarily represent morbidity (e.g. risk factors that *may* lead to Cardiovascular Disease (CVD) such as, elevated systolic or diastolic blood pressure, high cholesterol levels, etc.); and, 3) long-term risks that lead to adult morbidity and premature mortality (e.g. heart disease, atherosclerosis, colon cancer, etc.) (Must & Strauss, 1999). Table 1 presents a list of the many problematic physical and psychological health consequences of childhood and adolescent overweight and obesity (Ebbeling et al., 2002; Lobstein et al., 2004; Must & Strauss, 1999; Visscher & Seidell, 2001).

Table 1: Physical and psychological complications associated with childhood and adolescent overweight and obesity	
Immediate (short-term) & intermediate (mid-range) risks in children and adolelscents	
Cardiovascular	*Orthopaedic/Musculoskeletal*
Dyslipidaemia	Slipped capital femoral epiphysis
Hypertension	Blount's disease (tibia vara)
Coagulopathy	Forearm fracture
Chronic inflammation	Tibial torsion
Endothelial dysfunction	Flat feet
Fatty streaks	Ankle sprains
Left ventricular hypertrophy	Increased risk of other fractures
Endocrine	*Pulmonary*
Insulin resistance/impaired glucose tolerance	Sleep apnoea
Type II diabetes	Asthma
Precocious puberty/Menstrual abnormalities	Exercise intolerance
Polycystic ovary syndrome (girls)	Pickwickian syndrome
Hypogonadism (boys)	
Hypercorticism	
Gastrointestinal	*Renal*
Gallstones	Glomerulosclerosis
Steatohepatitis	
Cholelithiasis	
Liver steatosis/non-alcoholic fatty liver	
Gastro-oesophageal reflux	
Neurological	*Psychological/Psycho-social*
Idiopathic increased intracranial hypertension (e.g. Psudotumor cerebri)	Poor self-esteem
	Low confidence
	Depression
	Eating disorders
	Struggles in school
	Stigmatization from peers
Other	
Systemic inflammation/raised C-reactive protein	
Long-term risks (in adults who were obese as children or adolescents)	
Persistence of obesity into adulthood	
Adverse socioeconomic consequences, especially in women	
Cardiovascular risk factors, diabetes, cancers, depression, arthritis	
Premature mortality	

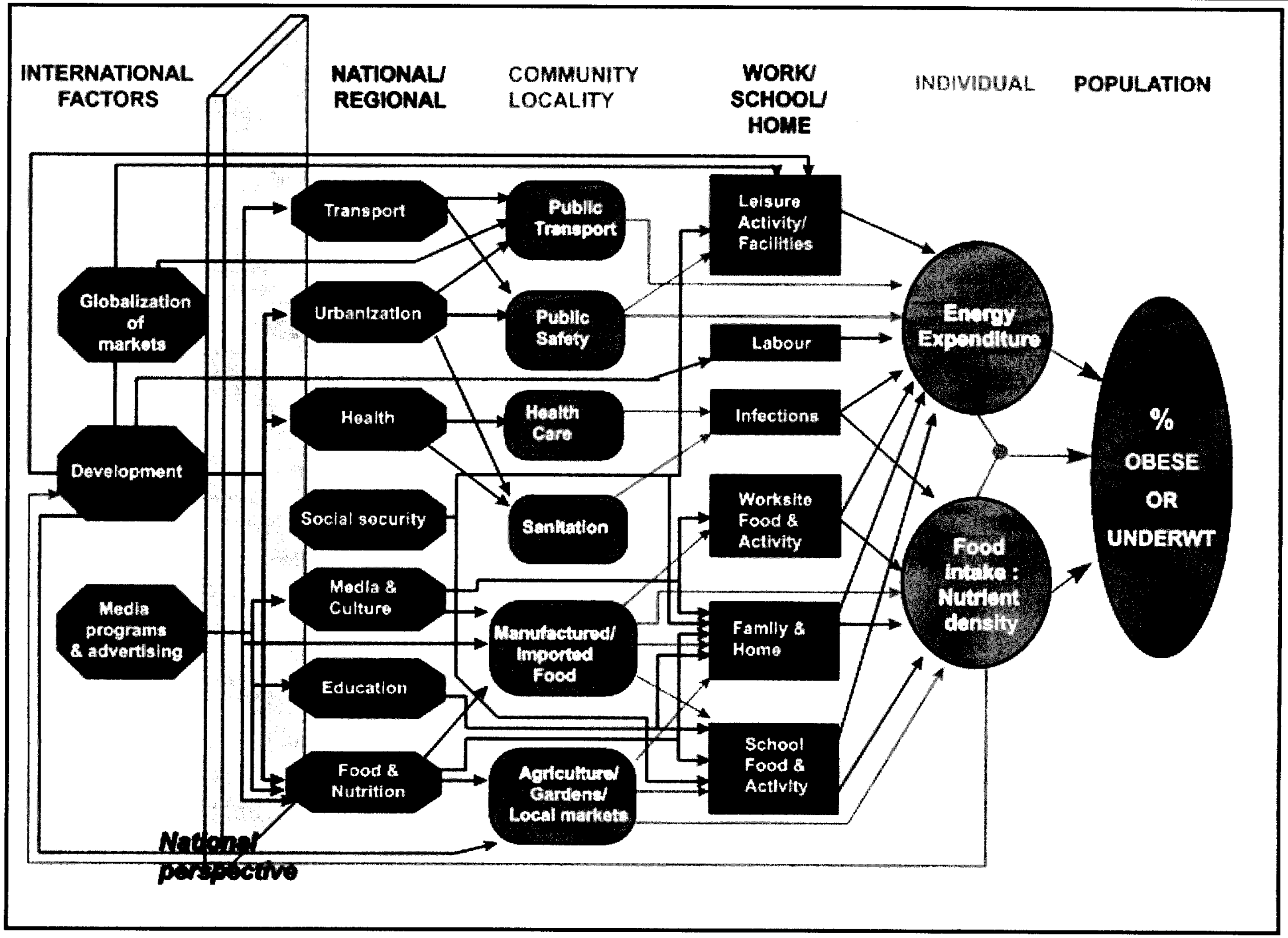
The rising prevalence and consequences of childhood overweight and obesity impose a direct and indirect economic burden on a nation and its health services (Katzmarzyk & Janssen, 2004; Lobstein et al., 2004; Wolf & Colditz, 1998; Wolf, 1998). Direct costs include the costs imposed to the health care system, including costs for the management of obesity and treatment of complications associated with or caused by obesity. Indirect costs include the costs associated with lost economic productivity following illness, disability, or premature death. In the case of children, such indirect costs result more from lost educational opportunities which can lead to lost economic contribution in adolescent and adult years, and lower employment productivity on behalf of the child's parent, older sibling, or caretaker who may be required to take leave to attend to the child's medical needs. In addition to the direct and indirect costs of overweight and obesity, 'intangible costs', which include social and personal costs associated with obesity, are more difficult to estimate yet may impact the individual child and the family more severly; these include, costs spent on weight loss programs and costs associated with psycho-social factors and reduction in quality of life, possibly including factors associated with school performance, job prospects, and employment (Lobstein et al., 2004).

1.1.4 The Aetiology & Complexity of Obesity

Body weight and body fatness are ultimately determined through the regulation of energy balance between caloric intake (diet) and energy expenditure (physical activity), and through physiological changes that regulate an individual's underlying metabolism (WHO, 2006; Taheri, 2006). Although genetic factors certainly play a role in an individual's propensity for weight gain, it is well agreed upon that there has not been a substantial change in the genetic makeup of the population to accompany the secular trend of overweight and obesity evident over the past three decades (Sorensen & Echwald, 2001; Wang & Brownell, 2005). Rather, the causes of overweight and obesity are multifactorial, stemming from factors related to growth and early life experiences, changes in lifestyles, behaviours, as well as family, social and physical environments that either act independently or interact with an individual's genetic make-up to influence how one regulates his/her diet and overall energy balance (Sorensen & Echwald, 2001; Wang & Brownell, 2005).

The International Obesity TaskForce (IOTF) developed the following schematic (Box 1) of the determinants of obesity to portray the interrelation between broad categories of determinants present at the individual level, to drivers of obesity acting at the level of the work/school/or home environment, the community locality, and at the national/regional and international level (Kumanyika et al., 2002). Determinants within each category and at each level act on, and interact with, each other to influence an individual's level of food intake, energy expenditure, and ultimate energy balance.

Box 1: IOTF schematic of the determinants of obesity



Source: Kumanyika S, Jeffery RW, Morabia A, Ritenbaugh C, Antipatis VJ, Public Health Approaches to the Prevention of Obesity (PHAPO) Working Group of the International Obesity Task Force (IOTF). Obesity Prevention: The Case for Action. *Int J Obes.* 2002;26(3):425-36.

More recently, a much more elaborate and intricate causal web of obesity (or obesity system map) was developed through the *Foresight Programme*[1] in the United Kingdom (UK) as a tool to visualize and address the complex systemic structure of obesity (Vandenbroeck, Goossens, & Clemens, 2007). This Obesity System Map is a causal loop model which centers on the core, foundational loop of energy balance. The foundational loop is surrounded by four main variables of obesity: The level of primary appetite control, the force of dietary habits, the level of physical activity, and the level of psychological ambivalence. These four key variables are influenced by a dense network of interlinked determinants of obesity (such as, genetic predisposition, level of recreational activity, the 'walkability' of the living environment, energy density of food, cost of food ingredients, levels of self esteem, education, and media consumption) that are organized into seven clusters of themes which determine the condition of obesity for an individual or a group of people. The seven clusters of variables are organized into the following themes: 1) Individual physiology (includes variables pertaining to the biological foundation of body weight management such as, metabolic, epigenetic, endocrinal, and neurological variables); 2) individual physical activity patterns (includes different activity components: recreational activity, domestic activity, occupational activity, transport activity, as well as parental modeling of activity, etc.); 3) physical activity environment (includes environmental enablers/disablers of physical activity such as, cost, safety, cultural values related to physical activity, etc.); 4) individual psychology (includes variables such as, level of self esteem, stress, parental control, control of diet, etc.); 5) social psychology (includes, level of education, acculturation, media availability, food advertising, etc.); 6) food consumption

[1] *Foresight Programme* (UK) Website: http://www.foresight.gov.uk/index.asp

(includes variables relating to the food market such as, food abundance, exposure and variety, as well as characteristics of food products such as, energy dense foods, portion sizes, etc); and, 7) food production (includes variables such as, industrial actors on the 'pressure for growth and profitability', the 'market price of food', and other upstream consumption drivers).

As is evident by the highly complex obesity system map just described, simultaneous efforts must be made to understand and address the determinants of obesity acting at multiple levels, from the individual level to the society at large, in order to create effective interventions to counter the obesity epidemic.

1.2 *Rationale*

One factor at the individual level proposed to contribute to the regulation of energy balance and overall body weight is sleep. As the prevalence of childhood obesity has been on the rise over the past three decades, some evidence suggests that time spent in bed has decreased among young children during this same period. One study comparing three birth cohorts (1974, 1979, and 1986) from the same Swiss population of children and adolescents aged 1 month to 16 years found that mean total sleep duration decreased across the three cohorts, especially in infants and young children; this was due to increased later bedtimes but unchanged wake times over the years (Iglowstein et al., 2003).

A reduction in sleep duration is suggested to create metabolic changes in hormones such as leptin and ghrelin, that regulate appetite, food selection, and patterns of energy expenditure, potentially contributing to the development of overweight and obesity by affecting both sides of the energy balance equation (Taheri, 2006; Taheri et al., 2004).

Growing evidence supports an association between sleep duration and obesity (Agras et al., 2004; Chaput et al., 2007; Chen et al., 2006; Cournot et al., 2004; Gangwisch et al., 2005; Gupta et al., 2002; Hasler et al., 2004; Knutson, 2005; Sekine et al., 2002a; Taheri et al., 2004; Vorona et al., 2005). Given that this association is likely to result from changes regulating appetite and energy balance, it is reasonable to suspect that differences in sleep duration should result in differences in dietary intake and eating behaviour in young children, ultimately affecting the regulation of body weight; however, research examining this 3-way association in children is lacking.

Sleep duration is a generally simple and modifiable risk factor. With more understanding of the relationship between sleep duration, dietary intake/eating behaviour, and overweight/obesity in young children, parents, physicians, and health educators may have greater opportunities and greater success with early interventions to counter the rising trend of childhood obesity.

CHAPTER 2: Literature Review

This chapter presents a literature review on what is currently known about the association between: 1) Sleep duration and overweight/obesity; 2) sleep duration and appetite, dietary intake, and eating behaviour; and, 3) dietary intake, eating behaviour and overweight/obesity.

2.1 *Sleep Duration and Overweight/Obesity*

The association between sleep duration and overweight/obesity has received increased attention in recent years. Numerous epidemiological studies show evidence of a dose-response association between short sleep duration and obesity in children, adolescents, and adults of different age groups and ethnic backgrounds (Agras et al., 2004; Chaput et al., 2007; Chen et al., 2006; Cournot et al., 2004; Gangwisch et al., 2005; Gupta et al., 2002; Hasler et al., 2004; Knutson, 2005; Sekine et al., 2002a; Taheri et al., 2004; Vorona et al., 2005).

In adult men, the trend of the association appears to be negative and monotonic, with shorter hours of sleep duration associating with higher BMI; while for women, a U-shaped, curvilinear relationship between sleep duration and BMI has been reported (Hasler et al., 2004). In children and adolescents, the majority of findings come from cross-sectional studies that cannot prove causality; however, the number of longitudinal studies showing strong evidence for an increased risk of obesity among children with shorter hours of sleep duration is increasing (e.g. Agras et al., 2004; Dieu et al., 2007; Landhuis et al., 2008; Reilly et al., 2005; Snell, Adam, & Duncan, 2007; Taveras et al., 2008). A large prospective cohort study conducted in the United Kingdom showed that short sleep duration (<10.5 hours per night) from the early age of 3 years significantly predicted obesity at the age of 7 years (OR=

1.45; 95% CI: 1.10, 1.89) in a sample of 5,493 children (children included in final multivariate analyses) (Reilly et al., 2005). Another longitudinal survey following 915 children in Massachusetts (USA) found that less than 12 hours of sleep per day in infancy (between the age of 6 months and 2 years) was associated with increased adiposity at age 3 years, observed through a higher BMI *z*-score (ß=0.16; 95% CI: 0.02, 0.29), a higher sum of subscapular and triceps skinfold thickness (ß=0.79 mm; 95% CI: 0.18, 1.40), and increased odds of overweight (OR= 2.04; 95% CI: 1.07, 3.91) at age 3 years (Taveras et al., 2008). The association between shorter sleep duration in childhood and overweight/obesity has also been seen to extend into adulthood. One study following a population birth cohort of 1037 participants born in New Zealand in 1972-1973, found a negative linear relationship between mean of sleep time (in hours) from age of 5 to 11 years and BMI (adjusted ß= -0.93; 95% CI: -1.54, -0.31) and obesity (OR=0.65; 95% CI: 0.43, 0.97) at age 32 years (Landhuis et al., 2008).

Only recently has the evidence of the association between sleep duration and childhood obesity been reviewed systematically and quantified by means of a meta-analysis. In a meta-analysis conducted by Cappuccio and colleagues which pooled 12 cross-sectional, population-based studies of the association between short sleep duration ($\leq$ 10 hours per night) and obesity in children, results revealed a pooled OR of 1.89 (95%CI: 1.43, 2.43; $P<0.0001$) for this association in participants ranging from ages 2 to 20 years (n=30,002) (Cappuccio et al., 2008). Although the aforementioned study was based only on cross-sectional findings, another meta-analysis conducted by Chen and colleagues included both cohort and cross-sectional studies of the general pediatric population; this meta-analysis found strong evidence for a relationship between short sleep duration (using each study's specific criterion) and increased risk of childhood overweight/obesity, resulting in a pooled

OR 1.58 (95% CI: 1.26, 1.98) for the total pediatric population (boys and girls combined) (Chen, Beydoun, & Wang, 2008). Furthermore, results from this same meta-analysis showed that children in the shortest sleep duration category (<9 hours per night for children aged <5years; <8 hours per night for children aged 5-10 years; and, <7 hours per night for children aged 10 or more) had an even higher risk (92%) of being overweight or obese in comparison to children with a longer sleep duration. Chen and colleagues also found that, on average, for every hour of increase in sleep, the risk of overweight/obesity was reduced by approximately 9% (pooled OR= 0.91; 95%CI: 0.84, 1.00). Neither of the two meta-analyses reviewed found evidence of a publication bias for studies in children or adults, examined through the use of funnel plots and Begg's tests (Cappuccio et al., 2008; Chen et al., 2008).

Even though the literature provides strong evidence for an association between short sleep duration and increased risk of overweight/obesity, there have been some inconsistent findings regarding the pattern of this association across the sexes in studies of children and adolescents (Chaput, Brunet, & Tremblay, 2006; Eisenmann, Ekkekakis, & Holmes, 2006; Knutson, 2005; Sekine et al., 2002a). Certain studies have found that the association between short sleep duration and overweight/obesity is stronger in boys than in girls (Sekine et al., 2002a) while in other studies, the association was non-existent in girls (Eisenmann et al., 2006; Knutson, 2005). The majority of other studies in children and adolescents did not report any sex-differences in the association between sleep duration and overweight/obesity. Nonetheless, results from Chen and colleagues' meta-analysis found support for a significant sex difference, with a stronger inverse association found in boys (pooled OR=2.50; 95% CI: 1.91, 3.26) in comparison to girls (pooled OR=1.24; 95% CI: 1.07, 1.45) (Chen et al., 2008).

Overall, further longitudinal research on the association between sleep duration and overweight/obesity in children is needed to: a) Provide evidence of a temporal sequence to assess the direction of the association and make a causal inference; b) examine the likely mechanisms involved; and, c) clarify potential sex-differences in the main association that may have been due to lack of control for important confounders.

2.2 *Sleep Duration and Appetite, Dietary Intake, and Eating Behaviour*

Sleep duration has been proposed to contribute to the development of overweight and obesity by affecting both sides of the energy balance equation through changes in metabolic hormones that regulate appetite, food selection, and patterns of energy expenditure (Crispim et al., 2007; Knutson et al., 2007; Taheri, 2006). Specifically, short sleep duration has been shown to associate with: 1) decreased levels of leptin, a peptide hormone released by adipocytes that acts as a signal of satiety to the hypothalamus; low levels of leptin signal an energy deficit, stimulating appetite (Leibel, 2002; Spiegel et al., 2004a; Taheri et al., 2004); 2) elevated levels of ghrelin, a hormone released primarily by the stomach (Kojima & Kangawa, 2005; Taheri et al., 2004); high levels of ghrelin signal hunger, increasing food intake; 3) decreased levels of serotonin, a neurotransmitter suggested to contribute to feelings of satiation and the feeling of general wellbeing (Rosmond and Bjorntorp, 2000); diminished levels are suggested to increase appetite and cravings for carbohydrate and energy-dense foods to restore this feeling of well-being; 4) variations in several other hormones (e.g. cortisol) that may stimulate excessive caloric intake, impair insulin resistance and glucose metabolism, and decrease energy expenditure (Spiegel et al., 1999); and 5) increased sympathetic activity (Spiegel et al., 1999). Furthermore, extended waking hours resulting from sleep deprivation create further opportunities for food intake and also contribute to daytime fatigue, reducing physical activity (Taheri, 2006); thus, both sides of the equation for energy balance are affected.

Several animal studies support the hypothesis that sleep deprivation influences patterns of food consumption (Elomaa, 1981; Martinez et al., 1991), with some studies showing that rats tend to over-eat when deprived of sleep (Brock et al., 1994; Tsai, Bergmann & Rechtschaffen, 1992). However, in rats, an increase in food intake in response to being subjected to partial sleep deprivation through an experimental intervention was followed by increased levels of energy expenditure and subsequent weight loss (Everson & Crowley, 2004; Koban & Swinson, 2005; Rechtschaffen et al., 2002).

Human studies examining the influence of sleep duration on appetite and food consumption have been scarce; however, the number of studies examining this association is slowly increasing. A randomized, crossover clinical study conducted on 12 healthy young men (mean [±SD] age, 22 ± 2 years) with normal weight revealed that short-term sleep restriction (2 nights of only 4 hours of sleep vs. 2 nights of 10 hours of sleep) was associated with decreased levels of the satiety hormone, leptin (18% reduction; $P = 0.04$) and increased levels of the hunger hormone, ghrelin (28% increase; $P < 0.04$), which was also accompanied by increased feelings of hunger (24% increase; $P < 0.01$) and appetite (23% increase; $P = 0.01$), particularly for carbohydrate-rich, calorie-dense foods such as sweets, salty snacks and starchy foods (33% to 45% increase; $P = 0.02$) (Spiegel et al., 2004b). Given that in Spiegel and colleague's study levels of energy intake and expenditure were kept as constant as possible, it is unknown whether such changes would translate into actual changes in food consumption patterns to ultimately induce a positive energy balance; however, this finding suggest that, given the opportunity and access to food ad libitum, sleep deprived individuals may opt for unhealthy food choices that may be conducive to weight gain. In fact, in a study on a sample of 50 undergraduate students, partial sleep deprivation was shown to alter patterns of food consumption and choice such that foods consumed were selected less for reasons of health and weight concerns but rather for mood and convenience (Wells & Cruess, 2006).

In another small study conducted with eleven (5 women, 6 men) healthy volunteers with a mean age of 39 years (SD: ± 5 years), individuals were randomly assigned to complete two 14-day stays with bed-times of either 5.5 or 8.5 hours per night in a sleep laboratory with ad libitum access to palatable foods and under controlled conditions of sedentary living (characteristic of the Westernized lifestyle) (Nedeltcheva et al., 2009). Results showed that sleep restriction (5.5 hours of sleep per night) was *not* associated with any significant differences in the quantity or distribution of energy intake across meals or in the macronutrient content (carbohydrate, fat, and protein) of meals, in comparison to that observed during the non-restricted sleep condition (8.5 hours of sleep per night); however, sleep restriction was associated with increased energy intake from snacks (1087 ± 541 versus 866 ± 365 kcal/day; $P = 0.026$) which contained more carbohydrates (65% versus 61% of energy; $P = 0.04$). In the sleep-restricted condition, the consumption of snacks was particularly increased between the hours of 1900 to 0700 ($P < 0.01$); furthermore, this increase in energy intake from snacks was not accompanied by an increase in energy expenditure to regulate energy balance (Nedeltcheva et al., 2009). This finding is unlike what is reported in studies with rodents (Everson & Crowley, 2004; Koban & Swinson, 2005; Rechtschaffen et al., 2002). Thus, Nedeltcheva and colleagues' study suggests that sleep deprivation in humans may contribute to a positive energy balance through an excess in caloric intake through carbohydrate-rich snacks that is not matched by caloric output through physical exercise, potentially leading to furthered weight gain. A more dated study conducted on a sample of college students also found that students who had short-sleeping durations (e.g. 6 hours per night) ate more small meals or snacks in comparison to students who slept 8 or more hours per night (Hicks et al., 1986).

Conversely, in a small study of 15 healthy, normal-weight men, Schmid and colleagues found that short-term sleep restriction was not associated with any differences in levels of hunger, appetite, leptin or ghrelin, and was not associated with differences in total energy intake following randomization to a condition of sleep restriction (two nights of only 4 hours sleep per night versus 2 nights of 8 hours sleep per night); however, sleep restriction was associated with higher fat intake ($P = 0.05$) and decreased levels of total physical activity ($P = 0.02$) (Schmid et al., 2008). Shi and colleagues also observed an association between short sleep duration (< 7 hours) and a higher intake of fat (1.5% more per day than those who slept 7-9 hours per night, $P = 0.005$) but a significantly lower intake of carbohydrates (1.8% less per day than those who slept 7-9 hours per night, $P = 0.001$) in a large cross-sectional study of 2828 Chinese men and women aged 20 years or older (mean= 47 years) (Shi et al., 2008); however, this latter finding is opposite to what was reported in the previous studies reviewed. The authors suggest that this contradictory finding of lower carbohydrate-intake in individuals with short sleep duration may reflect the ethnicity and different dietary patterns of an Asian cohort, in comparison to findings observed in studies with Western populations.

Some epidemiological data also demonstrates that short sleep duration, or sleep loss, is associated with differences in eating behaviour patterns. In a study of a large Australian birth cohort of children and their mothers, McDermott and colleagues found that children who experienced sleeplessness were more likely to be reported by their mothers as 'sometimes or often' having irregular eating patterns at age 2-4 years ($P = 0.001$), in comparison to children who rarely or never experienced sleeplessness (McDermott et al., 2008). Short sleep duration was also reported to associate with irregular eating habits in a large cross-sectional study of 30,000 individuals selected from the general population in Japan (Ohida et al., 2001). Finally, in a 6-year study of 2,000 male, Japanese factory workers aged 20 to 59 years, a short sleep duration was found to associate with irregular eating patterns, snacking between meals, excessive seasoning of food, and insufficient consumption of vegetables; however, it is important to note that these results were based on a serial evaluation utilizing simple correlations, with no control for other important covariates or confounders to the examined associations (Imaki et al., 2002).

Overall, the evidence reviewed suggests that short sleep duration may affect patterns of dietary intake and eating behaviour that may be conducive to weight gain; however, much of this evidence comes from small, short-term studies of adult men and women. Further population-based research is needed to clarify these associations, especially in children.

2.3 *Dietary Intake, Eating Behaviour, and Overweight/Obesity*

2.3.1 Dietary intake and Overweight/Obesity

It is well established that dietary intake is a key component of the energy balance equation which regulates body weight. Unless energy intake exceeds energy expenditure for a period of time, body weight will not increase; this has been clearly shown through intervention studies which manipulate the components of energy balance (Jebb et al., 1996; Prentice & Jebb, 2004).

Studies on the dietary determinants of obesity are many, however they are often crippled by methodological weaknesses and show inconsistent results. This is likely due to the fact that the problem of obesity is multifactorial and due to the methodological challenges of gathering reliable data on dietary intake and various eating practices.

Challenges also arise in finding evidence for causality as prospective studies tend to rely on less complex dietary questionnaires that may provide less accurate and inconclusive results; whereas, controlled dietary intervention studies face challenges in keeping trials 'double-blind', retaining participants over a long period of time, and avoiding that the process of informed consent act as an intervention in itself by causing self-monitoring and behaviour change (Jebb, 2007).

In spite of these methodological challenges and limitations, a clear trend and shift towards a diet with increased consumption of energy-dense foods that are high in fat and sugar content but low in nutrient value (low in vitamins, minerals, and other important micronutrients) has been implicated as the fundamental *dietary* cause in the rising levels of childhood obesity over the past three decades (WHO/FAO, 2003).

Studies on specific food-based determinants of obesity, mainly from adult and adolescent populations, also show an inverse relation between BMI, percent body fat, or skinfold-thickness and the consumption of: cereals (Bazzano et al., 2005); whole grains (Good et al., 2008; Harland & Garton, 2008; Lutsey et al., 2007; Rose et al., 2007); fruits (Bes-Rastrollo et al., 2006; Davis, Hodges, & Gillham, 2006; de Oliveira, Sichieri, & Mozzer, 2008; Goss & Grubbs, 2005; He et al., 2004; Sartorelli, Franco, & Cardoso, 2008; van de Vijver et al, 2009; te Velde, Twisk, & Brug, 2007; Vioque et al., 2008); vegetables (Bes-Rastrollo et al., 2006; Goss & Grubbs, 2005; He et al., 2004; te Velde et al., 2007; Vioque et al., 2008); and dairy products (Barba et al., 2005; Mirmiran, Esmaillzadeh, & Azizi, 2005). However, some studies show differences in the strength of these associations according to sex (e.g. Bes-Rastrollo et al., 2006; te Velde et al, 2007; van de Vijver et al, 2009), while other studies found no association or a positive relation between BMI and the consumption of some of these food groups in specific age or ethnic populations (e.g. Cheng et al., 2009; Shi et al., 2008). For example, one study based on a Chinese population found a positive association between vegetable intake and obesity, likely due to the increased use of vegetable oils in the cooking process of vegetables within this ethnic population (Shi et al., 2008).

In children, specific food-based determinants of overweight and obesity have been less well explored; nonetheless, study results seem to show a similar inverse pattern of association between BMI and the consumption of (or preference for) breads and cereals (Burke et al., 2005), fruits and vegetables (Faith et al., 2006; Field et al., 2003; Lakkakula et al., 2008), and dairy products (Barba et al., 2005) as that found in adolescents and adults. In one study of black children from a low-income public elementary school in Louisiana (United States), a negative association was found between a mean score of children's preferences for a list of fruits and vegetables in relation to measured BMI (Lakkakula et al., 2008). Another study which utilized self-reported weight and height found no association between the independent or combined intake of fruits, fruit juice, or vegetables and changes in BMI z-score in girls over a period of 3 years, while in boys, an inverse relationship was found between vegetable intake and subsequent changes in BMI z-score over 3 years (Beta, per serving = -0.003); however this last association became insignificant when adjustments were made for caloric intake (Field et al., 2003). Other findings from a study of children aged 1 to 4 years in low-income families showed that increased consumption of fruit juice was associated with increased weight gain over a period of 48 months, while consumption of whole fruits was associated with reduced weight gain over this same period; however, this finding only applied to children who were initially classified as at 'risk for overweight' or 'overweight' at the start of the study (Faith et al., 2006).

Another food-based culprit of weight gain that is seen to affect individuals of all ages, and of both sexes, is the increased consumption of sugar-sweetened beverages, including both soft-drinks and fruit drinks (Berkey et al., 2004; Dietz, 2006; Dubois et al., 2007a; Greenwood & Stanford, 2008; Raben et al., 2002). Sugar-sweetened beverages contribute to greater than 40% of sugar added in the average diet of an individual living in the United States (Guthrie & Morton, 2000; Johnson & Frary, 2001). In fact, a dramatic increase in the consumption of sugar-sweetened beverages has been observed across all ages in over the past three decades (Cavadini, Siega-Riz, & Popkin, 2000; French, Lin, & Guthrie, 2003; Nielsen & Popkin, 2004; Nielsen, Siega-riz, & Popkin, 2002; Rampersaud, Bailey, & Kauwell, 2003). One report using nationally representative data from the United States showed an overall increase in the consumption of sugar-sweetened beverages from 3.1% to 6.1% during meals and from approximately 10% to 12% during snacks from the years 1977 to 1996 (Nielsen et al., 2002). A later report indicated that, from 1977 to 2001, energy intake from sweetened beverages increased by 135%, contributing to a 278 caloric increase to the average diet (Nielsen & Popkin, 2004). Such increases in caloric intake have been shown to positively associate with overweight and obesity. For example, a longitudinal study on a large representative sample (n=1,944) of children born in 1998, in the province of Quebec (Canada), revealed that children who regularly consumed sugar-sweetened beverages four or more times per week 'between meals' at the ages of 2.5, 3.5, and 4.5 years, had more than double the odds (OR=2.41; 95% CI: 1.47, 3.95) of being classified as overweight at age 4.5 years in comparison to children who did not consume sugar-sweetened beverages between meals; this result was found after control for several important covariates (Dubois et al., 2007a).

With these general findings, in order to help regulate energy intake, reduce the risk of obesity and other related diseases, Health Canada's current food guide, *Eating Well with Canada's Food Guide,* recommends that girls and boys aged 4-8 years consume each day: 5 servings[2] of 'vegetables and fruits'; 4 servings of 'grain products'; 2 servings of 'milk and alternatives'; 1 serving of 'meat and alternatives'; and limit foods and beverages that are high in calories, fat, sugar or salt (sodium), including sugar-sweetened hot or cold beverages and fruit-flavoured- or soft-drinks (Health Canada, 2008).

2.3.2 Eating behaviour and Overweight/Obesity

One factor that closely relates to dietary intake and overweight/obesity is 'eating behaviour'. Individual differences in patterns of food intake and how one responds to the food environment are likely to contribute to overall energy intake and, consequently, body weight (Wardle, 2007).

In children, eating behaviour generally varies on a continuum from picky eating, to irregular eating, overeating, and disinhibited or binge eating (Lewinsohn et al., 2005; Marcus & Kalarchian, 2003). These eating behaviours have been defined in different ways across some studies. For example, 'picky eating' has also been termed as 'food neophobia', 'fussy eating', 'choosy eating', and 'problem eating' (Carruth & Skinner, 2000; Pelchat & Pliner, 1995; Sanders et al., 1993). Generally, picky eaters tend to eat slowly, eat small meals, be less interested in food, accept a limited selection of foods, are unwilling to try new foods, and have strong food preferences (Galloway, Lee, & Birch, 2003; Reau et al., 1996; Ziegler et al., 2006). The literature on irregular eating has been sparse, however, definitions of this eating behaviour have included 'omitting two meals at least once per week' or 'consuming

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[2] Serving size definitions per food type and food group, along with guidelines for other age groups, can be accessed through Health Canada's Website: www.hc-sc.gc.ca

between three and nine meals per day', as opposed to the average six meals per day (Farshchi, Taylor, & Macdonald, 2004; Sjöberg et al., 2003). Near the upper end of the continuum is 'overeating' which, unlike 'binge- and disinhibited eating', does not include a sense of loss of control but is defined as consuming large amounts of food within a specified period of time, eating rapidly, eating until uncomfortable, and eating large amounts of food without the presence of hunger (Baughcum et al., 2001; Shunk & Birch, 2004; Tanofsky-Kraff & Yanovski, 2004; Whitaker et al., 2000).

Such aforementioned eating behaviours have been shown to relate to body weight, both in children and adults, although the literature in children is less extensive. In adolescents, 'picky eating' has been associated with anorexia nervosa (Marchi & Cohen, 1990), while in childhood, this eating behaviour is seen to associate with weight loss, failure to gain weight, or an underweight body status (Dubois et al., 2007b; Webber et al., 2009; Wright & Birks, 2005). On the other hand, obesity studies show that snacking and irregular patterns of food intake (Francis, Lee, & Birch, 2003; Takahashi et al., 1999), as well as eating quickly, eating until full, or overeating (Dubois et al., 2007b; Maruyama et al., 2008; Webber et al., 2009) are associated with an increased risk of becoming overweight or obese, both in children and adults. However, some studies report no significant association between body weight and an irregular meal pattern (e.g. Farshchi et al., 2004). In a study by Dubois and colleagues, children who were reported by their parents as being 'overeaters' consistently at ages 2.5, 3.5, and 4.5 years were six times more likely to be overweight at age 4.5 years (adjusted OR= 6.10; 95% CI: 3.31, 11.24) in comparison to children who were never reported as being 'overeaters' (Dubois et al., 2007b). Furthermore, another study with the same cohort of children found that such eating behaviours related to dietary adequacy, such that 'overeaters' consumed more total energy, more of each macronutrient and, in particular, more servings of grain products, meats and alternatives per day than did children who were never reported as being 'overeaters'; yet, even when children consumed the same number of servings of grain products per day whether reported as 'overeaters' or never reported as having this eating behaviour, 'overeaters' were still found to have a higher body mass index (Dubois et al., 2007c).

2.4 *Gaps in the Literature*

Given the literature summarized in this chapter, there is a strong indication that dietary intake and eating behaviour may be important mediating factors to the association between sleep duration and overweight/obesity. Nonetheless, this 3-way association has not been adequately explored, particularly in young children.

Further population-based research is needed to examine whether differences in sleep duration associate with differences in dietary intake and eating behaviour at the population level, and to examine whether such dietary factors in fact mediate (either in part or in full) an association between short sleep duration and overweight/obesity.

CHAPTER 3: Study Objectives, Research Questions and Hypotheses

3.1 *Aim*

This study aims to examine: 1) The association between longitudinal sleep duration pattern and overweight/obesity in young children; and, 2) whether such an association, at the population level, may be mediated (in part or in full) by dietary intake and/or eating behaviour. Associations will be examined with consideration for other potential confounding factors.

3.2 *Objectives & Hypotheses*

Objective 1: To examine the independent association between longitudinal sleep duration pattern from age 2.5 to 6 years and: 1) Overweight/obesity at age 6 years; 2) overweight/obesity at age 7 years.

- *Hypothesis 1:* Children who have shorter sleep duration patterns from age 2.5 to 6 years will have a greater likelihood of being overweight/obese at age 6 and 7 years.

Objective 2: To examine whether dietary intake and/or eating behaviour at age 6 years mediate (in part or in full) an association between longitudinal sleep duration pattern (age 2.5 to 6 years) and overweight/obesity (at age 6 and 7 years), independently of other factors.

- *Hypothesis 2a:* Children who have shorter sleep duration patterns from age 2.5 to 6 years will have less favorable 'consumption frequencies' of various foods in comparison to children who sleep longer hours from age 2.5 to 6 years.

- *Hypothesis 2b:* Children who have shorter sleep duration patterns from age 2.5 to 6 years will be more likely to exhibit problematic eating behaviours (e.g.

'overeating/eating too fast') in comparison to children who sleep longer hours from age 2.5 to 6 years.

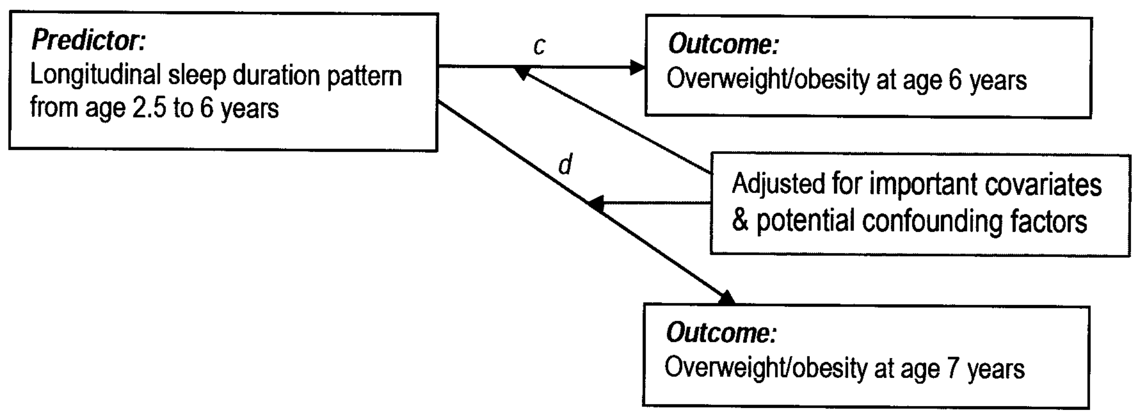
- *Hypothesis 2c:* Less favorable consumption frequencies for dietary intake and/or problematic eating behaviours (e.g. 'overeating/eating too fast') will act as partial or full mediators to an association between longitudinal sleep duration pattern (age 2.5 to 6 years) and overweight/obesity at both age 6 and 7 years.

3.3 *Conceptual Framework*

The conceptual framework for examining the variable relationships proposed in this chapter is presented in Figure 1 (see next page).

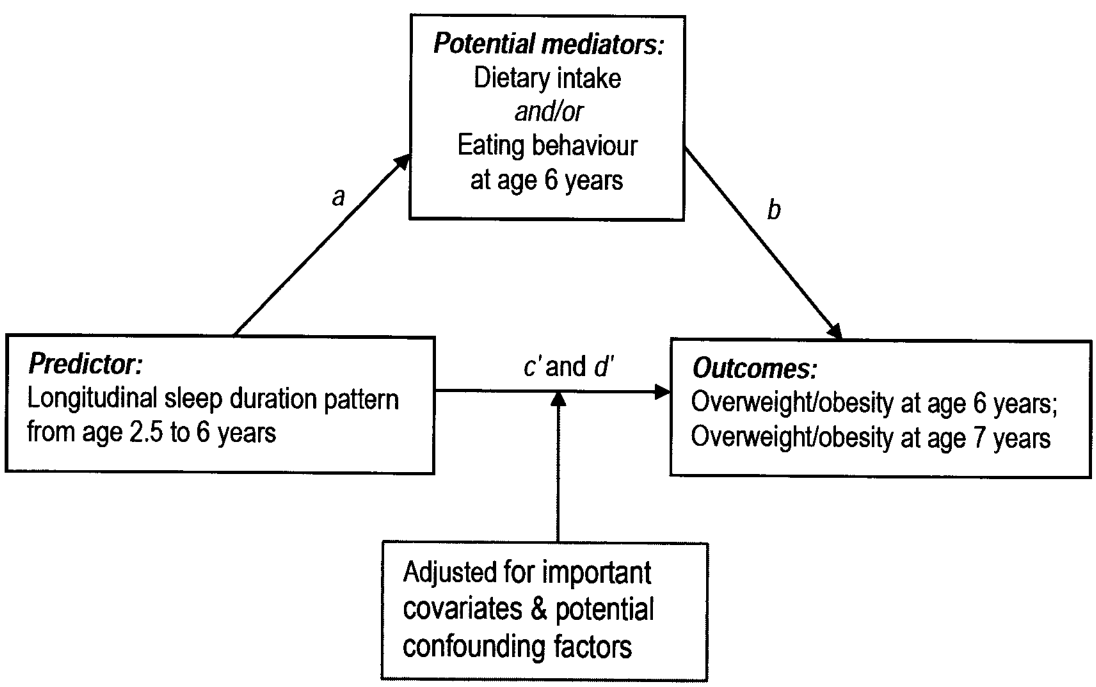
Figure 1: Conceptual Framework

a) ***Objective 1***



c,*d*: Effect of the Predictor on the Outcomes

b) ***Objective 2***



a: Association between the Predictor and the 'Potential mediators'
b: Association between the 'Potential mediators' and the Outcomes
c',*d'*: Effect of the Predictor on the Outcomes, *controlling* for 'Potential mediators'

CHAPTER 4: Methods

4.1 *Data source: The Québec Longitudinal Study of Child Development (QLSCD 1998 - 2010)*

The present study analyzes data obtained from the Québec Longitudinal Study of Child Development (QLSCD 1998 - 2010), a study conducted by *Santé Québec* (a division of the *Institut de la statistique du Québec,* ISQ) (Dubois et al., 2000). The QLSCD first began in 1998 by following a large birth cohort of children (n=2,223; 49% = female; 51% = male) representative of children born in 1997-1998 in the province of Québec, Canada. Its aim is to enhance knowledge about child development in the area of health, wellbeing and overall social and cognitive development. In 1998, data was collected when the children were approximately 5 months old (adjusted for gestational age), with later data collection points occurring annually. Information is collected on the children's body weights and heights, sleeping habits, as well as many other child, family, and broader characteristics of the social environment. As of December 2008, 11 cycles of data collection have been completed, with data from the first 8 cycles (when the children were approximately 7 years old) available for analysis at the start of the present thesis project.

Infants targeted at the start of the QLSCD were singleton births of 5 months (gestational age, adjusted for preterm birth) recruited through the *Fichier maître des naissances* (Master Birth Register) of the *ministère de la Santé et des Services sociaux* (MSSS) (Ministry of Health and Social Services). To obtain a representative sample of children born in 1997-1998, in the province of Québec, a randomized 3-level stratified survey design was used. The sample targeted was selected to be representative of: 1) the public health geographic regions of Québec, excluding Cree and Inuit regions, Indian reserves, and Northern Québec; 2) the number of births per each of these geographic regions; and 3) the proportion of births and the sex ratio within each area. Additionally, the survey targeted children born throughout the year to minimize the effect of seasonality. Infants from mothers who could not determine the duration of their pregnancy were excluded from the study. Further detail pertaining to the sampling frame and stratification of the sample can be obtained from Jetté and Des Groseilliers's (2000) report.

The original QLSCD sample targeted 2,940 children (Jetté & Des Groseilliers, 2000). Of this original sample, 452 families refused consent and 240 were excluded from the survey for the following reasons: death of the infant, inaccurate address and/or telephone information, family's involvement in another longitudinal study (e.g. *NLSCY – National Longitudinal Study of Children and Youth*), the family did not speak English or French, or the infant possessed severe physical and mental disabilities that were too complex to be accurately measured with the instruments used for the study. All efforts were made by *Santé Québec* to contact the targeted families either by phone, household visits, or through neighbourhood enquiries. Families that could not be reached were excluded only after all these measures were pursued. Thus, the first cycle included 2,223 children; however, 103 of these families were removed from the longitudinal part of the study as these families were a result of over-sampling measures taken to examine the effects of the ice-storm that occurred in January 1998. The ice-storm did not seem to have an effect on the children of this cohort, therefore the longitudinal study began with a sample of 2,120 children in cycle 1. Approximately 73% of this sample was retained to cycle 8 in 2005, and approximately 63% responded to all 8 cycles (see Table 2) (Plante & Courtemanche, 2006).

Table 2: Number of children retained in the QLSCD longitudinal study from 1998 to 2005

Cycle	Year	Age	Number of respondents at each cycle	Number of respondents followed longitudinally who participated in each cycle and *all* previous ones
1	1998	5 months	2223	2120
2	1999	17 months	2045	2045
3	2000	29 months	1997	1985
4	2001	41 months	1950	1924
5	2002	45-56 months	1944	1894
6	2003	5 years	1759	1712
7	2004	6 years	1492	1434
8	2005	7 years	1537	1336

Source: *Data courtesy of the Quebec Institute of Statistics, QLSCD 1998-2010* (Plante & Courtemanche, 2006).

The QLSCD collects information pertaining to the child, parents, and broader social environment through face-to-face interviews with mothers and fathers, using standardized computer-based and self-administered questionnaires, and through the mother's and child's medical records. Questionnaires pertaining to the children, including dietary and eating behaviour questionnaires, are addressed to the person deemed most knowledgeable (PMK) of the child, which generally has been the biological mother. A previous report from the first three cycles of the QLSCD indicated that the biological mother was the PMK approximately 99% of the time (Jetté, 2002).

Each year, participants were provided with detailed information on the aims and procedures of the QLSCD study, and participants and interviewers each signed, dated, and kept copies of a consent form approved by *le Comité d'ethique de la Direction Santé Québec* (Ethics Committee of Santé Québec Division). Consent forms were signed by either one or both parents of the child, and consisted of: 1) a description of the partnership between researchers involved in the study; 2) acknowledgement of the clear explanation of the survey; and 3) emphasis about their confidentiality, anonymity, and right to refuse or withdraw from the survey at any time without penalty. The original protocol for the QLSCD was submitted to the QLSCD Advisory Committee and Planning Committee as well as to *le Comité d'éthique de la Direction Santé Québec* (Ethics Committee of *Santé Québec* Division) to ensure that all objectives could be achieved and all administrative and data collection instruments valid. The proposal was then approved by an ethics review board, permitting for the final proposal and grant request to be submitted to the MSSS (Desrosiers, Boivin, & Des Groseilliers, 2001).

4.2 *Study Sample*

In accordance with the underlying research questions of this study, this thesis performed cross-sectional and longitudinal analyses on data obtained through the QLSCD from the start of the survey in 1998 to when the children were 7 years of age (cycles 1 to 8). These analyses took into consideration many important covariates and potential confounders to the main associations, collected from the start of the QLSCD survey (from Cycle 1).

In order to retain the greatest possible number of participants with longitudinal data on sleep duration from age 2.5 to 6 years, a statistical modeling approach (further described in Section 4.4) was used that permits for cases with some missing data points for the predictor variable (sleep duration) to be retained in the analyses; thus, children with up to two missing data points (out of five data points collected from cycle 3 to, and including, cycle 7) for sleep duration were included in the analyses, allowing for an initial inclusion of 1829 children. For a first set of analyses at age 6 years, the sample was then limited to children with: 1) no missing data on diet and eating behaviour variables collected at age 6 years; and, 2) no missing data on anthropometric measures of body weight and height collected at age 6 years. For a second set of analyses at age 7 years, the sample was further reduced to children with no missing data on anthropometric measures of body weight and height collected at age 7 years.

Thus, the relationship between longitudinal sleep duration pattern from age 2.5 to 6 years, dietary intake and eating behaviour at 6 years, and overweight/obesity at 6 and 7 years was tested on 1106 children at age 6 years, and 1015 children at age 7 years.

4.3 *Measures*

Secondary data analyses were performed from data collected through the responses to the following instruments utilized in the *Quebec Longitudinal Study of Child Development (QLSCD 1998 – 2010)*: The *Interviewer Completed Computerized Questionnaire (ICCQ)*, the *Interviewer Completed Paper Questionnaire (ICPQ)*, the *Self-Administered Questionnaire for the Mother (SAQM)*, the mother's and child's medical records, and anthropometric measurements taken of the child. The following is a brief overview of these questionnaires and measures. Further detail regarding the construction and validation of these instruments, along with the sources and rationales for the minor changes/additions that were made throughout the years of the study, may be obtained from the technical documentation available on the QLSCD's Website[3] (Jetté & Des Groseilliers, 2000; Thibault et al., 2003; Thibault, Jetté, & Desrosiers, 2001).

The *Interviewer Completed Computerized Questionnaire (ICCQ)* was based in most part from the questionnaire constructed for the *National Longitudinal Study of Children and Youth* conducted by Statistics Canada and Human Resources Development Canada in 1996, with some additions and modifications from the NLSCY and/or QLSCD researchers (Jetté & Des Groseilliers, 2000; Thibault et al., 2003; Thibault, Jetté, & Desrosiers, 2001). At the

[3] QLSCD Website: http://www.jesuisjeserai.stat.gouv.qc.ca

start of the QLSCD survey, this instrument was composed of approximately 600 variables and took approximately 50-60 minutes to complete. Some changes and additions were made throughout subsequent cycles of the study, with the merging of the *Interviewer Completed Paper Questionnaire (ICPQ)* into the ICCQ, starting at cycle 7 of the QLSCD study, in 2004; all these modifications are well documented and sourced on the survey Website[3]. The ICCQ consists of four sections: 1) Sociodemographic Questionnaire, 2) Parent's Questionnaire (separate questionnaires for the mother and father), 3) Child's Questionnaire, and 4) Absent biological Parent's Questionnaire (if applicable, this questionnaire was included in the mother's questionnaire). Responses are obtained by the 'Person Most Knowledgeable' (PMK) of the child, generally the biological mother. The data that was obtained from this questionnaire for the present study included: Data pertaining to the child's health and nutritional practices, parent and family demographic and socioeconomic data, and lifestyle and health habits of the parents and mother during pregnancy.

The *Interviewer Completed Paper Questionnaire (ICPQ)*, later merged with the ICCQ in 2004, consisted of a range of 23 to 28 variables across the first 6 cycles of its use in the QLSCD. This instrument collects data pertaining to: 1) The grandparents; 2) the perception of the socioeconomic situation; and 3) the child's diet and oral hygiene. The data obtained from this questionnaire for the present study included information regarding the child's dietary patterns, eating behaviour, and feeding patterns in infancy. These specific items were drawn from: the *Avon Longitudinal Study of Pregnancy and Childhood (ALSPAC, 1990)*; the *Third National Health and Nutrition Examination Survey (NHANES III-USA (1988-1991)*; the *Èvaluation de l'état nutritionnel en fer (ÈÈNFE)*; and, the *Ètude provinciale sur l'alimentation du nourrisson (ÈPAN)*. Again, responses to the ICPQ to were obtained from the person most knowledgeable (PMK) about the child.

The *Self-Administered Questionnaire for the Mother (SAQM)* contained between 43 and 92 items over the first 8 cycles of the QLSCD. This questionnaire was completed by the mother without assistance from the interviewer, unless requested. It includes items pertaining to the following themes: Experiences during pregnancy, sleeping habits of the child, health information about the child, the family environment (socioeconomic conditions, conjugal dynamics), and information about the health, leisure, lifestyle, and behavioural history of the mother and of the absent biological parent (if applicable). As in the ICPQ, these items were drawn from other population based surveys, reworked to meet the aims and goals of the QLSCD (1998-2010) study. Detailed information about the source and development of each item can be found in the technical documents available on the survey Website[3] (Jetté, 2002; Thibault et al., 2003; Thibault, Jetté, & Desrosiers, 2001). The items most pertinent to this study derived from this questionnaire were those providing information about the child's sleeping habits and health, experiences during pregnancy, health information about the mother, and socioeconomic conditions of the family.

Information obtained from the mother's and child's medical records, covering the period of hospitalization during the delivery, was also included in the QLSCD database. The QLSCD study team was granted legal access to the medical records for a period of 90 days after the biological mother of the infant signed an authorization form developed by the *ministère de la Santé et des Sevices sociaux* (MSSS) of *Québec* (Jetté, & Des Groseilliers, 2000). These medical records provided researchers with approximately 50 variables on the mother and infant gathered through: The mother's complete obstetrical file, the report on the anatomy/pathology of the placenta, the short-term hospital admission form for the mother, the infant's complete medical file and short-term hospital admission form, reports on the physical examinations of the newborn, and blood tests on samples taken from the umbilical cord. The present study utilized this data to obtain information pertaining to: The sex of the infant, duration of the pregnancy (total number of gestational weeks), and the infants' weight at birth.

Finally, as a part of a nutrition substudy in 2002, the *Enquête de nutrition auprès des enfants québécois de 4 ans,* anthropometric measurements were taken of the child in the home by a trained interviewer, starting at age 4.5 years, then again at age 6 years, and at approximately one-year intervals thereafter (Desrosiers et al., 2005; Institut de la statistique du Québec (Direction Santé Québec), 2005). Interviewers were trained to follow a standard protocol, taking measures of body weight, height, skinfold thickness and waist circumference, using standard instruments of measurement (e.g. a standard scale, calipers, and a measuring tape). Body weight was measured in kilograms on scales that were reset to zero for each measurement; children wore light clothing and removed their shoes. Height was measured in meters, with shoes and head accessories (on the top of the head) removed; children were requested to stand straight and look forward placing their back, scapulas, heels and buttocks against a wall while keeping their feet firmly placed flat on the ground. For both measures (weight and height), when the reading fell between two values, the lower measure was taken. A more detailed description of the procedures used to measure body weight and height is available on the QLSCD Website[3] (see *Questionnaires and Data Collection Instruments, Round 2005: "Paper Questionnaire Administered to the Child (PQAC)"*). From these measurements, the present study utilized values gathered on height and weight to derive each child's body mass index (BMI), calculated as weight (in kilograms)/height (in meters)^2, at age 6 and 7 years.

4.3.1 Predictor Variable

4.3.1.1 Sleep Duration

Sleep duration is the main predictor variable of interest in the present study. Information on sleep duration was obtained from responses to an open-ended question included in the *Self Administered Questionnaire for the Mother (SAQM)* of the QLSCD when the children were approximately 2.5, 3.5, 4, 5, and 6 years old. Mothers were asked to respond to the following question about their child, based on observations in the month prior to the interview: "Indicate how long in total he/she sleeps during the NIGHT (on average): [Do not count the hours that your child is awake]". Responses were recorded in hours and minutes. Items pertaining to children's sleeping habits in the SAQM were developed by a research team under the direction of Jacques Montplaisir of the *Centre d'étude du sommeil et des rythmes biologiques at the Hôpital du Sacré-Coeur de Montréal* (Center for the study of sleep and biological rhythms at the Sacred-Heart Hospital of Montreal) and the *Département de psychiatrie* (Department of Psychiatry) at the Université de Montréal. These items were developed specifically for the QLSCD (Thibault et al., 2003). Other studies have used a similar question to assess sleep duration in young children by means of a parental report (e.g. Taveras et al., 2008). Certain studies have also shown that parental reports of children's sleep duration are similar to results obtained through wrist actigraphy (Sadeh, 1994; Sekine et al., 2002b).

The present study examines sleep duration as a categorical variable, using the continuous data gathered on sleep duration to identify subgroups of children who maintained different developmental trajectories for sleep duration from age 2.5 to 6 years; this procedure follows the methods used by Touchette et al. (2007; 2008) on this same cohort of children and will be further described in a later section of this document (see section entitled *'Statistical Methods'*).

4.3.2 Mediating & Outcome Variables

4.3.2.1 Dietary Intake

The present study considers dietary intake firstly as an outcome variable and, secondly, as a potential mediating variable to a sleep duration-overweight/obesity association; thus, all dietary intake variables were analyzed firstly as outcome variables (in relation to longitudinal sleep duration pattern), secondly as predictor variables (in relation to overweight/obesity) to determine their role as possible mediators, and thirdly as mediating variables in a multivariate regression of the association between longitudinal sleep duration pattern and overweight/obesity.

Dietary information was obtained through a Food-Frequency questionnaire (FFQ) administered when the children were approximately 6 years old. The FFQ was a component of the ICPQ (merged with the ICCQ for the cycle of interest, in the year 2004), and was specifically developed for the QLSCD (1998-2010) by Lise Dubois of the *Département de medicine sociale et preventive* (Department of Social and Preventative Medicine) at the Université Laval (Dr. Lise Dubois is currently an Associate Professor in the Faculty of Medicine at the University of Ottawa) (Thibault et al., 2003). This instrument collects similar information to other common FFQs, except it does not require information about portion size, creating less respondent burden in comparison to other FFQs; thus, information gathered through this instrument was not intended to serve as a measure of the amount of food consumed, but rather to gather information about how frequently various foods are included or are absent from the children's daily diets (Dubois & Girard, 2002a). Food frequency questionnaires that do not burden respondents with information about portion sizes have also been used in other epidemiological studies, one example being an FFQ developed by the National Cancer Institute (NCI), whose application has been supported through its use in the National Health and Nutrition Examination Survey (NHANES) (National Cancer Institute, U.S. National Institutes of Health, 2008; Subar et al., 2006).

Responses to the FFQ utilized in the QLSCD were obtained from the PMK of the child, generally the mother. Mothers were asked to report the average frequency of various foods consumed by the child over the week prior to the interview, through the following question: "In the past week at home AND at school (or at the school's child care center), on average, how many times during the week or how many times per day has '*name of child*' eaten the following foods?". The surveyed items in the FFQ included: Milk, cheese, yogurt and milk desserts (e.g. Laura Secord milk puddings), fruits, juice and fruit drinks; sugar-sweetened beverages and soft-drinks, vegetables and potatoes, poultry and eggs, meats (e.g. pork, beef, veal, etc.), fish and seafood, legumes and pulses (e.g. lentils, tofu), bread, cereals (e.g. Corn Flakes, Froot Loops, etc.), pasta and rice. With the aid of a response card, mothers chose one of the following response options: "None; 1 to 2 times *a week*; 3 to 4 times *a week*; 5 to 6 times *a week*; once *a day*; twice *a day*; 3 times *a day*; 4 or more times *a day*; Do not know". As the frequency of consumption of the various foods were not additive, responses were weighted as an indication of their relative daily importance and to categorize foods into seven studied food and beverage consumption groups: 1) Vegetables; 2) Fruits (not including juices); 3) Fruits, fruit juices, and fruit drinks (combined); 4) Bread & grain products; 5) Milk products (and alternatives); 6) Meat & alternatives; and, 7) Sugar-sweetened beverages & soft-drinks. Thus, mother's responses to the FFQ were scored as follows: "None" was given a score of 0.0; "1 to 2 times *a week*" a score of 0.2; "3 to 4 times *a week*" a score of 0.5; "5 to 6 times *a week*" a score of 0.7; "once *a day*" a score of 1.0; "twice *a day*" a score of 2.0; "3 times *a day*" a score of 3.0; and "4 or more times *a day*" a score of 4.0. Scores belonging to each studied food group were added together and grouped into three consumption frequency categories: "Less than once a day"; "once a day"; or, "two or more times a day" (Dubois & Girard, 2002a). See Box 2 for an example of this scoring method.

Box 2: Example scoring method for Food Frequency questionnaire (FFQ)

Consumption frequency of fish & seafood		**Consumption frequency of meats (e.g. pork, beef, veal, etc.)**		**Consumption frequency of poultry & eggs**			**TOTAL Consumption frequency for "Meats & Alternatives"**
PMK's response	*Score*	*PMK's response*	*Score*	*PMK's response*	*Score*	*Total score*	
"1 to 2 times a week"	0.2	"3 to 4 times a week"	0.5	"5 to 6 times a week"	0.7	1.4	"Once a day"

Food and beverages surveyed were based on the Canadian Food Guide to Healthy Eating[4] (CFG) food groups: Vegetables and fruit, grain products, milk and alternatives, meat and alternatives; however, vegetables and fruits (not including juices) were treated as separate categories, and additional categories were created to assess the consumption frequency of "fruits and fruit juices/drinks (combined)" and "sugar-sweetened beverages and soft-drinks" (monitored in the present study as both consumption *per* week and *per* day). Fruit drinks were included in the same category as 'fruits and fruit juices' as, at the time of the survey, many parents did not differentiate between the "juices" and "drinks", mainly due to the marketing of vitamin-enriched products or products with some percentage of fruit juice (Dubois & Girard, 2002a). As for the consumption of sugar-sweetened beverages & soft

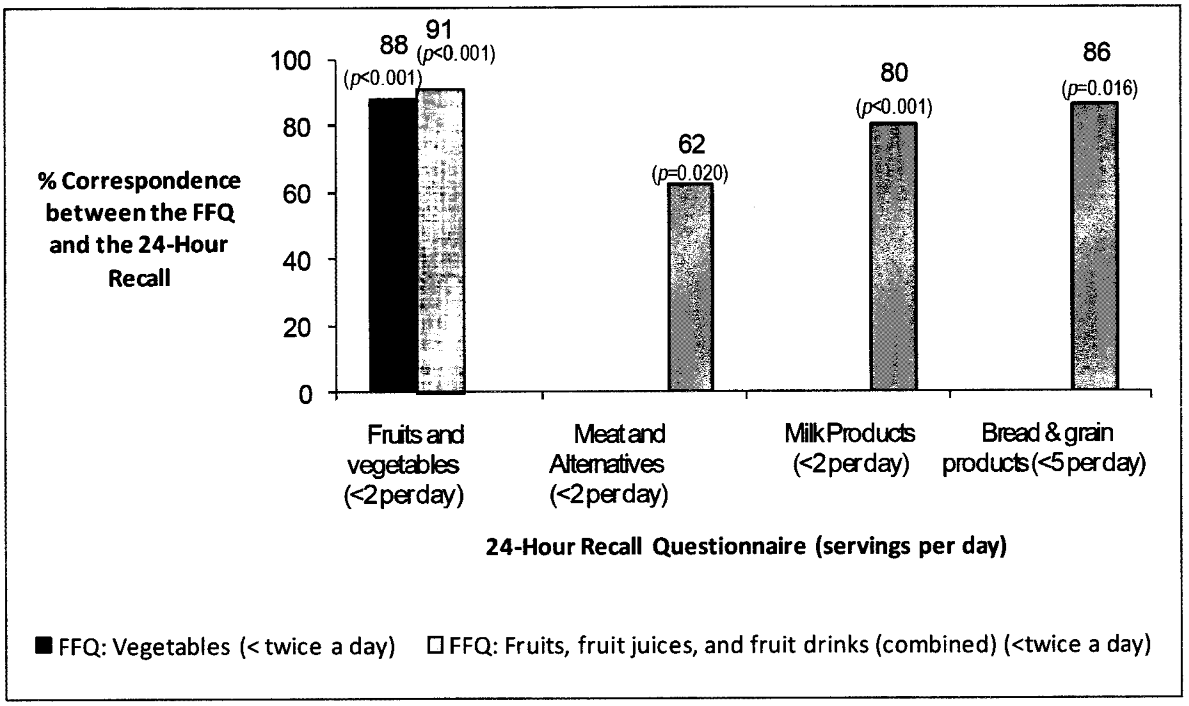
[4] CFG may be accessed through the Health Canada Website: http://www.hc-sc.gc.ca/fn-an/food-guide-aliment/index-eng.php

drinks, this category included any drink that had added sugar, consisting of both regular or non-diet carbonated drinks and fruit-flavoured drinks (e.g. fruit punch or citrus drinks), but not including pure fruit juices (e.g. 100% pure apple or orange juice) which are considered nutritional options in the CFG.

As an indication of the quality of responses obtained through the QLSCD Food Frequency questionnaire, responses from the FFQ were compared to mother's responses to a 24-hour recall questionnaire administered in the home by a trained nutritionist for 1550 children included in a nutrition sub-study of the QLSCD when the children were approximately 4 years old (in 2002). Responses to the 24-hour recall indicated the type, quantities, and recipes eaten by the child, with the aid of volume food models to determine portion sizes and the verification of nutrition labels to ensure accuracy. From these, the number of servings consumed across CFG's four main food groups was determined and was compared to the FFQ reported frequencies of consumption for the same food groups; however, fruits and vegetables are measured separately in the FFQ, thus, these were individually compared to the joint category of 'Fruits & Vegetables' documented through the 24-recall questionnaire. Figure 2 presents a comparison between responses across both dietary measures. It can be seen that there was a high correspondence (80% or higher, $p \leq 0.05$) between responses obtained through the FFQ and through the 24-hour recall for the food groups 'Fruits & Vegetables', 'Milk products', and 'Bread & Grain products' when the children were 4 years old. For the food group 'Meat and alternatives', the percent correspondence between the two dietary measures was lower (62%, $p \leq 0.05$); nonetheless, the results were significantly correlated. The generally high correspondence observed between the two dietary measures is a strong indication that responses obtained through the

QLSCD's FFQ provide valid information pertaining to frequencies of consumption of various food groups.

Figure 2: Correspondence between FFQ-reported frequencies of consumption of various foods and 24-hour recall-reported number of servings consumed, for four main food groups at 4 years of age.



Source: *Data courtesy of the Quebec Institute of Statistics, QLSCD 1998-2010*

4.3.2.2. Eating Behaviour

The present study also considers eating behaviour firstly as an outcome variable and, secondly, as a potential mediating variable to a sleep-overweight/obesity association; thus, all eating behaviour variables were also analyzed firstly as outcome variables (in relation to longitudinal sleep duration pattern), secondly as predictor variables (in relation to overweight/obesity) to determine their role as possible mediators, and thirdly as mediating variables in a multivariate regression of the association between longitudinal sleep duration pattern and overweight/obesity.

Information pertaining to children's general eating behaviour patterns, including behaviours such as picky eating, eating at irregular times/hours, and overeating or eating too quickly, were obtained through a general eating behaviour questionnaire administered to the PMK (typically, the mother) when the children were approximately 6 years old. This questionnaire was also a component of the ICPQ, merged with the ICCQ for the cycle of interest, in the year 2004. Items for the eating behaviour questionnaire were drawn from the *Avon Longitudinal Study of Parents and Children* (ALSPAC)[5] (Northstone et al., 2001). These items were reviewed by an expert advisory group composed of academics, researchers, and practitioners, and were then adapted specifically for the QLSCD (1998-2010) by Lise Dubois of the *Département de médecine sociale et preventive* (Department of Social and Preventive Medicine) at the Université Laval (currently an Associate Professor in the Faculty of Medicine at the University of Ottawa) (Thibault et al., 2003; Thibault, Jetté, Desrosiers, 2001). The adapted instrument was pre-tested with parents of a sample of preschool children (n= 150) not included in the QLSCD survey which lead to some minor modifications for clarity and comprehension (Bédard, Dubois, Girard, 2005; Dubois & Girard, 2002b). More details about the instrument can be found on the QLSCD Website[3].

Children were assessed in terms of 3 categories of eating behaviours through mother's rating of their child's general eating patterns, according to the questions presented in Box 3. Mother's responses were recorded on a Likert-type scale, with the help of a response card ranging from "Never" to "Often", or from "Almost never" to "Always".

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[5] ALSPAC Website: www.alspac.bristol.ac.uk

Box 3: Items used to categorize children according to three eating behaviour categories monitored at 6 years of age and its corresponding distribution in the study samples.		
Eating Behaviour	**Question**	**Response Categories**
Picky eater		
	"When *name of child* is at home with you for the main meal of the day, how often does he/she eat a meal that is different from the other members of your family?"	Always Almost always Sometimes Almost never
	"In general, does *name of child* refuse to eat the right food?"	Never Rarely Sometimes Often
	"In general, does *name of child* refuse to eat?"	Never Rarely Sometimes Often
Eats at irregular hours		
	"In general, does *name of child* eat between meals so is not hungry at mealtime?"	Never Rarely Sometimes Often
	"In general, does *name of child* eat at regular hours?"	Never Rarely Sometimes Often
Eats too much or too fast		
	"In general, does *name of child* over-eat?"	Never Rarely Sometimes Often
	"In general, does *name of child* eat too fast?"	Never Rarely Sometimes Often

Source: *Data courtesy of the Quebec Institute of Statistics, QLSCD 1998-2010*

For the purpose of this study, children were classified as 'Picky eaters' when mothers reported they either: 1) "Always" ate a meal different from that of other members of the family members; 2) "Often" refused to eat the right food; or, 3) "Often" refused to eat. Children were classified as those who 'Eat at irregular hours' if they either: 1) "Often" ate between meals so as to not be hungry at mealtime; or, 2) "Never", "Rarely", or "Sometimes" ate at regular times. Finally, children who "Eat too much or too fast" were defined as those whose mothers reported they either "Sometimes" or "Often" showed one of these behaviours. It is important to note that these eating behaviour categories are not mutually exclusive; thus, a child may exhibit more than one of these behaviours. In a previous study conducted with the QLSCD cohort, these eating behaviours were shown to associate with body weight at the age of 4.5 years (Dubois et al., 2007b).

4.3.2.3 Overweight/Obesity

Overweight/obesity is the main outcome variable of interest in the present study. Body mass index (BMI = weight(in kilograms)/height (in meters)^2) is considered by the *European Childhood Obesity Group* to be an acceptable indicator of adiposity in children and adolescents, and is commonly used as an indicator of overweight and obesity in large population studies (Dietz & Robinson, 1998). For this reason, the present study utilized an indicator of BMI derived from anthropometric measures taken of the children's body weights and heights by trained interviewers when the children were 6 and 7 years old. With this information, children were classified as being 'overweight or obese' according to the age- and sex-specific cut-offs defined by Cole and colleagues (the International Obesity Task Force (IOTF)) (Cole et al., 2000). This method strongly predicts children's likelihood of being overweight or obese at 18 years of age (Cole et al., 2000), and allows for both inter-provincial and international comparisons. According to the IOTF definition, children of age 6 and 7 years were classified as 'overweight or obese' as indicated in Table 3.

Table 3: IOTF BMI cut-offs for overweight (including obesity) in boys and girls at age 6 and 7 years.		
Sex of Child	**Overweight or obese**	
	BMI at age 6 years (kg/m^2)	*BMI at age 7 years* (kg/m^2)
Girls	≥17.34	≥17.75
Boys	≥17.55	≥17.92

Source: Cole et al., 2000.

Using the IOTF criteria, a previous report from the 2002 round of the QLSCD indicated that when the children were approximately 4 years old, 9.7% of children (8.5% of boys and 11% of girls) were classified as overweight and 3.8% of children were classified as obese (4.0% of boys and 3.6% of girls) (Desrosiers & Bédard, 2005).

4.3.3 Covariates

Given the breadth of topics covered and variables collected annually through the QLSCD, this study was able to control for a number of child, parent, and family demographic and socio-economic characteristics identified in the literature as being important covariates or to act as potential confounders to the association between sleep duration, dietary intake/eating behaviour, and overweight/obesity. Thus, covariates included in the study were based on the literature and on the best available variables in the study. These were obtained from children's birth records collected at the start of the survey in 1998 and from questionnaires administered annually starting from the age of 5 months. All covariates were analyzed as categorical variables, as was available in the QLSCD database. For certain covariates included in the study, the original variable included a larger number of variable categories that had to be collapsed due to low cell counts. The following sections describe the covariate characteristics and corresponding variable categories that were used in the present study.

4.3.3.1 Child Characteristics

Child characteristics analyzed in the present study, along with their variable categories (italicized below), were as follows:

- Sex of the child (Eisenmann, Ekkekakis, & Holmes, 2006; Knutson, 2005): *Male/female*
- Premature birth status (<37 weeks) (Mericq, 2006): *Yes/No*
- Premature birth (<37 weeks) *or* low birth weight (<2.5 kg) (Byberg et al., 2000; Dubois & Girard, 2006; Mericq, 2006): *Yes/No*
- Exposure to maternal smoking during pregnancy (Al Mamun et al., 2006; Dubois & Girard, 2006; Touchette et al., 2008): *Yes/No*
- Breastfed (partial or exclusive) for first 4 months of life (Arenz et al., 2004; Singhal & Lanigan, 2007; von Kries et al., 1999): *1) Never breastfed; 2) Breastfed <4 months; 3) Breastfed 4 or more months*
- Mother's perception of the child's general health status at age 6 years (Chen, Wang, & Jeng, 2006; Ohida et al., 2001): *1) Excellent; 2) Very good; 3) Good/Satisfactory/Poor*
- Overweight or obese status at age 2.5 years (using IOTF BMI cut-offs with children's BMI derived from mother-reported measures of body weight and height) (Touchette et al., 2008): *Yes (Child was overweight or obese at 2.5. years) / No (Child was not overweight or obese at 2.5 years)*
- Chronic illness (excluding allergies, but including asthma) at age 6 years (Cappuccio et al., 2008; Mahajan, Pearlman, & Okamoto, 1998): *Yes/No*
- Snoring at night at age 6 years (Redline et al., 1999): *1) Never/Sometimes; 2) Always/Often*

- Level of physical activity in comparison to other children ('Higher' or 'Much higher') (Anderson et al., 1998; Moore et al., 1995): *Yes/No*
- Watching Television for 3 or more hours per day (weekdays and week-ends) (Anderson et al., 1998; Dubois et al., 2008; von Kries et al., 2002): *Yes/No.*

4.3.3.2 Parent Characteristics

The parent characteristics analyzed in the present study were taken only from the mother for two main reasons: Firstly, a previous QLSCD analysis revealed that, for general demographic characteristics such as age and level of education, characteristics of mothers and fathers were highly correlated; secondly, more than 10% of data for many of the parent covariates of interest from the fathers had missing values. Thus, in order to avoid problems with collinearity and missing values, the present study did not include any data derived from the fathers. Additionally, given that mothers were most frequently deemed as being the PMK of the child and are commonly thought of as the primary care-giver in children's first years of life, it was considered appropriate to analyze the main study questions with the characteristics derived solely from mothers' responses.

The characteristics analyzed in the present study, along with their variable categories (italicized below), were as follows:

- Age of the Mother (when the child was 6 years old) (Dubois et al., 2007b): *1) 29 years or less; 2) 30-34 years; 3) 35-39 years; 4) 40 + years*
- Mother's level of education (highest diploma obtained when the child was 6 years old) (Rasmussen & Johansson, 1998; Strauss & Knight, 1999; Touchette et al., 2008): *1) No Secondary school diploma; 2) Secondary school diploma; 3) College or professional school diploma; 4) University diploma*

- Mother employed at the survey time-point (when the child was 6 years old) (Anderson, Butcher, & Levine, 2003; Hawkins et al., 2008): *Yes/No*
- Mother's smoking status (data obtained when the child was 3.5 years old) (Burke et al., 1998; Danielzik et al., 2004): *Yes (smoker) / No (non-smoker)*
- Mother's immigrant status (Is the mother an immigrant?) (Touchette et al., 2008; Whitaker & Orzol, 2006): *Yes (an immigrant) / No (not an immigrant)*
- Mother overweight or obese (BMI$\geq$ 25kg/m^2, derived from self-reported measures of body weight and height obtained in cycle 2, when the children were 17 months old) (Dubois & Girard, 2006; Strauss & Knight, 1999): *Yes (Mother was overweight or obese, BMI$\geq$ 25kg/m^2, when her child was 17 months old / No (Mother was not overweight or obese, BMI<25kg/m^2, when the child was 17 months old).*

These characteristics were obtained from different survey years where necessary, either because a characteristic was not measured in later years or because there was a high proportion of missing values for that characteristic at other survey time-points; thus, the characteristics were selected from years that provided the most reliable and complete data.

4.3.3.3 Family Demographic and Socio-economic Characteristics

Family demographic and socio-economic characteristics analyzed in the present study, along with their variable categories (italicized below), were as follows:

- The family experienced food insufficiency (reported in either cycle 2, in 1999, or cycle 5, in 2002) (Alaimo, Olson, & Frongillo, 2001; Dubois et al., 2006; McIntyre, Walsh, & Connor, 2001): *Yes/No.*

- Household income (when the child was 6 years old) (Dubois & Girard, 2006): *1) less than $30,000; 2) $30,000 - $49,999; 3) $50,000 - $79,999; 4) $80,000 or more.*

Food insufficiency is defined as "an inadequate amount of food intake due to a lack of money or resources" (Briefel & Woteki, 1992); it is a complex, dynamic and temporal process that may be experienced by various members within the family and at different times (Briefel & Woteki, 1992; Tarasuk, 2001). The item used in the QLSCD to measure food insufficiency was derived from the NLSCY survey (McIntyre et al., 2001). It is a single question that was administered in cycle 2 of the QLSCD, when the children were approximately 17 months old, and in cycle 5, when the children were approximately 4.5 years old. In cycle 2, mothers were asked: "Since the birth of your child, have you or a member of your family not eaten adequately because the family had run out of food or money to buy food?". In cycle 5, the question stated: "In the past 12 months, have you or a member of your family not eaten adequately because the family had run out of food or money to buy food?". In both cycles, response options included: "Regularly or every month"; "More than once a month"; "Only during certain months"; "Occasionally but not regularly"; and, "No". Families were categorized as "Having experienced food insufficiency" if mothers responded with *any* of the positive response-options, from "Occasionally" to "Regularly", at either cycle 2 or cycle 5. Children with mothers who responded with a "No" in both cycle 2 and cycle 5 were categorized as "Not having experienced food insufficiency". Similar methods for response combination have been used in other studies on food insufficiency (Alaimo et al., 1998; Christofar & Basiotis, 1992; Rose, Gundersen, & Oliveira, 1998). This method of estimating food insufficiency was also validated using a non-randon sample through an exploratory study conducted in the province of Québec, Canada (Hamelin, 1999).

Once again, family demographic and socio-economic characteristics included in the present study were obtained from different survey years where necessary, either because a characteristic was not measured in later years or because there was a high proportion of missing values for that characteristic at other survey time-points; thus, the characteristics were selected from years that provided the most reliable and complete data.

4.4 *Statistical Analyses*

All Statistical analyses were conducted using the latest version of SAS available (SAS Institute; Cary, NC), SAS version 9.1. Data were weighted according to factors involved in the survey design: A factor based on the inverse of the selection probability, the probability of non-response and the post-stratification and attrition rates (Cox & Cohen, 1985); this ensured that the sample was longitudinally representative of infants born in 1998.

In order to first identify subgroups of children who maintained different developmental trajectories for sleep duration from age 2.5 to 6 years, a semiparametric modeling approach was used to replicate and identify four longitudinal sleep duration patterns that were established through a prior study with the QLSCD dataset for the same surveyed years (Touchette et al., 2007; Touchette et al., 2008). This was accomplished using PROC TRAJ (Jones et al., 2001), a SAS® procedure (SAS Institute; Cary, NC) that estimates developmental trajectories by using all developmental data points collected to assign individuals to a sleep duration trajectory group on the basis of a posterior probability rule. This method measures the likelihood of an individual belonging to a particular trajectory group based on all observations gathered across various time-points; trajectory groups are then assigned according to the highest probability of belonging to a group, with analyses being weighted by posterior probabilities. Identified trajectory groups approximate the underlying continuous developmental process; thus, it is neither assumed nor required that 100% classification accuracy be achieved (Nagin, 2005).

To identify the sleep duration trajectory groups established through a prior study on this same dataset, the present study replicated the methods described in Touchette and colleague's paper (see Touchette et al., 2007; Touchette et al., 2008): A censored normal model, considered appropriate for continuous data that are normally distributed, was used to compare trajectory models with 2 to 5 trajectories with various shapes (e.g. intercept, linear, quadratic, or cubic). The maximum Bayesian Information Criterion (BIC) was used to select the best model with the optimal number of trajectory groups and patterns that best fit the data. As this procedure permits that cases with some missing data points be retained in the analyses, individuals with either zero, 1 or 2 missing data points for sleep duration, out of all five data-collection time-points (annual collections from age 2.5 to 6 years of age), were included in the analyses; this allowed for a greater number of children to be included in the trajectory analyses.

4.4.1 Bivariate Analyses

Chi-squared tests of association were used to examine the crude associations between the outcome and predictor variables, between the outcome and covariates, and between the predictor and covariates.

For the first set of analyses at age 6 years, the main bivariate associations examined included the association between:

1) longitudinal sleep duration pattern (age 2.5 to 6 years) and overweight/obesity (age 6 years);

2) longitudinal sleep duration pattern (age 2.5 to 6 years) and 8 variables for dietary intake (age 6 years);

3) longitudinal sleep duration pattern (age 2.5 to 6 years) and 3 eating behaviour variables (age 6 years);

4) 8 variables for dietary intake and overweight/obesity at age 6 years; and,

5) 3 eating behaviour variables and overweight/obesity at age 6 years.

Bivariate analyses were also used to examine the crude associations between covariates and the following main outcome and predictor variables: 1) Longitudinal sleep duration pattern; 2) overweight/obesity (age 6 years); and, 3) dietary intake/eating behaviour variables (age 6 years), to determine a final list of covariates to be included in the final multivariate models. Covariates found to significantly relate ($P \leq 0.05$) to overweight/obesity at age 6 and/or 7 years, and covariates that significantly related to: 1) Longitudinal sleep duration pattern *and* overweight/obesity at age 6 or 7 years; or, 2) longitudinal sleep duration pattern *and* dietary intake/eating behaviour variables; or, 3) dietary intake/eating behaviour variables *and* overweight/obesity at age 6 or 7 years, were retained to be further examined in multivariate analyses conducted at both age 6 and 7 years.

For the bivariate associations examined between longitudinal sleep duration pattern and dietary intake/eating behaviour variables, the statistical level to exclude dietary intake/eating behaviour variables as potential mediators in the final multivariate models was set at $P \leq 0.10$. For all other bivariate analyses summarized above, the level of significance was set at $P \leq 0.05$.

A second set of analyses at age 7 years examined the following main bivariate associations:

1) longitudinal sleep duration pattern (age 2.5 to 6 years) and overweight/obesity (age 7 years);

2) 8 variables for dietary intake (age 6 years) and overweight/obesity (age 7 years); and,

3) 3 eating behaviour variables (age 6 years) and overweight/obesity (age 7 years).

The level of statistical significance for this second set of analyses was also set at $P \leq 0.05$.

4.4.2 Multivariate Analyses

The independent association between longitudinal sleep duration pattern and overweight/obesity at both age 6 and 7 years, and the effect of potential mediating dietary intake/eating behaviour variables on this main association were examined through multivariate logistic regression analyses. Final multivariate models were assessed both with and without adjustments for a narrowed set of covariates.

In the final multivariate regression models, a dietary intake or eating behaviour variable was analyzed as a potential mediator to the main sleep duration-overweight/obesity association only if analyses at the bivariate level revealed a significant association between it and *both*: 1) Longitudinal sleep duration pattern (at the $P \leq 0.10$ level); and, 2) overweight/obesity at age 6 or 7 years (at the $P \leq 0.05$ level).

Covariates included in the final multivariate models were selected based on the literature, their influence on the main association, and on their non-collinearity with other variables included in the final multivariate models. More specifically, after a set of covariates was narrowed through criteria specified in bivariate analyses, these covariates were entered simultaneously into final multivariate models examined at age 6 and 7 years, and were further narrowed through a stepwise selection approach. Final multivariate models thus controlled for all covariates deemed to act as important risk factors for overweight/obesity and potential confounders to the main association. As certain covariates had the potential of being associated with one another, evidence for multicollinearity (indicated through large increases in the standard error estimates for the beta coefficients of two or more predictor or covariates) was monitored throughout all steps of the model selection process.

Statistical interactions between the main predictor variables (between longitudinal sleep duration pattern and dietary intake/eating behaviour variables) and between each covariate and main predictor variables, were also examined on a multiplicative scale through logistic regression by including interaction terms (e.g. 'Sleep duration trajectory' x 'Household income'; 'Eating too much *or* too fast' x 'Household Income'; etc.) in all final regression models. Interactions were tested at the $P \leq 0.01$ level to remain conservative.

Final model parameters were estimated with the use of the maximum likelihood method and tested for statistical significance through the use of the Wald statistic. Odds ratios were examined at the 95% confidence interval and statistical significance was set at the $P \leq 0.05$ level. The potential mediating effects of dietary intake/eating behaviour variables on the longitudinal sleep duration pattern – overweight/obesity association were evaluated through a qualitative approach and by comparing the change in the beta estimates between the base regression model of overweight/obesity onto longitudinal sleep duration pattern and each of the final regression models that included a potentially mediating dietary intake/eating behaviour variable. Dietary intake/eating behaviour variables were considered to act as partial- or full- mediators to the main association if their inclusion in the final multivariate models either reduced the beta estimates of longitudinal sleep duration pattern by 10% or more, or if their inclusion completely eliminated evidence for the statistical association between longitudinal sleep duration pattern and overweight/obesity at the $P \leq 0.05$ level.

The impact of missing data in the covariates was taken into consideration. If less than 5% of data were missing, this was considered as having no impact and was removed from the analyses. Otherwise, with- and without- analyses were conducted to evaluate the overall impact of missing values. Missing values shown to have an impact on the results were coded and retained for the analyses.

CHAPTER 5: Results

Due to an important finding revealing a significant interaction between 'sex of child' and 'longitudinal sleep duration pattern' on overweight/obesity at age 6 years (P=0.003), it was warranted that all analyses at both 6 and 7 years be stratified by sex and, thus, will be presented as such.

5.1 *Characteristics of the study sample*

From the initial 2223 children sampled in cycle 1, 1829 children were included in the sleep trajectory analyses to age 6 years, these having no more than 2 missing data points for sleep duration over all five cycles (cycle 3 through cycle 7, from age 2.5 to 6 years of age). Following this step, the association between longitudinal sleep duration pattern, BMI and dietary intake/eating behaviour was tested on 1106 children (47% boys, 53% girls) at age 6 years (40% had missing data on either of the main variables for BMI or dietary intake/eating behaviour), comprising 50% of the original cohort of 2223 children sampled in cycle 1 and 74% of children who remained in the study until cycle 7 (age 6 years). For the second set of analyses conducted at age 7 years, 8% of children from the sample used in analyses to age 6 years had missing data for anthropometric measures of body weight and height taken at age 7 years; thus, 1015 children (46% boys, 55% girls) remained in the analyses at age 7 years, comprising 46% of the original cohort sampled in cycle 1, and 66% of children who remained in the study until cycle 8 (age 7 years).

Table 4 presents the descriptive characteristics of children included in analyses at age 6 and 7 years and of those who were excluded (n = 1117, excluded) from the analyses due to missing data on the main variables for sleep duration, BMI, and dietary intake/eating behaviour. Very few children were born premature or with low birth weight, and few watched television for 3 or more hours per day or came from families who had experienced food insufficiency. In comparison to children included in analyses at age 6 years, more children excluded from analyses at age 6 years were male, were classified as overweight or obese at age 2.5 years, had missing information on snoring habits, and watched television for 3 or more hours per day (see table footnote for this last characteristic). More children excluded from analyses at age 6 years also had mothers with a lower level of education, who were unemployed at the survey time point, were smokers when the child was 3.5 years old, had missing information on height and weight (mother), and were immigrants. More children excluded from analyses at age 6 years also came from families with lower household incomes and from families who experienced slightly more food insecurity or did not report this information in comparison to children included in analyses at age 6 years.

Of the children included in analyses at age 6 years, 91 children were missing additional data on height and weight at 7 years; therefore a total of 1208 children from the original cohort were excluded from analyses at age 7 years. Again, in comparison to children included in analyses at age 7 years (Table 4), more children excluded from analyses at age 7 years were also male, were classified as overweight or obese at age 2.5 years, and had missing information on snoring habits at age 6 years. More children excluded from analyses at age 7 years also had mothers with a lower level of education, who were unemployed when the children were 6 years old, who were smokers when the child was 3.5 years old, and were immigrants in comparison to children included in analyses at age 7 years. Lastly, more children excluded from analyses at age 7 years also came from families with lower household income.

Table 4: Descriptive characteristics† of the sample included and excluded from analyses at age 6 and 7 years.

	Age 6 years		Age 7 years	
	Characteristics of Children included in analyses	Characteristics of Children excluded from analyses (Missing data on: Dietary Intake/ Eating behaviour at 6 years, on BMI at 6 years, and on more than 2 Sleep duration values from 2.5 to 6 years)	Characteristics of Children included in analyses	Characteristics of Children excluded from analyses (Includes children excluded from analyses at age 6 years *and* those missing additional data on BMI at 7 years)
Variable	(%)	(%)	(%)	(%)
Child / Birth Characteristics				
Sex of child				
Male	47.1	57.3**	45.5	53.3*
Female	52.9	42.7	54.5	46.7
Premature birth status (<37 weeks)				
No	93.7	94.3	94.0	93.7
Yes (born premature)	6.3	5.7	6.0	6.34
Born premature (<37 weeks) or with low birth weight (<2.5 kg)				
No	92.3	92.1	92.5	92.3
Yes (born premature *or* with low birth weight)	7.7	7.9	7.5	7.7
Mother smoked during pregnancy				
No	75.5	71.7‡	74.9	68.7‡
Yes (smoked during pregnancy)	24.0	27.9	24.5	32.0
Missing	0.5	0.4	0.6	0.3
Breastfed (partial or exclusive) for first 4 months				
Never breastfed	25.1	26.7	25.6	27.2
Breastfed < 4 months	29.8	34.1	30.4	35.1
Breastfed 4 or more months	45.1	39.2	44.1	37.7
Mother's perception of the child's general health status at age 6 years				
Excellent	63.5	58.9	63.6	59.7
Very good	26.4	29.6	27.2	29.3
Good / Satisfactory/ Poor	10.1	11.5	9.2	10.9
Overweight or obese at age 2.5 years				
No	75.9	61.2**	75.8	63.0**
Yes (overweight or obese at 2.5 years)	17.3	25.4	17.6	26.5
Missing	6.9	13.4	6.6	10.5
Chronic illness (excluding allergies, but including asthma) at age 6 years				
No	88.8	87.6	88.3	89.4
Yes (child has a chronic illness)	11.2	12.4	11.7	10.6

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Table 4 (*continued*)				
	Age 6 years		Age 7 years	
	Characteristics of Children included in analyses	**Characteristics of Children excluded from analyses** (Missing data on: Dietary Intake/ Eating behaviour at 6 years, on BMI at 6 years, and on more than 2 Sleep duration values from 2.5 to 6 years)	**Characteristics of Children included in analyses**	**Characteristics of Children excluded from analyses** (Includes children excluded from analyses at age 6 years *and* those missing additional data on BMI at 7 years)
Variable	**(%)**	**(%)**	**(%)**	**(%)**
Child / Birth Characteristics (continued)				
Snores at night at age 6 years				
Never/Sometimes	84.8	60.5**	85.2	66.0**
Always/Often	8.7	4.7	8.8	4.9
Missing	6.5	34.9	6.0	29.1
Level of physical activity in comparison to other children ('Higher' or 'Much higher')				
No ('Same as other children / Lower / or Much lower')	67.1	65.1‡	66.9	68.9
Yes ('Higher/Much higher')	32.8	34.1	33.1	31.1
Missing	0.1	0.8	0.0	0.0
Watches Television for 3 or more hours per day (weekdays and week-ends)				
No (< 3 hours per day)	94.9	90.5*‡	94.9	92.8‡
Yes (3 or more hours per day)	5.1	9.5	5.0	7.2
Missing	0.1	0.0	0.1	0.0
Parent Characteristics				
Mother's age (when the child was 6 years old)				
29 years or less	17.8	19.9	18.4	22.3
30-34 years	29.1	26.3	29.6	27.0
35-39 years	33.8	36.6	33.5	34.2
40 + years	19.0	15.4	18.1	15.1
Missing	0.4	1.8	0.4	1.3
Mother's level of education (highest diploma obtained when the child was 6 years old				
No Secondary school diploma	14.4	16.2**	14.3	15.4*
Secondary school diploma	21.4	23.1	21.9	24.5
College or professional school diploma	32.8	36.53	33.1	37.3
University diploma	31.1	22.4	30.2	21.6
Missing	0.4	1.8	0.4	1.3
Mother employed at the survey time-point (when the child was 6 years old)				
No (not employed)	26.7	34.4**	26.7	34.7**
Yes (employed)	73.0	63.5	72.8	63.7
Missing	0.4	2.0	0.4	1.7

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Table 4 (*continued*)

	Age 6 years		Age 7 years	
	Characteristics of Children included in analyses	**Characteristics of Children excluded from analyses** (Missing data on: Dietary Intake/ Eating behaviour at 6 years, on BMI at 6 years, and on more than 2 Sleep duration values from 2.5 to 6 years)	**Characteristics of Children included in analyses**	**Characteristics of Children excluded from analyses** (Includes children excluded from analyses at age 6 years *and* those missing additional data on BMI at 7 years)
Variable	**(%)**	**(%)**	**(%)**	**(%)**
Parent Characteristics (continued)				
Mother's smoking status (when the child was 3.5 years old)				
No (non-smoker)	75.4	66.7**	76.0	66.9**
Yes (smoker)	23.6	27.6	23.9	30.7
Missing	1.0	5.7	0.1	2.4
Mother's immigrant status (Is the mother an immigrant?)				
No (not an immigrant)	86.7	69.1**	89.9	76.0**
Yes (an immigrant)	12.9	29.1	9.6	22.6
Missing	0.4	1.8	0.4	1.3
Mother overweight or obese (BMI ≥ 25 kg/m²) when the child was 17 months old				
No (not overweight/obese)	69.7	70.8*	68.8	72.8
Yes (overweight/ obese)	28.6	24.7	29.6	25.0
Missing	1.7	4.5	1.6	2.2
Family Demographic and Socio-economic Characteristics				
The family experienced food insufficiency (when the child was either 17 months or 4.5 years old)				
No (did not experience food insufficiency)	93.0	89.6**	93.1	91.2‡
Yes (experienced food insufficiency)	6.8	8.4	6.7	7.6
Missing	0.2	2.0	0.2	1.3
Household income				
Less than $30,000	14.3	24.7**	13.4	24.5**
$30,000 - $49,999	22.8	25.3	23.2	22.8
$50,000 - $79,999	29.9	23.9	30.6	25.9
$80,000 or more	32.4	25.4	32.3	26.5
Missing	0.6	0.6	0.5	0.3

*Significant difference between those excluded and included (Chi-square, two-sided $p \leq 0.05$); ** Significant difference (Chi-square, two-sided $p \leq 0.01$)

† Weighted;

‡ Warning: ≥ 25% of the cells have an expected count less than 5. Chi-Square may not be a valid test.

Source: *Data courtesy of the Quebec Institute of Statistics, QLSCD 1998-2010*

Using the IOTF BMI cut-offs for overweight/obesity in boys and girls at age 6 and 7 years, approximately 16% (16% of boys; 16% of girls) of the sample was classified as overweight/obese at age 6 years, and 16% (15% of boys; 17% of girls) of the sample was considered as overweight/obese at age 7 years. Table 5 presents the mean distribution of BMI by overweight/obesity status (IOTF definition) in boys and girls at age 6 and 7 years.

Table 5: Mean† BMI (kg/m^2) by overweight/obesity status in boys and girls at age 6 and 7 years.

	BMI (Body Mass Index kg/m^2)	
	Sample included in analyses to age 6 years	
	Boys	Girls
Overweight/Obesity status at age 6 years (IOTF definition)	*Mean* (SD) & Range (lowest-highest value)	*Mean* (SD) & Range (lowest-highest value)
Non-overweight/ Obese at age 6 years (BOYS: BMI<17.55 kg/m^2 = 84.14%; GIRLS: BMI<17.34 kg/m^2 = 84.40%)	15.28 (1.12) (11.10 – 17.53)	15.08 (1.12) (11.92 – 17.42)
Overweight *or* obese at 6 years (BOYS: BMI ≥17.55 kg/m^2 = 15.86%; GIRLS: BMI ≥17.34 kg/m^2 = 15.60%)	19.50 (2.14) (17.58 – 27.14)	19.42 (2.14) (17.22 – 28.45)
	Sample included in analyses to age 7 years	
	Boys	Girls
Overweight/Obesity status at age 7 years (IOTF definition)	*Mean* (SD) & Range (lowest-highest value)	*Mean* (SD) & Range (lowest-highest value)
Non-overweight/ Obese at age 7 years (BOYS: BMI<17.92 kg/m^2 = 85.20%; GIRLS: BMI <17.75 kg/m^2 = 82.62%)	15.49 (1.26) (10.93 – 17.85)	15.22 (1.20) (11.71 – 17.70)
Overweight *or* obese at 7 years (BOYS: BMI ≥17.92 kg/m^2 = 14.80%; GIRLS: BMI ≥17.75 kg/m^2 = 17.38%)	20.56 (3.19) (17.75 – 35.77)	20.11 (2.82) (17.53 – 30.37)

† Weighted
Source: *Data courtesy of the Quebec Institute of Statistics, QLSCD 1998-2010*

The descriptive characteristics of the sample by sex and prevalence of overweight/obesity at age 6 and 7 years are seen in Table 6. At age 6 years, boys who were classified as overweight or obese using the IOTF criteria were more likely to be considered by their mothers as having a "good/satisfactory/or poor" health status (as opposed to a "very good" or "excellent" health status), to have been overweight or obese at 2.5 years, to have a mother with a lower level of education, and to come from a home with lower household income (Chi-square, $p \leq 0.05$), in comparison to boys who were not considered overweight or obese at age 6 years. Other characteristics also appear to be more prevalent in boys who were classified as overweight or obese at age 6 years; however, due to a large number of cells having an expected count less than 5, a Chi-square test may not be valid to determine whether these differences are statistically significant (please see table footnotes). Nonetheless, in comparison to boys who were not overweight or obese at 6 years of age, there is an indication that overweight/obese boys were more likely to come from mothers who were immigrants, mothers who were overweight or obese when the child was 17 months old, and from families who had experienced food insufficiency when the child was either 17 months or 4.5 years old. At 7 years of age, boys classified as overweight or obese were also more likely to have been overweight or obese at age 2.5 years and to have a mother between the ages of 35 to 39 years (Chi-square, $p \leq 0.05$), in comparison to boys who were not overweight or obese at 7 years of age. Again, other characteristics including having an immigrant mother and having a mother that was classified as overweight or obese when the child was 17 months old also appear to be more prevalent in boys who were overweight or obese at age 7 years; however, again, due to a large number of cells having an expected count less than 5, a Chi-square test may not be valid to determine whether these differences are statistically significant (please see table footnotes).

Girls who were considered overweight or obese at 6 years of age were more frequently never breastfed as infants or breastfed less than 4 months, were more likely to have been overweight or obese at age 2.5 years, and were more likely to come from lower income families in comparison to girls who were not overweight or obese at age 6 years (Chi-square, $p \leq 0.05$). More girls who were overweight or obese also had mothers who smoked during pregnancy and mothers who smoked when the child was 3.5 years old;

however, a Chi-square test of these differences may not be valid as a large number of cells had an expected count less than 5 (please see table footnotes). At age 7 years, girls who were overweight or obese were also more likely to have been overweight or obese at 2.5 years of age, to have a chronic illness at age 6 years, to be considered as having a level of physical activity that was 'same/lower/much lower' than other children, and to have a mother that was overweight or obese when the child was 17 months old in comparison to girls who were not overweight or obese at age 7 years (Chi-square, $p \leq 0.05$). More girls who were overweight or obese at 7 years also appear to have had mothers who smoked when the child was 3.5 years old in comparison to girls who were not overweight or obese at 7 years; however, again, due to low cell counts, a Chi-square test may not be valid to determine the statistical significance of these differences (please see table footnotes).

Table 6: Descriptive characteristics† of the sample by sex and prevalence of overweight/obesity (IOTF cut-offs) at age 6 and 7 years.

Variable	Sample included in analyses to age 6 years				Sample included in analyses to age 7 years			
	Boys		Girls		Boys		Girls	
	%	Cases (%) overweight *or* obese (BMI ≥ 17.55 kg/m²) (15.86%)	%	Cases (%) overweight *or* obese (BMI ≥ 17.34 kg/m²) (15.60%)	%	Cases (%) overweight *or* obese (BMI ≥ 17.92 kg/m²) (14.80%)	%	Cases (%) overweight *or* obese (BMI ≥ 17.75 kg/m²) (17.38%)
Child / Birth Characteristics								
Premature birth status (<37 weeks)								
No	92.3	88.3‡	95.0	96.2‡	92.5	90.4‡	95.2	92.9‡
Yes (born premature)	7.7	11.7	5.0	3.8	7.5	9.6	4.8	7.1
Born premature (<37 weeks) or with low birth weight (<2.5 kg)								
No	91.0	88.3	93.4	95.0‡	91.3	90.4‡	93.5	91.9‡
Yes (born premature *or* with low birth weight)	9.0	11.7	6.6	5.0	8.7	9.6	6.5	8.1
Mother smoked during pregnancy								
No	77.6	72.6‡	73.5	61.5*‡	78.0	76.0‡	72.4	61.1‡
Yes (smoked during pregnancy)	22.3	27.5	25.6	36.5	21.9	24.0	26.7	37.7
Missing	0.1	0.0	0.9	2.1	0.1	0.0	1.0	1.2
Breastfed (partial or exclusive) for first 4 months								
Never breastfed	24.2	28.4	25.9	27.8*	24.9	30.7	26.2	26.2
Breastfed < 4 months	26.8	21.69	32.5	45.9	28.3	22.9	32.1	37.1
Breastfed 4 or more months	49.0	49.9	41.6	26.4	46.8	46.4	41.8	36.7
Mother's perception of the child's general health status at age 6 years								
Excellent	63.9	60.9*	63.1	57.74	64.2	67.2	63.1	58.4
Very good	24.8	13.8	27.8	33.2	26.3	17.0	28.0	33.3
Good / Satisfactory/ Poor	11.3	25.3	9.0	9.1	9.5	15.8	8.9	8.3
Overweight or obese at age 2.5 years								
No	75.6	57.9*	76.1	57.3*	75.8	60.9*	75.9	52.6*
Yes (overweight or obese at 2.5 years)	16.9	32.8	17.7	31.7	17.0	33.1	18.1	39.1
Missing	7.5	9.3	6.3	11.0	7.3	6.1	6.0	8.3
Chronic illness (excluding allergies, but including asthma) at age 6 years								
No	88.3	85.8	89.2	85.6	87.4	88.7	89.1	77.9*
Yes (child has a chronic illness)	11.7	14.2	10.8	14.4	12.6	11.3	10.9	22.1

(continued on next page)

Table 6 (*continued*)

Variable	Sample included in analyses to age 6 years: Boys %	Boys: Cases (%) overweight *or* obese (BMI ≥ 17.55 kg/m²) (15.86%)	Girls %	Girls: Cases (%) overweight *or* obese (BMI ≥ 17.34 kg/m²) (15.60%)	Sample included in analyses to age 7 years: Boys %	Boys: Cases (%) overweight *or* obese (BMI ≥ 17.92 kg/m²) (14.80%)	Girls %	Girls: Cases (%) overweight *or* obese (BMI ≥ 17.75 kg/m²) (17.38%)
Child / Birth Characteristics (continued)								
Snores at night at age 6 years								
Never/Sometimes	83.8	78.4	85.6	89.6	84.2	80.0‡	86.0	85.9
Always/Often	9.9	16.7	7.6	7.2	9.8	15.8	8.0	10.8
Missing	6.3	4.9	6.8	3.2	6.1	4.2	6.0	3.3
Level of physical activity in comparison to other children ('Higher' or 'Much higher')								
No ('Same as other children / Lower / or Much lower')	66.3	64.6	67.9	75.4‡	66.8	62.2	66.9	78.2*
Yes ('Higher/Much higher')	33.7	35.4	31.9	24.6	33.2	37.8	33.1	21.8
Missing	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0
Watches Television for 3 or more hours per day (weekdays and week-ends)								
No (< 3 hours per day)	95.0	96.3‡	94.8	96.6‡	95.6	97.2‡	94.4	94.6‡
Yes (3 or more hours per day)	4.9	3.7	5.2	3.4	4.3	2.9	5.6	5.4
Missing	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0
Parent Characteristics								
Mother's age (when the child was 6 years old)								
29 years or less	18.6	14.2	17.1	20.7	20.0	18.6*	17.0	19.1
30-34 years	29.9	29.1	28.3	25.7	30.1	26.7	29.1	25.0
35-39 years	32.3	36.7	35.1	36.9	32.6	45.8	34.2	35.4
40 + years	18.9	18.8	19.0	14.9	16.9	7.2	19.2	20.5
Missing	0.3	1.3	0.4	1.7	0.4	1.7	0.5	0.0
Mother's level of education (highest diploma obtained when the child was 6 years old								
No Secondary school diploma	11.5	20.8*	17.0	19.2	10.6	7.8	17.4	17.6
Secondary school diploma	22.9	26.4	20.1	25.8	23.7	31.4	20.5	26.1
College or professional school diploma	35.1	31.8	30.8	23.3	36.1	36.1	30.6	29.2
University diploma	30.2	19.7	31.7	30.0	29.2	23.0	31.1	27.1
Missing	0.3	1.3	0.4	1.7	0.4	1.7	0.5	0.0
Mother employed at the survey time-point (when the child was 6 years old)								
No (not employed)	24.8	22.4‡	28.3	32.9‡	26.1	27.1‡	27.3	26.9‡
Yes (employed)	74.9	76.4	71.2	65.3	73.5	71.2	72.2	73.1
Missing	0.3	1.3	0.4	1.7	0.4	1.7	0.5	0.0

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Table 6 (*continued*)

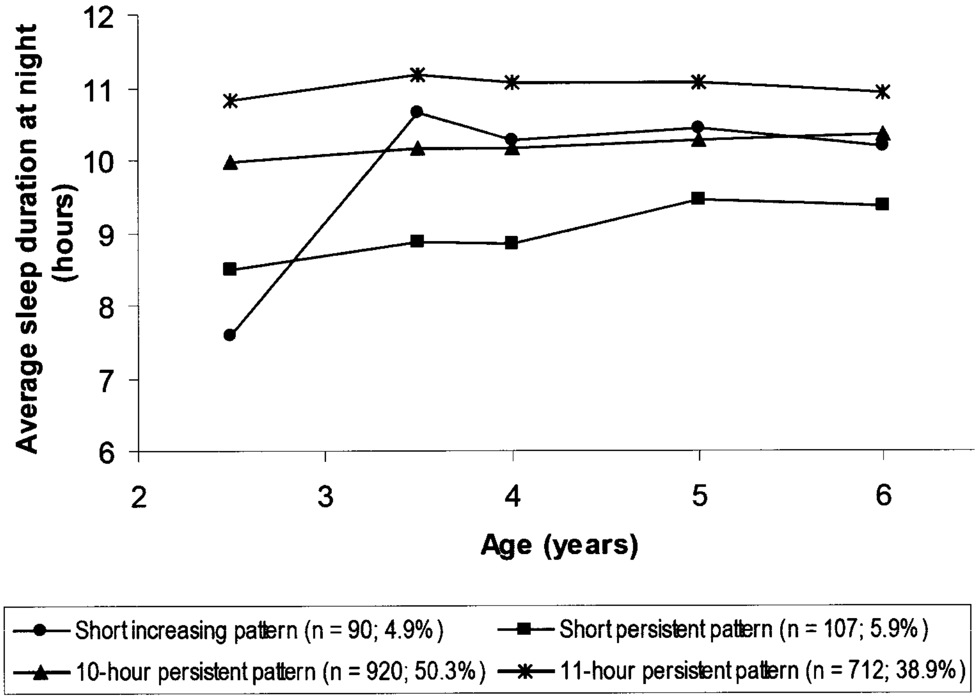
Variable	Sample included in analyses to age 6 years				Sample included in analyses to age 7 years			
	Boys		Girls		Boys		Girls	
	%	Cases (%) overweight *or* obese (BMI ≥ 17.55 kg/m²) (15.86%)	%	Cases (%) overweight *or* obese (BMI ≥ 17.34 kg/m²) (15.60%)	%	Cases (%) overweight *or* obese (BMI ≥ 17.92 kg/m²) (14.80%)	%	Cases (%) overweight *or* obese (BMI ≥ 17.75 kg/m²) (17.38%)
Parent Characteristics (continued)								
Mother's smoking status (when the child was 3.5 years old)								
No (non-smoker)	76.4	79.6‡	74.5	56.8*‡	78.0	71.9	74.3	63.2*‡
Yes (smoker)	22.2	26.6	24.8	43.3	22.0	28.1	25.5	35.6
Missing	1.4	2.8	0.7	0.0	0.0	0.0	0.2	1.2
Mother's immigrant status (Is the mother an immigrant?)								
No (not an immigrant)	85.8	67.8*‡	87.6	83.3‡	89.1	78.0*‡	90.6	88.1‡
Yes (an immigrant)	13.9	31.0	12.0	15.0	10.5	20.3	8.9	11.9
Missing	0.3	1.3	0.4	1.7	0.4	1.7	0.5	0.0
Mother overweight or obese (BMI ≥ 25 kg/m²) when the child was 17 months old								
No (not overweight/obese)	71.6	56.0*‡	68.0	57.7	70.4	57.0*‡	67.5	30.2*
Yes (overweight/ obese)	27.4	42.7	29.8	41.5	28.9	40.9	30.2	47.0
Missing	1.0	1.3	2.2	0.8	0.7	2.1	2.3	3.6
Family Demographic and Socio-economic Characteristics								
The family experienced food insufficiency (when the child was either 17 months or 4.5 years old)								
No (did not experience food insufficiency)	92.4	83.5*‡	93.6	92.9‡	92.4	90.5‡	93.8	91.8‡
Yes (experienced food insufficiency)	7.3	16.5	6.3	7.1	7.4	9.5	6.0	8.2
Missing	0.2	0.0	0.2	0.0	0.2	0.0	0.2	0.0
Household income								
Less than $30,000	13.7	26.5*	14.9	27.5*	11.9	16.5	14.6	19.2
$30,000 - $49,999	22.3	11.0	23.3	26.0	23.3	13.2	23.2	25.6
$50,000 - $79,999	30.3	35.5	29.6	22.0	31.0	38.6	30.2	29.1
$80,000 or more	32.9	25.4	31.9	25.5	33.1	31.8	31.6	25.1
Missing	0.9	1.6	0.4	0.0	0.7	0.0	0.4	1.1

*Significant difference present within the group category (Chi-square, two-sided $p \leq 0.05$)
† Weighted
‡ Warning: ≥ 25% of the cells have an expected count less than 5. Chi-Square may not be a valid test.
Source: *Data courtesy of the Quebec Institute of Statistics, QLSCD 1998-2010*

5.2 *Longitudinal sleep duration pattern*

Sleep duration trajectory analyses from age 2.5 to 6 years included 1829 children, replicating the precise methods used in Touchette and colleague's studies (Touchette et al., 2007; Touchette et al., 2008). As in Touchette and colleague's studies, four distinct longitudinal sleep duration patterns were identified; these are illustrated in Figure 3: 1) A '*short persistent*' pattern of sleep duration, in which 5.9% of children slept less than 10 hours per night, on average, from age 2.5 to 6 years; 2) a '*short increasing*' pattern of sleep duration, in which 4.9% of children slept fewer hours in early childhood but then increased their hours of average sleep duration around 3.5 years of age, maintaining more than 10 hours of sleep per night until age 6 years; 3) a '*10-hour persistent*' pattern of sleep duration, in which approximately 50% of children maintained an average of 10 hours of sleep per night from age 2.5 to 6 years; and, 4) an '*11-hour persistent*' pattern of sleep duration, in which approximately 39% of children maintained an average of 11 hours of sleep per night from age 2.5 to 6 years.

Figure 3: Longitudinal sleep duration pattern from 2.5 to 6 years of age



Source: *Data courtesy of the Quebec Institute of Statistics, QLSCD 1998-2010*

When these longitudinal sleep duration patterns were examined in the reduced sample of children (n=1106) for analyses with overweight/obesity and dietary intake/eating behaviour at age 6 years, it was noted that the frequencies in groups 1 and 2 for sleep duration ('*short persistent*' and '*short increasing*' pattern) were too low to be further explored in relation to the study's main outcomes. For this reason, the two longitudinal sleep duration pattern groups were merged after taking necessary precautions to ensure that: 1) There were no statistically significant differences (Chi-square, two-sided $p \leq 0.05$) between the two groups across several important sample characteristics (e.g. birth characteristics, health characteristics, parental and household characteristics); and, 2) bivariate analyses with the main variables of interest for overweight/obesity and dietary intake/eating behaviour produced the same results, regardless of whether the two groups were merged or left separate (data not shown). Thus, all analyses of the present study, at both age 6 and 7 years, analyzed longitudinal sleep duration pattern in 3 groups to eliminate the problem with low frequency cells. These three longitudinal sleep duration patterns are: 1) A merged group of children who showed either a '*short persistent* <u>*or*</u> *short increasing*' pattern of sleep duration (approximately 13% at age 6 years, and 12% at age 7 years); 2) a '*10-hour persistent*' pattern of sleep duration (approximately 49% at age 6 years, and 50% at age 7 years); and, 3) an '*11-hour persistent*' pattern of sleep duration (approximately 38% at age 6 years, and 38% at age 7 years). The proportion of boys and girls included in analyses at age 6 and 7 years by each longitudinal sleep duration pattern is presented in Table 7.

Table 7: Proportion† of the total sample in analyses at age 6 and 7 years, and of boys and girls separately, by longitudinal sleep duration pattern from age 2.5 to 6 years.

	Sample included in analyses to age 6 years			Sample included in analyses to age 7 years		
Longitudinal sleep duration pattern (2.5-6 years)	**Total (%)**	**Boys (%)**	**Girls (%)**	**Total (%)**	**Boys (%)**	**Girls (%)**
Short persistent <u>*or*</u> short increasing pattern	12.9	14.6	11.4	11.8	13.1	10.6
10-hour persistent pattern	49.4	52.4	46.6	49.8	53.1	47.1
11-hour persistent pattern	37.8	32.9	42.0	38.4	33.9	42.2

† Weighted
Source: *Data courtesy of the Quebec Institute of Statistics, QLSCD 1998-2010*

Table 8 compares the mean of average sleep duration (hours) across each year examined in the present study (from age 2.5 to 6 years), for the total sample included in initial trajectory analyses and separately for boys and girls included in analyses at age 6 and 7 years. It can be noted that, across all years, the mean of average sleep duration remained between 9.9 and 10.6 hours per night for both sexes.

Table 8: Mean† of average sleep duration (hours) from age 2.5 to 6 years, in the total sample included in trajectory analyses and in boys and girls included in analyses at age 6 and 7 years.

	Mean† (SD) & Range (lowest-highest value) of Sleep Duration (hours)				
	Sample included in Trajectory analyses	Sample included in analyses to age 6 years		Sample included in analyses to age 7 years	
Sleep duration at each age	Total (Boys & Girls)	Boys	Girls	Boys	Girls
Average sleep duration – at night (hours) at age 2.5 years	10.0 (1.22) (4.0 – 14.5)	9.9 (1.28) (4.0 – 14.5)	10.1 (1.16) (6.0 – 14.0)	10.0 (1.22) (4.0 – 14.5)	10.1 (1.17) (6.0 – 14.0)
Average sleep duration – at night (hours) at age 3.5 years	10.5 (0.97) (6.0 – 13.5)	10.4 (0.93) (6.0 – 13.5)	10.5 (0.99) (7.0 – 13.0)	10.4 (0.92) (6.0 – 13.0)	10.5 (0.98) (7.0 – 12.5)
Average sleep duration – at night (hours) at age 4 years	10.4 (0.90) (6.0 – 14.1)	10.4 (0.84) (7.5 – 12.5)	10.5 (0.96) (6.0 – 14.1)	10.4 (0.86) (7.5 – 12.5)	10.5 (0.98) (6.0 – 14.1)
Average sleep duration – at night (hours) at age 5 years	10.5 (0.84) (7.0 – 13.0)	10.5 (0.81) (7.0 – 13.0)	10.5 (0.86) (7.2 – 12.5)	10.5 (0.84) (7.0 – 13.0)	10.5 (0.86) (7.2 – 12.5)
Average sleep duration – at night (hours) at age 6 years	10.5 (0.85) (6.0 – 13.5)	10.4 (0.87) (6.0 – 13.5)	10.5 (0.81) (7.5 – 12.7)	10.4 (0.88) (6.0 – 13.5)	10.6 (0.80) (7.5 – 12.7)

† Weighted
Source: *Data courtesy of the Quebec Institute of Statistics, QLSCD 1998-2010*

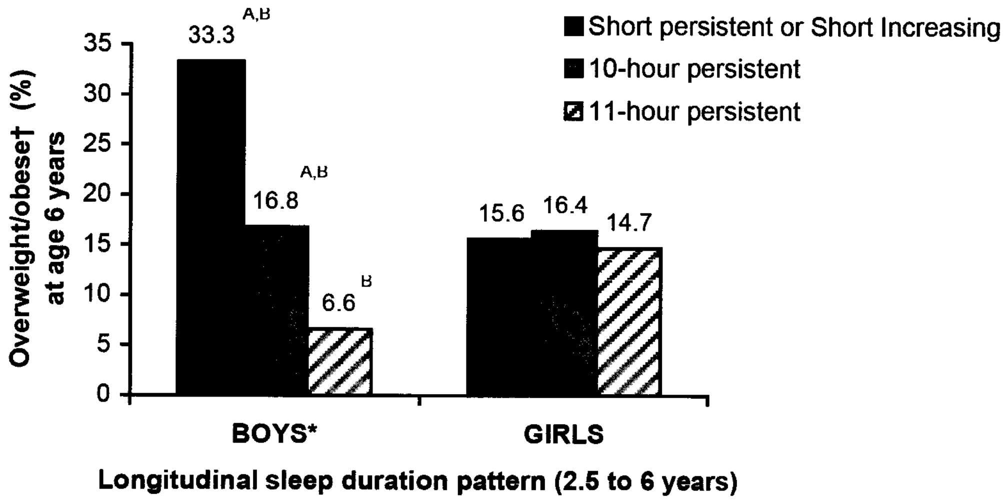
5.3 *Bivariate associations between the main study variables*

5.3.1 Longitudinal sleep duration pattern and overweight/obesity

As was briefly mentioned at the start of Chapter 5, analyses revealed a highly significant interaction between 'sex of child' and 'longitudinal sleep duration pattern' in a regression on overweight/obesity at age 6 years ($P < 0.001$). This interaction was not statistically significant when tested in relation to overweight/obesity at age 7 years; however, as the literature offers some support for possible sex-differences in the sleep duration – overweight/obesity association (Eisenmann et al., 2006; Knutson, 2005), all analyses at both age 6 and 7 years were stratified by sex to examine these potential differences.

At the bivariate level, a chi-squared test of independence showed that longitudinal sleep duration pattern from 2.5 to 6 years was significantly associated with being overweight or obese at both age 6 ($P < 0.001$) and 7 years ($P < 0.006$) in boys; however, this association was not present in girls at either age 6 or 7 years, at the 0.05 significance level. This sex difference is clearly illustrated in Figure 4 and Figure 5 which, respectively, present the prevalence of overweight or obesity in boys and girls at age 6 and 7 years according to each longitudinal sleep duration pattern. As is seen in Figure 4 and Figure 5, in boys, the prevalence of overweight/obesity at both age 6 and 7 years increased significantly across every *shorter* sleep duration pattern. Approximately one-third of boys who had '*short persistent* or *short increasing*' pattern of longitudinal sleep duration from age 2.5 to 6 years were considered overweight/obese both at age 6 and 7 years, whereas less than one-tenth of boys who had an '*11-hour persistent*' longitudinal sleep duration pattern were found to be overweight/obese at age 6 and 7 years. Crude odds ratios (OR) for the association between longitudinal sleep duration pattern and overweight/obesity in boys at age 6 and 7 years are presented in Table 20 and Table 21, respectively, included in section 5.5 of this document. For girls, the prevalence of overweight/obesity at both age 6 and 7 years remained relatively stable across all longitudinal sleep duration patterns (Figure 4 and Figure 5).

Figure 4: Prevalence† of overweight/obesity in boys and girls at age 6 years, according to longitudinal sleep duration pattern (age 2.5 to 6 years)



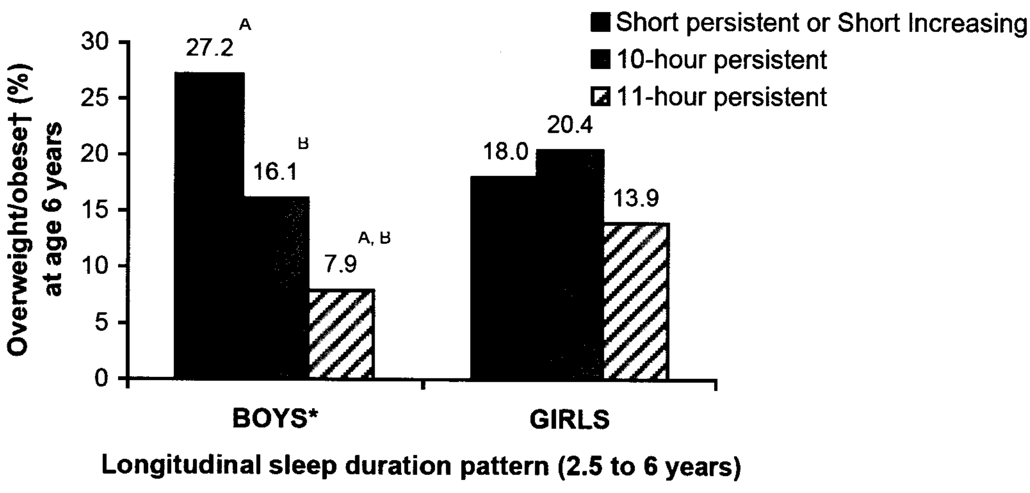
*Significant difference present within the group category (Chi-square, two-sided $p \leq 0.001$)

A, B There is a significant difference (Chi-square, two-sided $p \leq 0.01$) present in the prevalence of overweight/obesity (at 6 years) across longitudinal sleep duration pattern subgroups marked by the same superscript letter.

† Weighted

Source: *Data courtesy of the Quebec Institute of Statistics, QLSCD 1998-2010*

Figure 5: Prevalence† of overweight/obesity in boys and girls at age 7 years, according to longitudinal sleep duration pattern (age 2.5 to 6 years)



*Significant difference present within the group category (Chi-square, two-sided $p \leq 0.01$)

A, B There is a significant difference (Chi-square, two-sided $p \leq 0.05$) present in the prevalence of overweight/obesity (at 7 years) across longitudinal sleep duration pattern subgroups marked by the same superscript letter.

† Weighted

Source: *Data courtesy of the Quebec Institute of Statistics, QLSCD 1998-2010*

5.3.2 Longitudinal sleep duration pattern and dietary intake

Chi-squared tests of independence (expressed as odds ratios, using logistic regression) were also used to examine the bivariate associations between longitudinal sleep duration pattern from 2.5 to 6 years and dietary intake at 6 years of age, in both boys and girls. The proportion of children in each food/beverage consumption group according to longitudinal sleep duration pattern, is presented in Table 9 (for boys) and Table 10 (for girls); crude odds ratios (OR) and 95% confidence intervals (CI) are also provided.

For boys (Table 9), longitudinal sleep duration pattern was significantly associated with the daily frequency of consumption of: Vegetables ($P < 0.001$), fruits (only) ($P = 0.027$), and meat and alternatives ($P = 0.003$). Boys who had '*short persistent* or *short increasing* longitudinal sleep duration patterns from age 2.5 to 6 years consumed vegetables and fruits (only) significantly less often (≤ once per day) than those with *'10-hour persistent'* or *'11-hour persistent'* longitudinal sleep duration patterns, and consumed meat and alternatives significantly more often (> once per day) than did boys with *'10-hour persistent'* or *'11-hour persistent'* longitudinal sleep duration patterns, at the 0.05 significance level. Very few boys consumed soft drinks once a day or more, or more than 3 times per week; due to this fact, Chi-squared tests of independence for the association between longitudinal sleep duration and soft drink consumption patterns in boys could not be used to accurately determine whether a true association exists between these variables (please refer to the footnotes of Table 9).

Table 9: Proportions†, crude odds ratios† and 95% confidence intervals for the frequency of consumption of various foods/beverages according to longitudinal sleep duration pattern (2.5 to 6 years), in boys at age 6 years.

	BOYS – Dietary intake: Frequency of consumption of various foods & drinks at age 6 years									
	FFQ: Bread and grains (times per day)					FFQ: Vegetables (times per day)				
Longitudinal sleep duration pattern (2.5-6 years)	% ≤ 1/day (31.0%)	% > 1/day (69.0%)	*p*-value (Chisq.)	Crude OR§ for consuming ≤ 1/day	95% CI§	% ≤ 1/day (56.2%)	% > 1/day (43.8%)	*p*-value (Chisq.)	Crude OR§ for consuming ≤ 1/day	95% CI§
Short persistent *or* short increasing pattern (Boys = 14.6%)	37.0	63.0	0.540	1.45	0.81, 2.60	80.6 A, B	19.4 A, B	<0.01*	3.91*	2.03, 7.54
10-hour persistent pattern (Boys = 52.4%)	30.7	69.3		1.10	0.72, 1.68	52.3 A	47.7 A		1.03	0.70, 1.52
11-hour persistent pattern (Boys = 32.9%) £	28.8	71.2		1.00	–	51.6 B	48.4 B		1.00	–
	FFQ: Fruits and fruit juices (times per day)					FFQ: Fruits (only) (times per day)				
Longitudinal sleep duration pattern (2.5-6 years)	% ≤ 1/day (14.0%)	% > 1/day (86.0%)	*p*-value (Chisq.)	Crude OR§ for consuming ≤ 1/day	95% CI§	% ≤ 1/day (52.0%)	% > 1/day (48.0%)	*p*-value (Chisq.)	Crude OR§ for consuming ≤ 1/day	95% CI§
Short persistent *or* short increasing pattern (Boys = 14.6%)	12.3	87.7	0.429	1.10	0.47, 2.59	67.7 A, B	32.3 A, B	0.027*	2.44*	1.37, 4.35
10-hour persistent pattern (Boys = 52.4%)	16.2	83.9		1.52	0.85, 2.73	51.3 A	48.7 A		1.22	0.83, 1.81
11-hour persistent pattern (Boys = 32.9%) £	11.3	88.8		1.00	–	46.2 B	53.8 B		1.00	–
	FFQ: Milk products (times per day)					FFQ: Meat & alternatives (times per day)				
Longitudinal sleep duration pattern (2.5-6 years)	% ≤ 1/day (15.5%)	% > 1/day (84.5%)	*p*-value (Chisq.)	Crude OR§ for consuming ≤ 1/day	95% CI§	% ≤ 1/day (89.3%)	% > 1/day (10.7%)	*p*-value (Chisq.)	Crude OR§ for consuming ≤ 1/day	95% CI§
Short persistent *or* short increasing pattern (Boys = 14.6%)	23.8	76.2	0.170	1.82	0.91, 3.63	77.1 A, B	22.9 A, B	0.003*	0.21*	0.09, 0.48
10-hour persistent pattern (Boys = 52.4%)	13.7	86.4		0.92	0.53, 1.61	89.6 A	10.4 A		0.53	0.24, 1.13
11-hour persistent pattern (Boys = 32.9%) £	14.7	85.3		1.00	–	94.2 B	5.8 B		1.00	–
	General Q: Consumption of soft drinks (times per week)					General Q: Consumption of soft drinks (times per day)				
Longitudinal sleep duration pattern (2.5-6 years)	% ≤ 3/week (95.3%)	% > 3/week (4.7%)	*p*-value (Chisq.)	Crude OR§ for consuming > 3/week	95% CI§	% < 1/day (95.6%)	% ≥ 1/day (4.4%)	*p*-value (Chisq.)	Crude OR§ for consuming > 1/day	95% CI§
Short persistent *or* short increasing pattern (Boys = 14.6%)	93.6	6.4	0.817‡	1.46	0.44, 4.85	93.6	6.4	0.703‡	1.46	0.44, 4.85
10-hour persistent pattern (Boys = 52.4%)	95.6	4.4		0.99	0.39, 2.56	96.2	3.8		0.85	0.32, 2.24
11-hour persistent pattern (Boys = 32.9%) £	95.6	4.5		1.00	–	95.6	4.5		1.00	–

*Significant difference present within the group category (Chi-square, two-sided $p \leq 0.05$)

A, B There is a significant difference (CHISQ $p \leq 0.05$) present in the food consumption group by longitudinal sleep duration pattern as marked by variable subgroups with the same superscript letter.

† Weighted

‡ Warning: ≥ 25% of the cells have an expected count less than 5. Chi-Square may not be a valid test.

§ OR, odds ratio; CI, confidence interval; £ Reference category

Source: *Data courtesy of the Quebec Institute of Statistics, QLSCD 1998-2010*

For girls (Table 10), longitudinal sleep duration pattern was significantly associated with the daily frequency of consumption of: Vegetables ($P = 0.001$), fruits (only) ($P = 0.006$), milk products ($P = 0.001$), and consumption of soft drinks per week ($P < 0.001$) and per day ($P < 0.001$) at the bivariate level. More specifically, girls who had *'short persistent* or *short increasing'* longitudinal sleep duration pattern from age 2.5 to 6 years consumed vegetables, fruits (only), and milk products significantly less often (≤ once per day) than those with *'10-hour persistent'* or *'11-hour persistent'* longitudinal sleep duration patterns, and consumed soft drinks (measured both per week and per day) significantly more often (> 3 times per week and ≥ once per day) than did girls with *'10-hour persistent'* or *'11-hour persistent'* longitudinal sleep duration patterns, at the 0.05 significance level. It is important to note, however, that very few girls consumed meat and alternatives more than once a day, soft drinks once a day or more, or soft drinks more than 3 times per week; thus, Chi-squared tests of independence could not be used to provide an accurate reflection of the true association between longitudinal sleep duration pattern and these last food and beverage consumption groups in girls due to low cell counts (please refer to footnotes of Table 10).

Table 10: Proportions†, crude odds ratios† and 95% confidence intervals for the frequency of consumption of various foods/beverages according to longitudinal sleep duration pattern (2.5 to 6 years), in girls at age 6 years.

	GIRLS – Dietary intake: Frequency of consumption of various foods & beverages at age 6 years									
	FFQ: Bread and grains (times per day)					FFQ: Vegetables (times per day)				
Longitudinal sleep duration pattern (2.5-6 years)	**% ≤ 1/day (34.8%)**	**% > 1/day (65.2%)**	***p*-value (Chisq.)**	**Crude OR§ for consuming ≤ 1/day**	**95% CI§**	**% ≤ 1/day (46.7%)**	**% > 1/day (53.3%)**	***p*-value (Chisq.)**	**Crude OR§ for consuming ≤ 1/day**	**95% CI§**
Short persistent *or* short increasing pattern (Girls = 11.4%)	33.0	67.0		0.92	0.51, 1.66	71.0^{A,B}	29.0^{A,B}		2.84*	1.56, 5.17
10-hour persistent pattern (Girls = 46.6%)	35.2	64.8	0.959	1.02	0.70, 1.47	41.2^{A}	58.8^{A}	0.001*	0.82	0.57, 1.16
11-hour persistent pattern (Girls = 42.0%) £	34.8	65.2		1.00	--	46.3^{B}	53.7^{B}		1.00	--
	FFQ: Fruits and fruit juices (times per day)					FFQ: Fruits (only) (times per day)				
Longitudinal sleep duration pattern (2.5-6 years)	**% ≤ 1/day (15.8%)**	**% > 1/day (84.2%)**	***p*-value (Chisq.)**	**Crude OR§ for consuming ≤ 1/day**	**95% CI§**	**% ≤ 1/day (46.7%)**	**% > 1/day (53.3%)**	***p*-value (Chisq.)**	**Crude OR§ for consuming ≤ 1/day**	**95% CI§**
Short persistent *or* short increasing pattern (Girls = 11.4%)	16.7	83.4		1.08	0.51, 2.27	67.5^{A,B}	32.5^{A,B}		2.40*	1.34, 4.31
10-hour persistent pattern (Girls = 46.6%)	15.8	84.2	0.986	1.01	0.62, 1.64	42.0^{A}	58.0^{A}	0.006*	0.84	0.59, 1.20
11-hour persistent pattern (Girls = 42.0%) £	15.7	84.3		1.00	--	46.3^{B}	53.7^{B}		1.00	--
	FFQ: Milk products (times per day)					FFQ: Meat & alternatives (times per day)				
Longitudinal sleep duration pattern (2.5-6 years)	**% ≤ 1/day (12.4%)**	**% > 1/day (87.6%)**	***p*-value (Chisq.)**	**Crude OR§ for consuming ≤ 1/day**	**95% CI§**	**% ≤ 1/day (90.5%)**	**% > 1/day (9.5%)**	***p*-value (Chisq.)**	**Crude OR§ for consuming ≤ 1/day**	**95% CI§**
Short persistent *or* short increasing pattern (Girls = 11.4%)	29.0^{A,B}	71.0^{A,B}		3.30*	1.68, 6.50	85.6	14.4		0.64	0.28, 1.45
10-hour persistent pattern (Girls = 46.6%)	9.7^{A}	90.3^{A}	0.001*	0.86	0.48, 1.54	91.9	8.1	0.396‡	1.22	0.66, 2.26
11-hour persistent pattern (Girls = 42.0%) £	11.0^{B}	89.0^{B}		1.00	--	90.3	9.7		1.00	--
	General Q: Consumption of soft drinks (times per week)					General Q: Consumption of soft drinks (times per day)				
Longitudinal sleep duration pattern (2.5-6 years)	**% ≤ 3/week (91.5%)**	**% > 3/week (8.5%)**	***p*-value (Chisq.)**	**Crude OR§ for consuming > 3/week**	**95% CI§**	**% < 1/day (92.1%)**	**% ≥ 1/day (8.0%)**	***p*-value (Chisq.)**	**Crude OR§ for consuming > 1/day**	**95% CI§**
Short persistent *or* short increasing pattern (Girls = 11.4%)	73.0^{A,B}	27.0^{A,B}		4.79*	2.28, 10.05	73.0^{A,B}	27.0^{A,B}		5.35*	2.51, 11.43
10-hour persistent pattern (Girls = 46.6%)	94.8^{A}	5.2^{A}	<0.001*‡	0.72	0.34, 1.49	95.4^{A}	4.6^{A}	<0.001*‡	0.70	0.32, 1.53
11-hour persistent pattern (Girls = 42.0%) £	92.8^{B}	7.2^{B}		1.00	--	93.5^{B}	6.5^{B}		1.00	--

*Significant difference present within the group category (Chi-square, two-sided $p \leq 0.05$)

A B There is a significant difference (CHISQ $p \leq 0.05$) present in the food consumption group by longitudinal sleep duration pattern as marked by variable subgroups with the same superscript letter.

† Weighted

‡ Warning: ≥ 25% of the cells have an expected count less than 5. Chi-Square may not be a valid test.

§ OR, odds ratio; CI, confidence interval; £ Reference category

Source: *Data courtesy of the Quebec Institute of Statistics, QLSCD 1998-2010*

5.3.3 Longitudinal sleep duration pattern and eating behaviour

Bivariate associations between longitudinal sleep duration pattern from 2.5 to 6 years and three eating behaviours (picky eating, eating at irregular hours, and eating too much or too fast) at age 6 years, were also examined in both boys and girls through Chi-squared tests of independence (expressed as odds ratios, using logistic regression) (Table 11). In boys, longitudinal sleep duration pattern was significantly associated with 'eating at irregular hours' ($P = 0.001$) and 'eating too much or too fast' ($P = 0.007$), such that the crude odds ratios for boys who had a '*short persistent* or *short increasing*' pattern, or '*10-hour persistent*' pattern of longitudinal sleep duration were 6.81 (95% CI: 2.68, 17.34) and 2.60 (95% CI: 1.10, 6.13), respectively, for eating at irregular hours, and 2.78 (95% CI: 1.57, 4.90) and 1.54 (95% CI: 1.02, 2.32) for eating too much or too fast, in comparison to boys who had an '*11-hour persistent*' pattern of longitudinal sleep duration. No such association was found in girls; however, it is important to note that only very few girls were reported as eating at irregular hours, making Chi-squared tests of independence possibly invalid and unable to detect whether a true association exists between these variables for girls (please refer to footnotes of Table 11). The proportion of boys and girls for each eating behaviour group according to longitudinal sleep duration pattern is presented in Table 11, along with crude odds ratios (OR) and 95% confidence intervals (CI).

Table 11: Proportions†, crude odds ratios† and 95% confidence intervals for three eating behaviours according to longitudinal sleep duration pattern (2.5 to 6 years), in boys and girls at age 6 years.

	Eating Behaviour at age 6 years									
	BOYS					GIRLS				
	Picky Eater					Picky Eater				
Longitudinal sleep duration pattern (2.5-6 years)	% No (83.0%)	% Yes (17.0%)	*p*-value (Chisq.)	Crude OR§ for being a Picky Eater	95% CI§	% No (83.1%)	% Yes (16.9%)	*p*-value (Chisq.)	Crude OR§ for being a Picky Eater	95% CI§
Short persistent *or* short increasing pattern (Boys = 14.6%; Girls = 11.4%)	77.2	22.9		1.54	0.77, 3.06	80.8	19.2		0.98	0.49, 1.98
10-hour persistent pattern (Boys = 52.4%; Girls = 46.6%)	84.1	15.9	0.454	0.98	0.58, 1.67	86.0	14.0	0.333	0.68	0.42, 1.09
11-hour persistent pattern (Boys = 32.9%; Girls = 42.0%) £	83.8	16.2		1.00	--	80.5	19.5		1.00	--
	Eats at irregular hours					Eats at irregular hours				
Longitudinal sleep duration pattern (2.5-6 years)	% No (89.8%)	% Yes (10.2%)	*p*-value (Chisq.)	Crude OR§ for Eating at irregular hours	95% CI§	% No (91.5%)	% Yes (8.5%)	*p*-value (Chisq.)	Crude OR§ for Eating at irregular hours	95% CI§
Short persistent *or* short increasing pattern (Boys = 14.6%; Girls = 11.4%)	76.8 [A, B]	23.2 [A, B]		6.81*	2.68, 17.34	90.5	9.5		1.04	0.41, 2.68
10-hour persistent pattern (Boys = 52.4%; Girls = 46.6%)	89.7 [A, C]	10.3 [A, C]	0.001*	2.60*	1.10, 6.13	92.3	7.7	0.835‡	0.82	0.43, 1.55
11-hour persistent pattern (Boys = 32.9%; Girls = 42.0%) £	95.8 [B, C]	4.2 [B, C]		1.00	--	90.8	9.2		1.00	--
	Eats too much or too fast					Eats too much or too fast				
Longitudinal sleep duration pattern (2.5-6 years)	% No (60.4%)	% Yes (10.2%)	*p*-value (Chisq.)	Crude OR§ for Eating too much or too fast	95% CI§	% No (71.1%)	% Yes (29.0%)	*p*-value (Chisq.)	Crude OR§ for Eating too much or too fast	95% CI§
Short persistent *or* short increasing pattern (Boys = 14.6%; Girls = 11.4%)	44.7 [A, B]	55.3 [A, B]		2.78*	1.57, 4.90	72.0	28.0		1.11	0.60, 2.06
10-hour persistent pattern (Boys = 52.4%; Girls = 46.6%)	59.3 [A, C]	40.7 [A, C]	0.007*	1.54*	1.02, 2.32	68.1	31.9	0.432	1.34	0.91, 1.98
11-hour persistent pattern (Boys = 32.9%; Girls = 42.0%) £	69.1 [B, C]	30.9 [B, C]		1.00	--	74.1	25.9		1.00	--

*Significant difference present within the group category (Chi-square, two-sided $p \leq 0.05$)

[A, B, C] There is a significant difference (CHISQ $p \leq 0.05$) present in the eating behaviour group by longitudinal sleep duration pattern as marked by variable subgroups with the same superscript letter.

† Weighted

‡ Warning: ≥ 25% of the cells have an expected count less than 5. Chi-Square may not be a valid test.

§ OR, odds ratio; CI, confidence interval; £ Reference category

Source: *Data courtesy of the Quebec Institute of Statistics, QLSCD 1998-2010*

5.3.4 Dietary intake and overweight/obesity

Bivariate associations between dietary intake at age 6 years and overweight/obesity at age 6 and 7 years were also examined in both boys and girls through Chi-squared tests of independence (expressed as odds ratios, using logistic regression). In boys (Table 12), eating vegetables one or less times per day at age 6 years was significantly related to being overweight or obese at both age 6 and 7 years, at the 0.05 significance level. Eating fruits (only) one or less times per day at age 6 years also significantly related to being overweight at 6 years, but not at 7 years. The proportion of overweight/obese boys according to each food/beverage consumption group, along with crude odds ratios (OR) and 95% confidence intervals (CI), is presented in Table 12.

Table 12: Proportions†, crude odds ratios† and 95% confidence intervals for being overweight/obese at age 6 and 7 years according to the frequency of consumption of various foods/beverages at age 6 years, in boys.

	BOYS									
	Overweight or obese at age 6 years					Overweight or obese at age 7 years				
Dietary intake: Frequency of consumption of various foods & beverages at age 6 years	% Not overweight or obese (84.1%)	% Overweight or obese (15.9%)	*p*-value (Chisq.)	Crude OR§ for being overweight or obese	95% CI§	% Not overweight or obese (85.2%)	% Overweight or obese (14.8%)	*p*-value (Chisq.)	Crude OR§ for being overweight or obese	95% CI§
FFQ: Bread and grains (times per day)										
≤ 1/day (Boys= 31.0% at age 6years; 31.4% at age 7 years)	83.7	16.3	0.875	1.05	0.63, 1.76	82.9	17.1	0.421	1.29	0.75, 2.23
> 1/day (Boys= 69.0% at age 6years; 68.6% at age 7 years) £	84.3	15.7		1.00	–	86.2	13.8		1.00	–
FFQ: Vegetables (times per day)										
≤1/day (Boys= 56.2% at age 6years; 54.8% at age 7 years)	80.4	19.7	0.022*	1.98*	1.18, 3.31	80.7	19.3	0.010*	2.31*	1.31, 4.09
> 1/day (Boys= 43.8% at age 6years; 45.2% at age 7 years) £	89.0	11.0		1.00	–	90.6	9.4		1.00	–
FFQ: Fruits and fruit juices (times per day)										
≤ 1/day (Boys= 14.0% at age 6years; 13.6% at age 7 years)	83.0	17.0	0.809	1.10	0.56, 2.17	87.7	12.3	0.605	0.78	0.35, 1.77
> 1/day (Boys= 86.0% at age 6years; 86.4% at age 7 years) £	84.3	15.7		1.00	–	84.8	15.2		1.00	–
FFQ: Fruits (only) (times per day)										
≤1/day (Boys= 52.0% at age 6years; 49.8% at age 7 years)	80.5	19.6	0.040*	1.80*	1.10, 2.97	83.2	16.8	0.288	1.48	0.82, 2.34
> 1/day (Boys= 48.0% at age 6years; 50.2% at age 7 years) £	88.1	11.9		1.00	–	87.2	12.8		1.00	–
FFQ: Milk products (times per day)										
≤ 1/day (Boys= 15.5% at age 6years; 14.6% at age 7 years)	83.5	16.5	0.878	1.06	0.55, 2.04	89.4	10.6	0.361	0.64	0.28, 1.48
> 1/day (Boys= 84.5% at age 6years; 85.4% at age 7 years) £	84.3	15.7		1.00	–	84.5	15.5		1.00	–
FFQ: Meat & alternatives (times per day)										
≤1/day (Boys= 89.3% at age 6years; 90.5% at age 7 years)	84.0	16.1	0.779	1.14	0.51, 2.55	85.5	14.6	0.684‡	0.82	0.35, 1.90
> 1/day (Boys= 10.7% at age 6years; 9.5% at age 7 years) £	85.7	14.4		1.00	–	82.8	17.2		1.00	–

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Table 12 (*continued*)

	BOYS									
	Overweight or obese at age 6 years					Overweight or obese at age 7 years				
Dietary intake: Frequency of consumption of various foods & beverages at age 6 years	% Not overweight or obese (84.1%)	% Overweight or obese (15.9%)	*p*-value (Chisq.)	Crude OR§ for being overweight or obese	95% CI§	% Not overweight or obese (85.2%)	% Overweight or obese (14.8%)	*p*-value (Chisq.)	Crude OR§ for being overweight or obese	95% CI§
General Q: Consumption of soft drinks (times per week)										
≤3/week (Boys= 95.3% at age 6years; 94.8% at age 7 years) £	84.0	16.0	0.712‡	1.00	--	85.6	14.5	0.426‡	1.00	–
>3/week (Boys= 4.7% at age 6years; 5.2% at age 7 years)	87.2	12.8		0.77	0.22, 2.64	78.7	21.3		1.61	0.57, 4.50
General Q: Consumption of soft drinks (times per day)										
<1/day (Boys= 95.6% at age 6years; 95.2% at age 7 years) £	84.0	16.0	0.807‡	1.00	--	85.6	14.4	0.341‡	1.00	–
≥1/day (Boys= 4.4% at age 6years; 4.8% at age 7 years)	86.3	13.7		0.84	0.24, 2.90	77.1	22.9		1.77	0.62, 5.01

*Significant difference present within the group category (Chi-square, two-sided $p \leq 0.05$)
† Weighted
‡ Warning: ≥ 25% of the cells have an expected count less than 5. Chi-Square may not be a valid test.
§ OR, odds ratio; CI, confidence interval
£ Reference category
Source: *Data courtesy of the Quebec Institute of Statistics, QLSCD 1998-2010*

At the bivariate level, the prevalence of overweight/obesity at age 6 years was also significantly higher in girls who consumed vegetables one or less times per day at age 6 years, at the 0.05 significance level (Table 13); however, this association was not maintained to age 7 years. No other dietary intake variables were found to associate with overweight/obesity at either age 6 or 7 years in girls through Chi-squared tests of independence. The proportion of overweight/obese girls according to each food/beverage consumption group, along with crude odds ratios (OR) and 95% confidence intervals (CI), is presented in Table 13.

Table 13: Proportions†, crude odds ratios† and 95% confidence intervals for being overweight/obese at age 6 and 7 years according to the frequency of consumption of various foods/beverages at age 6 years, in girls.

	GIRLS									
	Overweight or obese at age 6 years					Overweight or obese at age 7 years				
Dietary intake: Frequency of consumption of various foods & beverages at age 6 years	% Not overweight or obese (84.4%)	% Overweight or obese (15.6%)	*p*-value (Chisq.)	Crude OR§ for being overweight or obese	95% CI§	% Not overweight or obese (82.6%)	% Overweight or obese (17.4%)	*p*-value (Chisq.)	Crude OR§ for being overweight or obese	95% CI§
FFQ: Bread and grains (times per day)										
≤ 1/day (Girls= 34.8% at age 6years; 35.6% at age 7 years)	84.6	15.4	0.937	0.98	0.61, 1.58	85.8	14.2	0.210	0.70	0.43, 1.14
> 1/day (Girls= 65.2% at age 6years; 64.4% at age 7 years) £	84.3	15.7		1.00	--	80.9	19.1		1.00	--
FFQ: Vegetables (times per day)										
≤1/day (Girls= 46.7% at age 6years; 45.4% at age 7 years)	80.2	19.8	0.025*	1.82*	1.15, 2.90	80.3	19.7	0.261	1.34	0.86, 2.10
> 1/day (Girls= 53.3% at age 6years; 54.6% at age 7 years) £	88.1	11.9		1.00	--	84.5	15.5		1.00	--
FFQ: Fruits and fruit juices (times per day)										
≤ 1/day (Girls= 15.8% at age 6years; 16.6% at age 7 years)	85.1	14.9	0.856	0.94	0.50, 1.77	80.1	19.9	0.549	1.22	0.69, 2.18
> 1/day (Girls= 84.2% at age 6years; 83.4% at age 7 years) £	84.3	15.7		1.00	--	83.12	16.9		1.00	--
FFQ: Fruits (only) (times per day)										
≤1/day (Girls= 46.7% at age 6years; 47.4% at age 7 years)	82.6	17.4	0.332	1.29	0.82, 2.04	79.7	20.4	0.131	1.48	0.95, 2.32
> 1/day (Girls= 53.3% at age 6years; 52.6% at age 7 years) £	86.0	14.0		1.00	--	85.3	14.7		1.00	--
FFQ: Milk products (times per day)										
≤ 1/day (Girls= 12.4% at age 6years; 11.5% at age 7 years)	92.6	7.4	0.077	0.40	0.16, 1.00	92.0	8.0	0.069	0.38*	0.15, 0.98
> 1/day (Girls= 87.6% at age 6years; 88.5% at age 7 years) £	83.2	16.8		1.00	--	81.4	18.6		1.00	--
FFQ: Meat & alternatives (times per day)										
≤1/day (Girls= 90.5% at age 6years; 91.0% at age 7 years)	84.0	16.0	0.461	1.45	0.61, 3.47	82.6	17.4	0.913	1.05	0.48, 2.32
> 1/day (Girls= 9.5% at age 6years; 9.0% at age 7 years) £	88.4	11.6		1.00	--	83.3	16.7		1.00	--

(continued on next page)

Table 13 (*continued*)

	GIRLS									
	Overweight or obese at age 6 years					Overweight or obese at age 7 years				
Dietary intake: Frequency of consumption of various foods & beverages at age 6 years	% Not overweight or obese (84.4%)	% Overweight or obese (15.6%)	*p*-value (Chisq.)	Crude OR§ for being overweight or obese	95% CI§	% Not overweight or obese (82.6%)	% Overweight or obese (17.4%)	*p*-value (Chisq.)	Crude OR§ for being overweight or obese	95% CI§
General Q: Consumption of soft drinks (times per week)										
≤3/week (Girls= 91.5% at age 6years; 91.8% at age 7 years) £	85.0	15.1	0.300	1.00	--	83.0	17.0	0.462	1.00	–
>3/week (Girls= 8.5% at age 6years; 8.2% at age 7 years)	78.5	21.5		1.55	0.75, 3.22	78.0	22.0		1.38	0.65, 2.92
General Q: Consumption of soft drinks (times per day)										
<1/day (Girls= 92.1% at age 6years; 92.4% at age 7 years) £	85.1	15.0	0.207	1.00	--	83.2	16.9	0.326	1.00	–
≥1/day (Girls= 8.0% at age 6years; 7.6% at age 7 years)	76.9	23.1		1.71	0.82, 3.58	76.2	23.8		1.54	0.72, 3.29

*Significant difference present within the group category (Chi-square, two-sided $p \leq 0.05$)
† Weighted
§ OR, odds ratio; CI, confidence interval
£ Reference category
Source: *Data courtesy of the Quebec Institute of Statistics, QLSCD 1998-2010*

5.3.5 Eating behaviour and overweight/obesity

Chi-squared tests of independence (expressed as odds ratios, using logistic regression) were used to examine the bivariate associations between three eating behaviours (picky eating, eating at irregular hours, and eating too much or too fast) at age 6 years and overweight/obesity at age 6 and 7 years, in both boys and girls.

Table 14 presents the proportion of overweight/obese boys at age 6 and 7 years according to each eating behaviour monitored at age 6 years, along with crude odds ratios (OR) and 95% confidence intervals (CI). It can be seen that boys who were reported to 'eat at irregular hours' at age 6 years were significantly more likely to be overweight or obese at age 6 years ($P = 0.002$), but not at 7 years ($P = 0.099$), at the bivariate level. However, 'eating too much or too fast' at age 6 years was significantly related to overweight/obesity in boys at both age 6 and 7 years, at the 0.05 significance level.

Table 14: Proportions†, crude odds ratios† and 95% confidence intervals for being overweight/obese at age 6 and 7 years according to the three eating behaviours at age 6 years, in boys.

	BOYS									
	Overweight or obese at age 6 years					Overweight or obese at age 7 years				
Eating Behaviour at age 6 years	% Not overweight or obese (84.1%)	% Overweight or obese (15.9%)	*p*-value (Chisq.)	Crude OR§ for being overweight or obese	95% CI§	% Not overweight or obese (85.2%)	% Overweight or obese (14.8%)	*p*-value (Chisq.)	Crude OR§ for being overweight or obese	95% CI§
Picky Eater										
No (Boys= 83.0% at age 6years; 82.7% at age 7 years) £	83.6	16.4	0.547	1.00	--	84.3	15.7	0.322	1.00	--
Yes (Boys= 17.0% at age 6years; 17.3% at age 7 years)	86.6	13.4		0.79	0.40, 1.55	89.3	10.7		0.64	0.30, 1.39
Eats at irregular hours										
No (Boys= 89.8% at age 6years; 90.3% at age 7 years) £	86.1	13.9	0.002*	1.00	--	86.2	13.8	0.099‡	1.00	--
Yes (Boys= 10.2% at age 6years; 9.8% at age 7 years)	67.0	33.1		3.06*	1.61, 5.81	75.6	24.4		2.02	0.96, 4.27
Eats too much or too fast										
No (Boys= 60.4% at age 6years; 61.1% at age 7 years) £	92.5	7.5	<0.001*	1.00	--	92.5	7.5	<0.001*	1.00	--
Yes (Boys= 39.6% at age 6years; 38.9% at age 7 years)	71.4	28.6		4.90*	2.89, 8.30	73.7	26.3		4.43*	2.52, 7.78

*Significant difference present within the group category (Chi-square, two-sided $p \leq 0.05$)

† Weighted

‡ Warning: ≥ 25% of the cells have an expected count less than 5. Chi-Square may not be a valid test.

§ OR, odds ratio; CI, confidence interval

£ Reference category

Source: *Data courtesy of the Quebec Institute of Statistics, QLSCD 1998-2010*

In girls (Table 15), bivariate analyses revealed that both 'eating at irregular hours' and 'eating too much or too fast' at age 6 years were significantly related to body mass index at both age 6 and 7 years, at the 0.05 significance level; however, conversely to boys, girls reported to 'eat at irregular hours' were *less* likely to be overweight or obese at age 6 and 7 years. The direction of the relationship between 'eating too much or too fast' and overweight/obesity in girls remained similar to that found in boys, such that 'eating too much or too fast' at age 6 years was positively related to being overweight or obese at both age 6 and 7 years, at the 0.05 significance level. Table 15 presents the proportion of overweight/obese girls at age 6 and 7 years according to each eating behaviour monitored at age 6 years, along with crude odds ratios (OR) and 95% confidence intervals (CI).

Table 15: Proportions†, crude odds ratios† and 95% confidence intervals for being overweight/obese at age 6 and 7 years according to the three eating behaviours at age 6 years, in girls.

	GIRLS									
	Overweight or obese at age 6 years					Overweight or obese at age 7 years				
Eating Behaviour at age 6 years	% Not overweight or obese (84.4%)	% Overweight or obese (15.6%)	*p*-value (Chisq.)	Crude OR§ for being overweight or obese	95% CI§	% Not overweight or obese (82.6%)	% Overweight or obese (17.4%)	*p*-value (Chisq.)	Crude OR§ for being overweight or obese	95% CI§
Picky Eater										
No (Girls= 83.1% at age 6years; 84.1% at age 7 years) £	83.6	16.4	0.547	1.00	–	82.6	17.4	0.993	1.00	--
Yes (Girls= 16.9% at age 6years; 15.9% at age 7 years)	86.6	13.4		1.01	0.55, 1.86	82.7	17.3		1.00	0.54, 1.84
Eats at irregular hours										
No (Girls= 91.5% at age 6years; 91.1% at age 7 years) £	86.1	13.9	0.002*	1.00	–	81.4	18.7	0.030*	1.00	--
Yes (Girls= 8.5% at age 6years; 9.0% at age 7 years)	67.0	33.1		0.63	0.25, 1.63	95.6	4.4		0.20*	0.05, 0.82
Eats too much or too fast										
No (Girls= 71.1% at age 6years; 71.5% at age 7 years) £	92.5	7.5	<0.001*	1.00	–	87.3	12.7	<0.001*	1.00	--
Yes (Girls= 29.0% at age 6years; 28.5% at age 7 years)	71.4	28.6		3.09*	1.93, 4.94	70.8	29.2		2.84*	1.79, 4.50

*Significant difference present within the group category (Chi-square, two-sided $p \leq 0.05$)

† Weighted

§ OR, odds ratio; CI, confidence interval

£ Reference category

Source: *Data courtesy of the Quebec Institute of Statistics, QLSCD 1998-2010*

5.4 *Bivariate associations between covariates and the main study variables*

As an association between longitudinal sleep duration pattern and overweight/obesity was not found in girls at either age 6 or 7 years at the bivariate level, the covariate selection process for multivariate analyses was restricted to associations present among boys included in analyses to age 6 and 7 years. For this reason, the following sections on covariate associations with the main study variables will present data pertaining only to boys included in analyses to age 6 and 7 years.

5.4.1 Association between longitudinal sleep duration pattern and covariates in boys

Chi-squared tests of independence were used to examine the bivariate associations between longitudinal sleep duration pattern (2.5 to 6 years) and all covariates in boys, at both age 6 and 7 years. Table 16 presents the group proportions of all significant covariates across the three longitudinal sleep duration patterns in the samples studied to age 6 and 7 years. Results showed that, in the sample included in analyses to age 6 years, longitudinal sleep duration pattern was significantly associated with: the child having a 'premature birth status' (P=0.002), being 'born premature *or* with low birth weight' (P=0.002), 'mother's perception of the child's general health status' (P=0.015), the child 'snoring at night' (P=0.027), mother's 'immigrant status' (P<0.001), and 'family experience of food insufficiency' (P=0.002). However, it is important to note that, due to low cell counts, Chi-square tests for covariate associations with 'mother's immigrant status' and 'family experience of food insufficiency' may not accurately reflect a true statistical association with longitudinal sleep duration pattern in boys at age 6 years (see footnotes of Table 16).

In the sample followed to age 7 years, longitudinal sleep duration pattern remained associated with having a 'premature birth status' (P=0.002), being 'born premature *or* with low birth weight' (*P*=0.001), 'mother's perception of the child's general health status' (*P*=0.038), and mother's 'immigrant status' (*P*=0.004). Again, it is important to note that, due to low cell counts, the Chi-square test for the covariate association with 'mother's immigrant status' may not accurately reflect a true statistical association with longitudinal sleep duration pattern in boys at age 6 years (see footnotes of Table 16).

Table 16: Covariates significantly* related to longitudinal sleep duration pattern (2.5-6 years) in boys followed to age 6 and 7 years – Group percentages

Variable	Boys included in analyses to age 6 years — Longitudinal sleep duration pattern (average sleep at night from age 2.5 to 6yrs)			Boys included in analyses to age 7 years — Longitudinal sleep duration pattern (average sleep at night from age 2.5 to 6yrs)		
	% Short persistent *or* short increasing pattern (14.6%)	% 10-hour persistent pattern (52.4%)	% 11-hour persistent pattern (32.9%)	% Short persistent *or* short increasing pattern (13.1%)	% 10-hour persistent pattern (53.1%)	% 11-hour persistent pattern (33.9%)
Child / Birth Characteristics						
Premature birth status (<37 weeks)						
No	12.8	53.9	33.3	11.2	54.4	34.4
Yes (born premature)	36.5	35.2	28.3	36.2	36.7	27.2
Born premature (<37 weeks) or with low birth weight (<2.5 kg)						
No	12.7	53.9	33.5	11.0	54.5	34.5
Yes (born premature *or* with low birth weight)	34.5	38.2	27.3	35.0	38.2	26.8
Mother's perception of the child's general health status at age 6 years						
Excellent	12.6	54.7	32.7	11.2	54.8	34.0
Very good	11.9	51.3	36.8	11.3	52.5	36.3
Good / Satisfactory/ Poor	32.0	42.2	25.9	30.8	42.9	26.3
Snores at night at age 6 years						
Never/Sometimes	12.7	54.8	32.5	--	--	--
Always/Often	31.5	37.1	31.4	--	--	--
Missing	14.3	44.9	40.8	--	--	--
Parent Characteristics						
Mother's immigrant status (Is the mother an immigrant?)						
No (not an immigrant)	11.9	51.7	36.4‡	11.1	52.3	36.6‡
Yes (an immigrant)	30.9	57.5	11.7	29.4	60.1	10.5
Missing	34.1	27.6	38.3	31.4	28.8	39.9
Family Demographic and Socio-economic Characteristics						
The family experienced food insufficiency (when the child was either 17 months or 4.5 years old)						
No (did not experience food insufficiency)	12.6	53.7	33.7‡	--	--	--
Yes (experienced food insufficiency)	40.1	38.5	21.3	--	--	--
Missing	0.0	0.0	100.0	--	--	--

*Significant difference present within the group categories (Chi-square, two-sided $p \leq 0.05$)
† Weighted; ‡ Warning: ≥ 25% of the cells have an expected count less than 5. Chi-Square may not be a valid test.
Source: *Data courtesy of the Quebec Institute of Statistics, QLSCD 1998-2010*

5.4.2 Association between overweight/obesity and covariates in boys

Bivariate associations between overweight/obesity in boys at age 6 and 7 years and each covariates were assessed through Chi-squared tests of independence (Table 17). In the sample examined to age 6 years, analyses showed that 'mother's perception of the child's general health status at age 6 years' ($P < 0.001$), 'child classified as overweight/obese at age 2.5 years' ($P = 0.001$), 'mother's level of education' ($P = 0.033$), 'mother's immigrant status' ($P < 0.001$), 'mother classified as overweight or obese when the child was 17 months old' ($P = 0.013$), 'family experience of food insufficiency when the child was either 17 months or 4.5 years old' ($P = 0.010$), and 'household income' ($P = 0.005$) were all significantly related to the prevalence of overweight/obesity in boys at age 6 years. However, it is important to note that, due to low cell counts, Chi-square tests for covariate associations with 'mother's immigrant status', 'mother classified as overweight or obese when the child was 17 months old', and 'family experience of food insufficiency when the child was either 17 months or 4.5 years old' may not accurately reflect a true statistical association with overweight/obesity in boys at age 6 years (see footnotes of Table 17).

In the sample of boys retained for analyses to age 7 years, covariates including 'child classified as overweight/obese at age 2.5 years' ($P = 0.004$), 'mother's age (when the child was 6 years old)' ($P = 0.044$), 'mother's immigrant status' ($P = 0.010$), and 'mother classified as overweight or obese when the child was 17 months old' ($P = 0.046$) also remained significantly related to the prevalence of overweight/obesity in boys at age 7 years. Again, however, Chi-square tests for associations with 'mother's immigrant status' and 'mother classified as overweight or obese when the child was 17 months old' may not be valid due to low cell counts (see footnotes of Table 17). The prevalence of overweight/obesity in boys at age 6 and 7 years by each significant covariate is presented in Table 17.

Table 17: Covariates significantly* related to overweight/obesity in boys at age 6 and 7 years – Group percentages

	Boys included in analyses to age 6 years		Boys included in analyses to age 7 years	
	Overweight or obese at age 6 years		Overweight or obese at age 7 years	
Variable	% Not overweight or obese (84.1%)	% Overweight or obese (15.9%)	% Not overweight or obese (85.2%)	% Overweight or obese (14.8%)
Child / Birth Characteristics				
Mother's perception of the child's general health status at age 6 years				
Excellent	84.9	15.1	--	--
Very good	91.2	8.8	--	--
Good / Satisfactory/ Poor	64.5	35.5	--	--
Overweight or obese at age 2.5 years				
No	87.8	12.2	88.1	11.9
Yes (overweight or obese at 2.5 years)	69.2	30.8	71.1	28.9
Missing	80.4	19.6	87.7	12.3
Parent Characteristics				
Mother's age (when the child was 6 years old)				
29 years or less	--	--	86.3	13.7
30-34 years	--	--	86.9	13.1
35-39 years	--	--	79.2	20.8
40 + years	--	--	93.7	6.3
Missing	--	--	31.4	68.6
Mother's level of education (highest diploma obtained when the child was 6 years old)				
No Secondary school diploma	71.4	28.6	--	--
Secondary school diploma	81.7	18.3	--	--
College or professional school diploma	85.6	14.4	--	--
University diploma	89.6	10.4	--	--
Missing	38.3	61.7	--	--
Mother's immigrant status (Is the mother an immigrant?)				
No (not an immigrant)	87.5	12.5‡	87.0	13.0‡
Yes (an immigrant)	64.7	35.4	71.5	28.5
Missing	38.3	61.7	31.4	68.6
Mother overweight or obese (BMI≥ 25 kg/m²) when the child was 17 months old				
No (not overweight/obese)	87.6	12.4‡	88.0	12.0‡
Yes (overweight/ obese)	75.3	24.7	79.1	20.9
Missing	79.5	20.5	56.2	43.8
Family Demographic and Socio-economic Characteristics				
The family experienced food insufficiency (when the child was either 17 months or 4.5 years old)				
No (did not experience food insufficiency)	85.7	14.3‡	--	--
Yes (experienced food insufficiency)	64.2	35.8	--	--
Missing	100.0	0.0	--	--
Household income				
Less than $30,000	69.3	30.7	--	--
$30,000 - $49,999	92.2	7.8	--	--
$50,000 - $79,999	81.4	18.6	--	--
$80,000 or more	87.7	12.3	--	--
Missing	71.8	28.2	--	--

*Significant difference present within the group categories (Chi-square, two-sided $p \leq 0.05$)
† Weighted; ‡ Warning: ≥ 25% of the cells have an expected count less than 5. Chi-Square may not be a valid test.
Source: *Data courtesy of the Quebec Institute of Statistics, QLSCD 1998-2010*

5.4.3 Association between dietary intake and covariates in boys

In bivariate analyses described in section 5.3, it was seen that only two dietary intake variables, 'consumption of vegetables per day' and 'consumption of fruits (only) per day', were significantly related to *both* longitudinal sleep duration pattern and overweight/obesity in boys at 6 years. Furthermore, only 'consumption of vegetables per day' remained significantly related *both* to longitudinal sleep duration pattern and overweight/obesity in boys at age 7 years. Thus, as only these two dietary intake variables met the criteria of 'potential mediators' previously specified for inclusion in multivariate analyses, this section will only present covariate associations with these two mentioned dietary intake variables for the sample of boys included to age 6 years, and only associations with 'consumption of vegetables per day' in the sample of boys included in analyses at age 7 years. Table 18 presents the group proportions of boys in each dietary intake consumption group according to each significant covariate; group proportions are presented for the sample included in analyses at age 6 years and the sample analyzed to age 7 years.

Chi-squared tests of independence revealed that, in the sample of boys followed to age 6 years, the 'consumption of vegetables per day' was significantly related to 'breastfeeding practices (partial or exclusive) in the first 4 months of life' (P=0.009), 'mother's level of education' (P=0.001), 'mother's immigrant status' (P<0.001), 'family experience of food insufficiency' (P=0.002), and 'household income' (P= 0.040). In the sample followed to age 7 years, the 'consumption of vegetables per day' remained significantly associated with 'breastfeeding practices (partial or exclusive) in the first 4 months of life' (P=0.007), 'mother's level of education' (P=0.007), 'mother's immigrant status' (P=0.006), and 'family experience of food insufficiency' (P=0.006). Due to low cell counts, however, it must be noted that Chi-squared tests may not accurately reflect a valid association between the 'consumption of vegetables per day' and the covariates: 'mother's immigrant status' and 'family experience of food insufficiency', in boys both at age 6 and 7 years (see footnotes of Table 18).

In the sample of boys analyzed to age 6 years, the 'consumption of fruits (only) per day' was significantly associated only with 'mother's perception of the child's general health status' (*P*=0.024) and 'mother's level of education' (*P*=0.009). As this dietary intake variable would not be included in final multivariate models at age 7 years, associations with covariates in the sample followed to age 7 years are not presented.

Table 18: Covariates significantly* related to the 'consumption of vegetables per day' and the 'consumption of fruits (only) per day' in boys followed to age 6 and 7 years – Group percentages

Variable	Boys included in analyses to age 6 years				Boys included in analyses to age 7 years	
	Consumption of Vegetables (times per day) at age 6 years		Consumption of Fruits (only) (times per day) at age 6 years		Consumption of Vegetables (times per day) at age 6 years	
	% ≤ 1/day (56.2%)	% > 1/day (43.8%)	% ≤ 1/day (52.0%)	% > 1/day (48.0%)	% ≤ 1/day (54.8%)	% > 1/day (45.2%)
Child / Birth Characteristics						
Breastfed (partial or exclusive) for first 4 months						
Never breastfed	66.9	33.1	--	--	64.4	35.6
Breastfed < 4 months	80.5	39.5	--	--	61.0	39.0
Breastfed 4 of more months	48.6	51.4	--	--	45.9	54.1
Mother's perception of the child's general health status at age 6 years						
Excellent	--	--	47.3	52.8	--	--
Very good	--	--	57.2	42.8	--	--
Good / Satisfactory/ Poor	--	--	67.6	32.4	--	--
Parent Characteristics						
Mother's level of education (highest diploma obtained when the child was 6 years old)						
No Secondary school diploma	78.1	21.9	75.3	24.7	71.5	28.5
Secondary school diploma	63.3	36.7	53.3	46.7	62.9	37.1
College or professional school diploma	55.8	44.3	49.4	50.6	55.7	44.3
University diploma	42.8	57.2	44.7	55.3	40.9	59.1
Missing	72.4	27.6	100.0	0.0	71.3	28.8
Mother's immigrant status (Is the mother an immigrant?)						
No (not an immigrant)	51.7	48.3‡	--	--	51.8	48.2‡
Yes (an immigrant)	83.7	16.3	--	--	79.8	20.2
Missing	72.4	27.6	--	--	71.3	28.8
Family Demographic and Socio-economic Characteristics						
The family experienced food insufficiency (when the child was either 17 months or 4.5 years old)						
No (did not experience food insufficiency)	53.9	46.1‡	--	--	52.6	47.4‡
Yes (experienced food insufficiency)	86.7	13.3	--	--	83.7	16.3
Missing	0.0	100.0	--	--	0.0	100.0
Household income						
Less than $30,000	71.8	28.2	--	--	--	--
$30,000 - $49,999	62.6	37.4	--	--	--	--
$50,000 - $79,999	52.2	47.8	--	--	--	--
$80,000 or more	49.0	51.0	--	--	--	--
Missing	59.4	40.6	--	--	--	--

*Significant difference present within the group categories (Chi-square, two-sided $p \leq 0.05$)
† Weighted
‡ Warning: ≥ 25% of the cells have an expected count less than 5. Chi-Square may not be a valid test.
Source: *Data courtesy of the Quebec Institute of Statistics, QLSCD 1998-2010*

5.4.4 Association between eating behaviour and covariates in boys

Previous bivariate analyses with the main study variables (presented in section 5.3) also revealed that only two eating behaviour variables ('eating at irregular hours' and 'eating too much or too fast') met the criteria for inclusion in multivariate analyses as 'potential mediators' to the main association between longitudinal sleep duration pattern and overweight/obesity in boys at age 6. Furthermore, only one of these eating behaviours ('eating too much or too fast') met this criteria in boys in analyses at age 7 years. For this reason, this section will review covariate associations only in relation to these two mentioned eating behaviour variables.

Table 19 presents the group proportions for covariates significantly related to 'eating at irregular hours' and 'eating too much or too fast', in the sample of boys followed to age 6 and 7 years. In boys examined to age 6 years, 'eating at irregular hours' was significantly associated with 'mother's perception of the child's general health status' (P<0.001), the child having a 'chronic illness' (P<0.001), the child 'snoring at night' (P=0.025), and 'family experience of food insufficiency' (P=0.002). However, once again, Chi-squared tests of the statistical association between the 'eating at irregular hours' and the covariates: 'child having a chronic illness', 'child snoring at night', and 'family experience of food insufficiency', may not be valid due to low cell counts (see footnotes of Table 19). As this eating behaviour variable is not retained for final multivariate models at age 7 years, covariate associations in the sample followed to age 7 years are not presented.

In boys included in analyses at age 6 years, 'eating too much or too fast' was found to associate with: the child 'snoring at night' (P=0.026), 'mother's immigrant status' (P<0.001), and 'family experience of food insufficiency (P=0.038); however, the Chi-squared associations found with the latter two covariates may not be valid due to low cell counts. In the sample of boys followed to age 7 years, 'eating too much or too fast' maintained a significant association with: the child 'snoring at night' (P=0.035), and 'mother's immigrant status' ($P<0.001$), and was also found to associate with 'household income' ($P=0.046$). Again, however, Chi-squared tests of the statistical association between 'eating too much or too fast' and the covariates: 'mother's immigrant status' found significant in boys both at age 6 and 7 years, and 'family experience of food insufficiency' found significant only at age 6 years, may not be a valid representation of a true association due to low cell counts (see footnotes of Table 19).

Table 19: Covariates significantly* related to the eating behaviours: 'eating at irregular hours' and 'eating too much or too fast', in boys followed to age 6 and 7 years – Group percentages

Variable	Boys included in analyses to age 6 years				Boys included in analyses to age 7 years	
	Eats at irregular hours		Eats too much or too fast		Eats too much or too fast	
	% No (89.8%)	% Yes (10.2%)	% No (60.4%)	% Yes (10.2%)	% No (61.1%)	% Yes (38.9%)
Child / Birth Characteristics						
Mother's perception of the child's general health status at age 6 years						
Excellent	92.5	7.5	--	--	--	--
Very good	93.4	6.6	--	--	--	--
Good / Satisfactory/ Poor	66.8	33.2	--	--	--	--
Chronic illness (excluding allergies, but including asthma) at age 6 years						
No	91.9	8.1‡	--	--	--	--
Yes (child has a chronic illness)	74.1	25.9	--	--	--	--
Snores at night at age 6 years						
Never/Sometimes	91.2	8.8‡	62.3	37.7	62.9	37.1
Always/Often	77.1	22.9	40.3	59.7	40.8	59.2
Missing	91.3	8.7	67.1	32.9	68.1	31.9
Parent Characteristics						
Mother's immigrant status (Is the mother an immigrant?)						
No (not an immigrant)	--	--	64.9	35.1‡	64.8	35.2‡
Yes (an immigrant)	--	--	32.5	67.5	29.5	70.5
Missing	--	--	72.4	27.6	71.3	28.8
Family Demographic and Socio-economic Characteristics						
The family experienced food insufficiency (when the child was either 17 months or 4.5 years old)						
No (did not experience food insufficiency)	91.3	8.7‡	62.2	37.8‡	--	--
Yes (experienced food insufficiency)	70.3	29.7	40.2	59.8	--	--
Missing	100.0	0.0	0.0	100.0	--	--
Household income						
Less than $30,000	--	--	--	--	62.2	37.8
$30,000 - $49,999	--	--	--	--	47.8	52.2
$50,000 - $79,999	--	--	--	--	62.0	38.0
$80,000 or more	--	--	--	--	69.6	30.5
Missing	--	--	--	--	45.4	54.6

*Significant difference present within the group categories (Chi-square, two-sided $p \leq 0.05$)
† Weighted
‡ Warning: ≥ 25% of the cells have an expected count less than 5. Chi-Square may not be a valid test.
Source: *Data courtesy of the Quebec Institute of Statistics, QLSCD 1998-2010*

5.4.5 Covariates retained for final multivariate analyses

Nine covariates met the criteria for inclusion in further multivariate analyses; these are: 'mother's perception of the child's general health status at age 6 years', 'child classified as overweight or obese at age 2.5 years', 'child snores at night at age 6 years', 'mother's age', 'mother's level of education', 'mother's immigrant status', 'mother classified as overweight or obese when the child was 17 months old', 'family experience of food insufficiency', and 'household income'. These were retained based on results presented in the previous sections on covariate associations with the main study variables, showing that these variables were either significantly related (Chi-squared, $P \leq 0.05$) to overweight/obesity in boys at age 6 and/or 7 years, or were significantly related to both: 1) longitudinal sleep duration pattern *and* overweight/obesity at age 6 or 7 years; or, 2) longitudinal sleep duration pattern *and* dietary intake/eating behaviour variables; or, 3) dietary intake/eating behaviour variables *and* overweight/obesity at age 6 or 7 years, in the sample of boys followed to age 6 and 7 years.

5.5 *Final multivariate models*

A set of multivariate logistic regression models was used to examine the association between longitudinal sleep duration pattern (from 2.5 to 6 years) and overweight/obesity in boys at both age 6 and 7 years, and to examine the potential mediating role of dietary intake and eating behaviour variables that met the criteria of 'potential mediators' to the main association in bivariate analyses. These multivariate models were examined with and without adjustments for covariates deemed to act as important risk-factors for overweight/obesity or important confounders to the main association.

Of the nine covariates retained from bivariate analyses with the main variables (see section 5.4.5), a final set of four covariates were narrowed through a stepwise selection approach applied to all final models at age 6 and 7 years. The four covariates retained for the final multivariate models included: 'child classified as overweight or obese at age 2.5 years', 'mother's immigrant status', 'mother classified as overweight or obese when the child was 17 months old', and 'household income'. All four of these covariates remained significantly related ($P \leq 0.05$) to overweight/obesity across all final models analyzed at age 6 years, and across all but the last model (Model 3, Table 21) examined at age 7 years.

No statistically significant interactions were found on a multiplicative scale between the main predictor variables (between longitudinal sleep duration pattern and dietary intake/eating behaviour variables) or between any of the four covariates and the main predictor variables at the $P \leq 0.01$ level, across any of the multivariate models examined at either age 6 or 7 years.

5.5.1 Final models at age 6 years

Table 20 presents a final set of six models explored to examine the strength of association between longitudinal sleep duration pattern from 2.5 to 6 years and overweight/obesity in boys at 6 years, with and without adjustment for a set list of covariates, and with and without adjustments for 'potentially mediating' dietary intake and eating behaviour variables. Unadjusted and adjusted odds ratios and 95% confidence intervals for overweight/obesity in boys at age 6 years, for the 6 models reviewed in this section, are also presented in Table 20. Data are presented for boys with no missing values on any of the covariates (n =474 boys at age 6 years), as only minor differences were found in the results when children with missing covariate values were included in the analyses; these differences will be discussed in Section 5.5.3.

A base model (Base Model 1, Table 20) of a regression of overweight/obesity in boys at age 6 years onto longitudinal sleep duration pattern (from 2.5 to 6 years), examined with and without adjustments for covariates, was used as a reference to compare the potential mediating role of dietary intake and eating behaviour variables included in all following models (Models 2 to 6, Table 20). In this base model, it can be seen that boys who had *'short persistent* or *short increasing'* ($P \leq 0.001$) and *'10-hour persistent'* ($P = 0.020$) longitudinal sleep duration patterns from 2.5 to 6 years were significantly more likely to be classified as overweight or obese at age 6 years in comparison to boys who had an *'11-hour persistent'* longitudinal sleep duration pattern, even after control for important covariates. The adjusted odds of being overweight or obese at 6 years of age was 5.26 (95% CI: 2.13, 13.02) for boys who had a *'short persistent* or *short increasing'* longitudinal sleep duration pattern and 2.49 (95% CI: 1.16, 5.37) for boys who had a *'10-hour persistent'* longitudinal sleep duration pattern in comparison to those who maintained an *'11-hour persistent'* longitudinal sleep duration pattern from 2.5 to 6 years of age.

In Model 2 (Table 20), 'frequency of consumption of vegetables (times per day)' in boys was added to the regression of overweight/obesity at age 6 years onto longitudinal sleep duration pattern (from 2.5 to 6 years), and was examined with and without adjustments for important covariates. In both the covariate-unadjusted and covariate-adjusted versions of this model, the frequency of consumption of vegetables per day was no longer significantly related to overweight or obesity in boys at 6 years of age (unadjusted $P = 0.098$; adjusted $P = 0.603$); thus, it was not found to mediate an association between longitudinal sleep duration pattern and overweight or obesity in boys at age 6 years. Similarly, the frequency of consumption of fruits (only) per day (Model 3, Table 20) was not found to act as a mediator to the association between longitudinal sleep duration pattern and overweight or obesity in boys at age 6 years, as it did not show a statistical association with overweight/obesity in either version of Model 3 (unadjusted $P = 0.183$; adjusted $P = 0.140$).

When the eating behaviour 'eating at irregular hours in the day' (Model 4, Table 20), was added to the base model of overweight/obesity at age 6 years onto longitudinal sleep duration pattern (from 2.5 to 6 years) in boys, it was found that this eating behaviour independently associated (adjusted $P = 0.038$) with overweight/obesity in boys at age 6 years, such that, after controlling for important covariates, boys who ate at irregular hours in the day had adjusted odds of 2.28 (95% CI: 1.05, 4.96) for being overweight or obese at age 6 years in comparison to boys who ate at regular hours in the day. Furthermore, with this eating behaviour variable included in the model, the strength of the association between longitudinal sleep duration pattern and overweight/obesity at age 6 years was reduced from that found in the base model, such that the beta estimate for boys with a *'short persistent* or *short increasing'* pattern of longitudinal sleep duration reduced by greater than 10%, from a beta of 1.660 (adjusted beta in Base Model) to a beta of 1.490 (adjusted beta in Model 4). For boys who had a *'10-hour persistent'* longitudinal sleep duration pattern, the strength of the association with overweight/obesity at age 6 years remained similar across both the Base Model and Model 4. Thus, 'eating at irregular hours in the day' appears to have partially mediated the association between longitudinal sleep duration and 'overweight/obesity' in boys who had a *'short persistent* or *short increasing'* pattern of longitudinal sleep duration, but not in boys who had a *'10-hour persistent'* pattern of longitudinal sleep duration from 2.5 to 6 years; this finding was maintained across both the covariate-unadjusted and covariate-adjusted versions of Model 4.

In Model 5 (Table 20), the eating behaviour variable 'eating too much *or* too fast' was added to the base model of overweight/obesity at age 6 years onto longitudinal sleep duration pattern (from 2.5 to 6 years) in boys. Results showed a highly significant and independent association between this eating behaviour variable (adjusted $P<0.001$) and overweight/obesity in boys at age 6 years, such that, after controlling for important covariates, boys who were reported as 'eating too much or too fast' had adjusted odds of 4.56 (95% CI: 2.38, 8.74) of being overweight or obese at age 6 years in comparison to boys who did not show this eating behaviour. Additionally, the inclusion of this variable in the model reduced the strength of the association between longitudinal sleep duration pattern in both boys who had a *'short persistent* or *short increasing'* pattern or *'10-hour persistent'* pattern of longitudinal sleep duration. For these two groups, greater than a 10% reduction in beta estimates was observed from the base models, such that the beta estimate for boys with a *'short persistent* or *short increasing'* pattern of longitudinal sleep duration reduced from a beta of 1.660 (adjusted beta in Base Model) to a beta of 1.460 (adjusted beta in Model 5), and the beta estimate for boys with a *'10-hour persistent'* pattern of longitudinal sleep duration reduced from a beta of 0.913 (adjusted beta in Base Model) to a beta of 0.810 (adjusted beta in Model 5). This finding suggests that 'eating too much or too fast' partially mediated the association between longitudinal sleep duration pattern and overweight/obesity at age 6 years in boys who had a *'short persistent* or *short increasing'* pattern of longitudinal sleep duration and in boys who had a *'10-hour persistent'* pattern of longitudinal sleep duration from 2.5 to 6 years. This finding was supported in both the covariate-unadjusted and covariate-adjusted versions of Model 5.

Due to the findings in Model 4 and Model 5, an additional model that contained both significant eating behaviour variables was explored. In this model (Model 6, Table 20), the variables 'eating at irregular hours in the day' and 'eating too much or too fast' were added simultaneously to the base regression of overweight/obesity at age 6 years onto longitudinal sleep duration pattern (from 2.5 to 6 years) in boys; this model was also explored with and without adjustments for important covariates. In both the covariate-unadjusted and covariate-adjusted versions of this model, 'eating at irregular hours in the day' (P=0.028) and 'eating too much *or* too fast' (P<0.001) remained independently, highly statistically related to overweight/obesity at age 6 years in boys. Furthermore, the strength of the association between longitudinal sleep duration pattern and overweight/obesity at age 6 years, in boys, was further reduced when these two eating behaviour variables were explored simultaneously in the model 6. For boys who had a *'short persistent* or *short increasing'* pattern of longitudinal sleep duration, the adjusted beta estimate for overweight/obesity at age 6 years reduced from 1.660 (adjusted OR: 5.26; 95% CI: 2.13, 13.02) in the Base Model to 1.274 (adjusted OR: 3.58; 95% CI: 1.37, 9.36) in the adjusted version of Model 6, showing over a 20% reduction in beta. Similarly, a 20% reduction in the beta estimate of boys who had a *'10-hour persistent'* pattern of longitudinal sleep duration was found in the covariate-unadjusted version of Model 6; however, in the covariate-adjusted version of this model, the reduction in the beta estimate was less than 20%, but still reduced more than 10% from the Base Model (Base Model adjusted beta = 0.913; OR: 2.49; 95% CI: 1.16, 5.37) to Model 6 (Model 6 adjusted beta = 0.774; OR: 2.17; 95% CI: 0.98, 4.82), making the association with overweight/obesity at age 6 years no longer significant for boys who had a '*10-hour persistent*' longitudinal sleep duration pattern. This finding suggests that, when both of the eating behaviour variables 'eating at irregular hours in the day' and 'eating too much or too fast' are considered together, these eating behaviours play an important role in mediating part of the association between longitudinal sleep duration pattern and overweight/obesity at age 6 years in both boys who have a *'short persistent* or *short increasing'* pattern of longitudinal sleep duration and in mediating the full association in boys who have a *'10-hour persistent'* pattern of longitudinal sleep duration from 2.5 to 6 years of age, after adjustments for important covariates.

Table 20: Unadjusted and adjusted† odds ratios£ and 95% confidence intervals for overweight/obesity in boys at 6 years of age, according to longitudinal sleep duration pattern (2.5 to 6 years) alone, or with adjustments for dietary intake and eating behaviour at 6 years of age.

	BOYS			
	Overweight *or* obese at 6 years (15.2%)			
Base Model 1: Longitudinal sleep duration pattern *only – Adjusted and unadjusted for potential confounders*				
Variable	**Unadjusted OR§**	**95% CI§**	**Adjusted for other covariates † OR**	**95% CI**
Longitudinal sleep duration pattern (average sleep at night from age 2.5 to 6yrs)				
Short persistent *or* short increasing pattern (13.9%)	5.41**	2.38, 12.33	5.26**	2.13, 13.02
10-hour persistent pattern (52.7%)	2.55*	1.26, 5.17	2.49*	1.16, 5.37
11-hour persistent pattern (33.4%) ‡	1.00	--	1.00	--
Model 2: Longitudinal sleep duration pattern and Vegetable consumption – *Adjusted and unadjusted for potential confounders*				
Variable	**Adjusted for the model's main variables only OR**	**95% CI**	**Adjusted for additional covariates † OR**	**95% CI**
Longitudinal sleep duration pattern (average sleep at night from age 2.5 to 6yrs)				
Short persistent *or* short increasing pattern (13.9%)	4.77**	2.07, 10.99	5.13**	2.06, 12.76
10-hour persistent pattern (52.7%)	2.55*	1.25, 5.17	2.52*	1.17, 5.44
11-hour persistent pattern (33.4%) ‡	1.00	--	1.00	--
FFQ: Vegetables (times per day)				
≤1/day (56.1%)	1.62	0.92, 2.86	1.18	0.63, 2.23
> 1/day (43.9%) ‡	1.00	--	1.00	--
Model 3: Longitudinal sleep duration pattern and Fruit consumption (excluding juices) – *Adjusted and unadjusted for potential confounders*				
Variable	**Adjusted for the model's main variables only OR**	**95% CI**	**Adjusted for additional covariates † OR**	**95% CI**
Longitudinal sleep duration pattern (average sleep at night from age 2.5 to 6yrs)				
Short persistent *or* short increasing pattern (13.9%)	5.06**	2.21, 11.59	5.16**	2.07, 12.88
10-hour persistent pattern (52.7%)	2.51*	1.24, 5.10	2.59*	1.19, 5.63
11-hour persistent pattern (33.4%) ‡	1.00	--	1.00	--
FFQ: Fruits (only) (times per day)				
≤1/day (51.3%)	1.44	0.84, 2.48	1.55	0.87, 2.77
> 1/day (48.7%) ‡	1.00	--	1.00	--

(continued on next page)

Table 20 (*Continued*)

	BOYS Overweight *or* obese at 6 years (15.2%)			
Model 4: Longitudinal sleep duration pattern and Eating Behaviour Pattern (Eats at irregular hours in the day) – *Adjusted and unadjusted for potential confounders*				
Variable	**Adjusted for the model's main variables only OR**	**95% CI**	**Adjusted for additional covariates † OR**	**95% CI**
Longitudinal sleep duration pattern (average sleep at night from age 2.5 to 6yrs)				
Short persistent *or* short increasing pattern (13.9%)	4.29**	1.83, 10.03	4.44*	1.76, 11.21
10-hour persistent pattern (52.7%)	2.35*	1.15, 4.79	2.42*	1.12, 5.24
11-hour persistent pattern (33.4%) ‡	1.00	--	1.00	--
Eats at irregular hours in the day				
No (88.9%)‡	1.00	--	1.00	--
Yes – Irregular eater (11.1%)	2.58*	1.30, 5.11	2.28*	1.05, 4.96
Model 5: Longitudinal sleep duration pattern and Eating Behaviour Pattern (Eats too much *or* too fast) – *Adjusted and unadjusted for potential confounders*				
Variable	**Adjusted for the model's main variables only OR**	**95% CI**	**Adjusted for additional covariates † OR**	**95% CI**
Longitudinal sleep duration pattern (average sleep at night from age 2.5 to 6yrs)				
Short persistent *or* short increasing pattern (13.9%)	4.37**	1.87, 10.20	4.31*	1.68, 11.05
10-hour persistent pattern (52.7%)	2.31*	1.12, 4.76	2.25*	1.02, 4.98
11-hour persistent pattern (33.4%) ‡	1.00	--	1.00	--
Eats too much or too fast				
No (59.6%)‡	1.00	--	1.00	--
Yes – Eats too much or too fast (40.4%)	3.98**	2.26, 7.04	4.56**	2.38, 8.74
Model 6: Longitudinal sleep duration pattern and *both* Eating Behaviour Patterns – *Adjusted and unadjusted for potential confounders*				
Variable	**Adjusted for the model's main variables only OR**	**95% CI**	**Adjusted for additional covariates † OR**	**95% CI**
Longitudinal sleep duration pattern (average sleep at night from age 2.5 to 6yrs)				
Short persistent *or* short increasing pattern (13.9%)	3.28*	1.36, 7.93	3.58*	1.37, 9.36
10-hour persistent pattern (52.7%)	2.08*	1.00, 4.33	2.17	0.98, 4.82
11-hour persistent pattern (33.4%) ‡	1.00	--	1.00	--
Eats at irregular hours in the day				
No (88.9%)‡	1.00	--	1.00	--
Yes – Irregular eater (11.1%)	3.05*	1.47, 6.32	2.51*	1.11, 5.71
Eats too much or too fast				
No (59.6%)‡	1.00	--	1.00	--
Yes – Eats too much or too fast (40.4%)	4.27**	2.39, 7.64	4.71**	2.44, 9.11

* Significantly different from the reference category (two-sided $p \leq 0.05$)
** Significantly different from the reference category (two-sided $p \leq 0.001$)
†Adjusted for all variables in the model as well and the following covariates: 'Child overweight *or* obese at 2.5yrs'; 'mother's immigrant status'; 'mother classified as overweight *or* obese'; and, 'household income'.
‡Reference category
§ OR, odds ratio; CI, confidence interval
£ Weighted.

Across all 6 models examined at age 6 years, all four covariates included in the adjusted versions of each model remained significantly related to overweight/obesity in boys at age 6 years at the 0.05 significance level. When looking particularly at Base Model 1 and Models 4, 5, and 6, where significant eating behaviour mediators were found, the odds for overweight/obesity at age 6 years were:

1) significantly *higher* among boys who were overweight or obese at 2.5 years of age (P<0.001 across Base Model 1 and Models 4-6) in comparison to those who were not, with odds for overweight/obesity at 6 years ranging from 3.75 (95% CI: 1.97, 7.13) in Model 4 to 4.58 (95% CI: 2.35, 8.95) in Model 5, in boys who were overweight or obese at 2.5 years of age;
2) significantly *higher* among boys who had immigrant mothers (P≤0.01 across Base Model 1 and Models 4-6) in comparison to boys whose mothers were not immigrants, with odds for overweight/obesity at 6 years ranging from 2.81 (95% CI: 1.28, 6.13) in Model 6 to 4.38 (95% CI: 2.13, 9.00) in Base Model 1, in boys who had immigrant mothers; and,
3) significantly *higher* among boys who had mothers who were overweight or obese when the child was 17 months old (P≤0.01 across Base Model 1 and Models 4-6) in comparison to boys whose mothers were not overweight or obese, with odds for overweight/obesity in boys at 6 years ranging from 2.44 (95% CI: 1.29, 4.62) in Model 5 to 3.00 (95% CI: 1.61, 5.59) in Model 4, in boys who had mothers who were overweight or obese.
4) significantly *lower* among boys who came from a family with a household income of $30,000 - $49,999 ($P$≤0.001 across Base Model 1 and Models 4-6) in comparison to boys whose family household income was less than $30,000, with odds ranging from 0.14 (95%CI: 0.05, 0.42) in Model 5 to 0.25 (95% CI: 0.09, 0.69) in Model 4.

5.5.2 Final models at age 7 years

Table 21 presents a set of three models explored to examine the strength of association between longitudinal sleep duration pattern from 2.5 to 6 years and overweight/obesity in boys at age 7 years, with and without adjustment for a set list of covariates, and with and without adjustments for 'potentially mediating' dietary intake and eating behaviour variables measured at 6 years of age. Unadjusted and adjusted odds ratios and 95% confidence intervals for overweight/obesity in boys at age 7 years, are also presented for the three models reviewed in this section (Table 21). Data are presented for boys with no missing values on any of the covariates (n =425 boys at age 7 years), as only minor differences were found in the results when children with missing covariate values were included in the analyses; these differences will be discussed in Section 5.5.3.

Firstly, a base model (Base Model 1, Table 21) of a regression of overweight/obesity in boys at age 7 years onto longitudinal sleep duration pattern (from 2.5 to 6 years), with and without adjustments for covariates (listed in the table footnotes), was examined and used as a reference to compare the potential mediating role of dietary intake and eating behaviour variables included in all following models. Through this base model, it was found that boys who had *'short persistent* or *short increasing'* (adjusted $P = 0.003$) longitudinal sleep duration patterns from 2.5 to 6 years were significantly more likely to be classified as overweight or obese at age 7 years in comparison to boys who had an *'11-hour persistent'* longitudinal sleep duration pattern, after control for important covariates; however, unlike the findings in analyses conducted at age 6 years (see Base Model at age 6 years), after control for important covariates, no association was found between boys who had a *'10-hour persistent'* pattern of longitudinal sleep duration pattern and overweight/obesity at age 7 years. The adjusted odds of being overweight or obese at 7 years of age was 4.16 (95% CI:

1.64, 10.54) for boys who had a *'short persistent* or *short increasing'* longitudinal sleep duration pattern in comparison to those who maintained an *'11-hour persistent'* longitudinal sleep duration pattern from 2.5 to 6 years of age.

In Model 2 (Table 21) , 'frequency of consumption of vegetables (times per day)' at age 6 years was added to a regression of overweight/obesity in boys at age 7 years onto longitudinal sleep duration pattern (from 2.5 to 6 years), and was explored with and without adjustments for important covariates. Unlike findings from analyses examined at age 6 years, when this dietary intake variable was included in the model, the 'frequency of consumption of vegetables per day' at age 6 years remained significantly (covariate-adjusted $P = 0.045$) and independently associated with overweight/obesity in boys at age 7 years, such that boys who ate vegetables one or less times per day had 1.96 increased odds (95%CI: 1.01, 3.80) of being overweight or obese at age 7 years, after control for important covariates. Despite this association, the findings do not suggest that 'frequency of consumption of vegetables per day' mediates an association between longitudinal sleep duration pattern and overweight/obesity at age 7 years as the reduction in the beta estimate of boys who had a *'short persistent* or *short increasing'* longitudinal sleep duration pattern remained within a 10% range of difference between the covariate-adjusted version of Base Model 1 (adjusted beta = 1.426) and the covariate-adjusted version of Model 2 (adjusted beta = 1.301).

The last model explored in multivariate analyses at age 7 years (Model 3, Table 21) included the eating behaviour variable 'eating too much *or* too fast' measured at age 6 years in a regression model of overweight/obesity at age 7 years onto longitudinal sleep duration from 2.5 to 6 years; this model was also examined with and without adjustments for important covariates.

As is seen in Table 21, when the eating behaviour variable ‘eating too much *or* too fast’ was added to the model (Model 3), results showed a highly significant and independent association between this eating behaviour variable (adjusted $P<0.001$) and overweight/obesity in boys at age 7 years, such that, after controlling for important covariates, boys who were reported as ‘eating too much or too fast’ had adjusted odds of 4.00 (95% CI: 2.07, 7.71) of being overweight or obese at age 7 years in comparison to boys who did not show this eating behaviour. Furthermore, the inclusion of this variable in the model reduced the strength of the association between longitudinal sleep duration pattern and overweight/obesity at 7 years in boys who had a *‘short persistent* or *short increasing’* pattern of longitudinal sleep duration. For boys with this longitudinal sleep duration pattern, a greater than 10% reduction in the beta estimate for overweight/obesity at 7 years was observed from the Base Model to Model 3, such that the beta estimate for a *‘short persistent* or *short increasing’* pattern was 1.426 in the covariate-adjusted Base Model, and reduced to 1.231 in the covariate-adjusted version of Model 3. Due to this finding, the eating behaviour ‘eating too much *or* too fast’, measured at age 6 years, was deemed to act as a partial mediator to the association between a *‘short persistent* or *short increasing’* pattern of longitudinal sleep duration from 2.5 to 6 years and overweight/obesity at age 7 years; this finding was supported in both the covariate-unadjusted and covariate-adjusted versions of Model 3.

Table 21: Unadjusted and adjusted† odds ratios£ and 95% confidence intervals for overweight/obesity in boys at age 7 years, according to longitudinal sleep duration pattern (2.5 to 6 years) alone, or with adjustments for dietary intake and eating behaviour at 6 years of age.

	BOYS			
	Overweight *or* obese at 7 years (14.6%)			
Base Model 1: Longitudinal sleep duration pattern *only – Adjusted and unadjusted for potential confounders*				
Variable	**Unadjusted OR§**	**95% CI§**	**Adjusted for other covariates † OR**	**95% CI**
Longitudinal sleep duration pattern (average sleep at night from age 2.5 to 6yrs)				
Short persistent *or* short increasing pattern (13.4%)	4.29**	1.83, 10.04	4.16*	1.64, 10.54
10-hour persistent pattern (52.3%)	2.10*	1.03, 4.28	1.91	0.90, 4.07
11-hour persistent pattern (34.3%) ‡	1.00	–	1.00	--
Model 2: Longitudinal sleep duration pattern and Vegetable consumption				
Variable	**Adjusted for the model's main variables only OR**	**95% CI**	**Adjusted for additional covariates † OR**	**95% CI**
Longitudinal sleep duration pattern (average sleep at night from age 2.5 to 6yrs)				
Short persistent *or* short increasing pattern (13.4%)	3.51*	1.48, 8.34	3.67*	1.43, 9.42
10-hour persistent pattern (52.3%)	2.08*	1.02, 4.24	1.97	0.92, 4.23
11-hour persistent pattern (34.3%) ‡	1.00	–	1.00	--
FFQ: Vegetables (times per day)				
≤1/day (54.9%)	2.12*	1.14, 3.94	1.96*	1.01, 3.80
> 1/day (45.1%)‡	1.00	–	1.00	--
Model 3: Longitudinal sleep duration pattern and Eating Behaviour Pattern (Eats too much *or* too fast)				
Variable	**Adjusted for the model's main variables only OR**	**95% CI**	**Adjusted for additional covariates † OR**	**95% CI**
Longitudinal sleep duration pattern (average sleep at night from age 2.5 to 6yrs)				
Short persistent *or* short increasing pattern (13.4%)	3.35*	1.39, 8.04	3.42*	1.31, 8.96
10-hour persistent pattern (52.3%)	1.92	0.93, 3.96	1.71	0.79, 3.72
11-hour persistent pattern (34.3%) ‡	1.00	–	1.00	--
Eats too much or too fast				
No (59.9%)‡	1.00	–	1.00	--
Yes – Eats too much or too fast (40.1%)	3.63**	2.00, 6.60	4.00**	2.07, 7.71

* Significantly different from the reference category (two-sided $p \leq 0.05$)

** Significantly different from the reference category (two-sided $p \leq 0.001$)

†Adjusted for all variables in the model as well and the following covariates: 'Child overweight *or* obese at 2.5yrs'; 'mother's immigrant status'; 'mother classified as overweight *or* obese'; and, 'household income'.

‡Reference category

§ OR, odds ratio; CI, confidence interval

£ Weighted.

All four covariates included in the adjusted versions of each model remained significantly related to overweight/obesity in boys at age 7 years in Model 2, at the 0.05 significance level. However, in Base Model 1, all covariates except for 'household income' ($P > 0.05$) remained significantly related to overweight/obesity at age 7 years, and in Model

3, all covariates except for 'mother's immigrant status' ($P = 0.061$) and 'mother classified as overweight *or* obese when the child was 17 months old' ($P = 0.093$) remained significantly related to overweight/obesity at age 7 years, at the 0.05 significance level. Nonetheless, the four covariates were retained in the covariate-adjusted version of all models to maintain consistency across the models explored.

Similar to results from analyses at age 6 years, when looking at all three models explored at age 7 years, the odds for overweight/obesity in boys at 7 years of age were:

1) Significantly *higher* among boys who were overweight or obese at 2.5 years of age ($P<0.001$, across all three models at age 7 years) in comparison to those who were not, with odds for overweight/obesity at 7 years ranging from 3.31 (95% CI: 1.69, 6.47) in Model 2 to 3.89 (95% CI: 1.95, 7.76) in Model 3, in boys who were overweight or obese at 2.5 years of age;
2) significantly *higher* among boys who had immigrant mothers ($P \leq 0.01$, in Base Model 1 and Model 2), except for in Model 3 (as previously mentioned), in comparison to boys who had mothers who were not immigrants, with odds for overweight/obesity at 7 years ranging from 2.87 (95% CI: 1.25, 6.58) in Model 2 to 3.35 (95% CI: 1.49, 7.56) in Base Model 1, in boys who had immigrant mothers; and,
3) significantly *higher* among boys who had mothers who were overweight or obese when the child was 17 months old ($P \leq 0.05$, in Base Model 1 and Model 2), except for in Model 3 (as previously mentioned), in comparison to boys who had mothers who were not overweight or obese, with odds for overweight/obesity in boys at 7 years ranging from 1.96 (95% CI: 1.05, 3.67) in Base Model 1 to 1.99 (95% CI: 1.06, 3.75) in Model 2, in boys who had mothers who were overweight or obese.

4) significantly *lower* among boys who came from a family with a household income of $30,000 - $49,999 ($P \leq 0.05$ across Models 2 and 3 at age 7 years), except for in Base Model 1 (as previously mentioned), in comparison to boys whose family household income was less than $30,000, with odds ranging from 0.22 (95%CI: 0.07, 0.72) in Model 3 to 0.30 (95% CI: 0.10, 0.97) in Model 2.

5.5.3 Assessing the impact of excluding children with missing covariate values

In order to examine the impact of excluding children with missing covariate values from multivariate analyses, all multivariate models explored at age 6 and 7 years were re-examined with the inclusion (i.e. 'with-' analyses) of boys with missing values on the four covariates selected for final multivariate analyses: 'child classified as overweight or obese at 2.5 years of age'; 'mother's immigrant status'; 'mother classified as overweight *or* obese when the child was 17 months old'; and, 'household income'. This was done by adding a separate 'missing values' subgroup to the covariate categories. All results from final multivariate models conducted as 'with-' analyses at age 6 and 7 years are included in Appendix A and Appendix B, respectively.

In analyses at age 6 years, 8.8% (46 out of 520) of boys had missing values on covariates included in final multivariate models. Similarly, 8.6% (40 out of 465) of boys had missing values on the four covariates included in the final multivariate models at age 7 years. For analyses at both age 6 and 7 years, the largest proportion of missing values was found with the covariate 'child classified as overweight or obese at 2.5 years of age'; 7.5% of boys had missing values on this variable in analyses at age 6 years, and 7.3% of boys had missing values on this variable at age 7 years. The proportion of missing values for each of the three remaining covariates included in the final models was 1% or less, for both analyses at age 6 and 7 years.

A re-examination of the final multivariate models with the inclusion of a 'missing values' category for each covariate ('with-' analyses), found similar results to analyses conducted excluding children with missing values on covariates ('without-' analyses), at age 6 and 7 years.

In analyses at age 6 years (Appendix A), the direction of the associations remained the same across all six models in both 'with-' and 'without-' analyses. The strength of almost all associations increased slightly in 'with-' analyses, with small increases in the odds for overweight/obesity at age 6 years in boys with a *'10-hour persistent'* pattern of longitudinal sleep duration, and more distinct increases in those odds for boys with a *'short-persistent* or *short-increasing'* pattern of longitudinal sleep duration, across all 6 models. The odds for overweight/obesity at age 6 years also increased slightly in boys who were reported as 'eating too much or too fast' in Model 5 and 6 of 'with-' analyses. The only association that was found to be less strong in 'with-' analyses was that found between boys who were reported as 'eating at irregular hours in the day' and overweight/obesity at age 6 years (Models 4 and 6), with results showing a slight decrease in the odds for overweight/obesity in this eating behaviour group in 'with-' analyses, in comparison to results in 'without-' analyses. With this reduction, 'eating at irregular hours in the day' no longer met the criteria of a 'partial mediator' to the longitudinal sleep duration pattern – overweight/obesity association (less than 10% reduction in the beta estimates of longitudinal sleep duration pattern from Base Model 1) when considered alone in Model 4 of 'with-' analyses. However, the combined inclusion of this variable with the eating behaviour variable 'eating too much *or* too fast' in Model 6 coincided with findings from 'without-'

analyses, which indicated that when both these eating behaviour variables were considered together, these eating behaviours played an important role in mediating part of the association between longitudinal sleep duration pattern and overweight/obesity at age 6 years both in boys who had a *'short persistent* or *short increasing'* pattern of longitudinal sleep duration and boys who had a *'10-hour persistent'* pattern of longitudinal sleep duration from 2.5 to 6 years of age, after adjustments for important covariates. Note, however, that only 'partial mediation' was established for boys who had a *'10-hour persistent'* pattern of longitudinal sleep duration in Model 6, as a statistically significant association with overweight/obesity was maintained for this group, in 'with-' analyses; while, in previous 'without-' analyses, 'full mediation' was established for this longitudinal sleep duration pattern group in Model 6, as the association with overweight/obesity at age 6 was no longer statistically significant in boys who had a *'10-hour persistent'* pattern of longitudinal sleep duration. The 'partial mediating' role of the eating behaviour variable 'eating too much or too fast', considered alone in Model 4, was also supported in 'with-' analyses. Please refer to Appendix A for unadjusted and adjusted odds ratios and 95% confidence intervals for overweight/obesity in boys at age 6 years, using 'with-' analyses for all final models examined at age 6 years.

Similar to analyses at age 6 years, a comparison of 'with-' and 'without-' analyses for final multivariate models examined at age 7 years (Appendix B) also found minor differences in the results, with the direction of all associations remaining the same across all three models explored. Across all three models, the odds for overweight/obesity at age 7 years increased slightly in 'with-' analyses in boys with a *'short persistent* or *short increasing'* pattern of longitudinal sleep duration, and the association between a *'10-hour persistent'* pattern of longitudinal sleep duration and overweight/obesity at age 7 years became statistically significant in Base Model 1 and Model 2 of 'with-' analyses, while the association was insignificant in previous 'without-' analyses. The association between 'eating too much or too fast' and overweight/obesity at age 7 years (Model 3) was also slightly stronger in 'with-' analyses, such that the odds for overweight/obesity at age 7 years in boys with this eating behaviour was slightly higher, in comparison to the odds obtained through 'without-' analyses at age 7 years. The odds for overweight/obesity at age 7 years in boys who consumed vegetables 'once-per-day or less' (Model 2) was slightly reduced in 'with-' analyses, in comparison to 'without-' analyses; however, the direction of the association and its statistical significance was maintained. Again, the 'partial mediating' role of the eating behaviour variable 'eating too much or too fast' (Model 3) in the association between a *'short persistent* or *short increasing'* pattern of longitudinal sleep duration and overweight/obesity in boys at age 7 years was supported in 'with-' analyses. Furthermore, in 'with-' analyses, this eating behaviour was found to fully mediate the association between a '10-hour persistent' pattern of longitudinal sleep duration and overweight/obesity in boys at age 7 years, as this association became insignificant when this eating behaviour was considered in Model 3. Note, however, that this result was not found in 'without-' analyses as no association with overweight/obesity was found in boys with a '10-hour persistent' pattern across all three models in 'without-' analyses. Please refer to Appendix B for unadjusted and adjusted odds ratios and 95% confidence intervals for overweight/obesity in boys at age 7 years, using 'with-' analyses for all final models examined at age 7 years.

In comparing the results obtained through 'with-' and 'without-' analyses at age 6 and 7 years, it was deemed that excluding children with missing covariate values from final multivariate models did not largely impact the findings and also produced more conservative results. For this reason, the discussion of the findings of this study will center mainly on results obtained through analyses of the sample of boys with no missing values on covariate values in final multivariate models (‘without’ analyses), as was presented in Sections 5.5.1 and 5.5.2.

CHAPTER 6: Discussion

In recent years, much research has provided evidence for the contributing role of sleep duration in the obesity epidemic across all ages and particularly in younger age groups (Cappuccio et al., 2008; Chen et al., 2008; Patel & Hu, 2008; Van Cauter & Knutson, 2008). This association is generally implied to result from underlying metabolic changes that occur when sleep duration is chronically shortened or restricted over a period of time, and which regulate appetite, food selection, and patterns of energy expenditure, key drivers in the regulation of overall body weight (Taheri, 2006; Taheri et al., 2004; Van Cauter & Knutson, 2008). Even though this is the general mechanism by which short sleep duration is proposed to contribute to the increased prevalence of overweight and obesity, little research has properly explored the potential role of dietary intake and eating behaviour as key mediators in the sleep duration – overweight/obesity association, particularly in young children.

To our knowledge, this study is the first to explore the potential mediating role of dietary intake and eating behaviour in a longitudinal study of the association between sleep duration pattern and overweight/obesity in young children.

6.1 *Summary of findings*

In this study, the prevalence of overweight/obesity was approximately 16% in both boys and girls in the sample followed to age 6 years, and 15% and 17% in boys and girls, respectively, followed to age 7 years. These prevalence rates are lower than what was previously reported in 2004, where 26% of children and adolescents aged 2 to 17 years old from the total Canadian population were classified as overweight or obese, and 23% were classified as such in the province of Québec in that same year (Shields, 2005). Nonetheless, the prevalence rates found in this study sample may reflect the rates for that particular narrow age group (children aged 6 and 7 years only) within the province of Québec, as opposed to the much wider age range of 2 to 17 years.

Although the prevalence of overweight/obesity was fairly similar across both sexes, results showed that longitudinal sleep duration pattern from age 2.5 to 6 years significantly related to overweight/obesity at age 6 and 7 years in boys, but not in girls. This association was found to be independent of other child, parent, and family demographic/socio-economic characteristics suggested by the literature to act as risk factors for overweight/obesity or to act as potential confounders to the main association.

The highest prevalence of overweight/obesity, at both age 6 and 7 years, was found in boys who had a *'short persistent* or *short increasing'* longitudinal sleep duration pattern from 2.5 to 6 years. Approximately one-third of boys who had a *'short persistent* or *short increasing'* longitudinal sleep duration pattern were classified as overweight or obese, while less than one-tenth of boys who had an *'11-hour persistent'* longitudinal sleep duration pattern were overweight or obese at either age 6 or age 7 years. The second highest prevalence of overweight/obesity was found in boys who had a *'10-hour persistent'* longitudinal sleep duration pattern, with approximately one-sixth of children being classified as overweight or obese at age 6 and 7 years.

After taking into consideration 'dietary intake', 'eating behaviour', and several important child, parent, and family characteristics that associate with childhood overweight and obesity, it was found that boys who had a *'short persistent* or *short increasing'* longitudinal sleep duration pattern from 2.5 to 6 years had between 3.6 to more than 5 times the odds of being overweight/obese at age 6 years in comparison to boys who had an *'11-hour persistent'* longitudinal sleep duration pattern, across all final covariate-controlled models examined to age 6 years. Boys who maintained a *'10-hour persistent'* longitudinal sleep duration pattern were also found to have more than twice the odds of being overweight/obese at age 6 years in comparison to boys who had a *'11-hour persistent'* pattern across five of the six final models examined to age 6 years. The association between longitudinal sleep duration pattern and overweight/obesity in boys also persisted to age 7 years. Boys who had a *'short persistent* or *short increasing'* longitudinal sleep duration pattern from 2.5 to 6 years had odds of 3.4 to 4.2 for being overweight/obese at age 7 years in comparison to boys who had an *'11-hour persistent'* longitudinal sleep duration pattern, across all three final covariate-controlled models examined at age 7 years. However, the association between a *'10-hour persistent'* longitudinal sleep duration pattern and overweight/obesity evident at age 6 years was no longer significant in boys at age 7 years. Nonetheless, the findings are in accordance with the study's primary hypothesis which suggested that children who had shorter sleep duration patterns from age 2.5 to 6 years would have a greater likelihood of being overweight or obese at age 6 and 7 years.

On the contrary, parts of the study's secondary hypotheses were not supported by the study results. Even though, at the bivariate level, boys who had a *'short persistent* or *short increasing'* longitudinal sleep duration pattern from 2.5 to 6 years were found to have less favorable 'consumption frequencies' ('once per day or less' versus 'more than once per day') of vegetables, fruits (not including juices), and meat and alternatives in comparison to boys who had an *'11-hour persistent'* longitudinal sleep duration pattern, dietary intake at age 6 years was *not* found to mediate (neither in part nor in full) the association between longitudinal sleep duration pattern from age 2.5 to 6 years and overweight/obesity, in boys, at either age 6 or 7 years. Nonetheless, it is important to note that, although 'frequency of consumption of vegetables per day' at age 6 years was not found to act as a mediator to the sleep duration – overweight/obesity association in boys, consuming vegetables 'once per day or less' at age 6 years was significantly and independently associated with a higher prevalence of overweight/obesity in boys at age 7 years (but not at age 6 years), even after consideration for longitudinal sleep duration pattern and other important covariates. No other dietary intake variable maintained a statistically significant association with overweight/obesity in boys at either age 6 or 7 years when examined with consideration for longitudinal sleep duration pattern and other important covariates.

In correspondence with the studies' secondary hypotheses, however, it was found that certain 'eating behaviours' played an important role in the association between longitudinal sleep duration pattern and overweight/obesity found in boys. A significantly larger proportion of boys who had a *'short persistent* or *short increasing'* or a *'10-hour persistent'* longitudinal sleep duration pattern from age 2.5 to 6 years were reported to have problematic eating behaviours ('eating at irregular hours in the day' and 'eating too much or too fast') at age 6 years, in comparison to boys who had an *'11-hour persistent'* longitudinal sleep duration pattern from age 2.5 to 6 years. When these eating behaviours were examined for their role as potential mediators to the sleep duration – overweight/obesity association (with control for other important covariates), it was found that 'eating at irregular hours in the day' partially mediated the association between longitudinal sleep duration and 'overweight/obesity' at age 6 years in boys who had a *'short persistent* or *short increasing'* pattern of longitudinal sleep duration, but not in boys who had a *'10-hour persistent'* pattern of longitudinal sleep duration from 2.5 to 6 years. On the other had, 'eating too much or too fast' was found to partially mediate *both* the association between longitudinal sleep duration and 'overweight/obesity' at age 6 years in boys who had a *'short persistent* or *short increasing'* pattern of longitudinal sleep duration and in boys who had a *'10-hour persistent'* pattern of longitudinal sleep duration from 2.5 to 6 years. The mediating role of these two eating behaviours was found to be even more pronounced when they were considered simultaneously as mediators to the sleep duration – overweight/obesity association at age 6 years. When considered together, it was found that these eating behaviours strongly mediated part of the association between longitudinal sleep duration pattern and overweight/obesity at age 6 years in boys who had a *'short persistent* or *short increasing'* pattern of longitudinal sleep duration, and together they mediated the *full* association between longitudinal sleep duration pattern and overweight/obesity at age 6 years in boys who had a *'10-hour persistent'* pattern of longitudinal sleep duration from 2.5 to 6 years. The mediating role of the eating behaviour 'eating too much or too fast' also persisted to age 7 years such that, the presence of this eating behaviour at age 6 years partially mediated the association between boys who had a *'short persistent* or *short increasing'* pattern of longitudinal sleep duration from 2.5 to 6 years and overweight/obesity at age 7 years, even after control for other important factors. Finally, it is important to note that both the problem eating behaviours 'eating at irregular hours in the day' and 'eating too much or too fast' significantly and independently associated with a higher prevalence of overweight/obesity in boys at age 6 years, even when examined with consideration for longitudinal sleep duration pattern and other important covariates; however, only the eating behaviour 'eating too much or too fast' at age 6 years was longitudinally associated with a higher prevalence of overweight/obesity in boys at age 7 years.

Other important factors that remained significantly and independently associated with a higher prevalence of overweight/obesity in boys at age 6 and 7 years, when examined with consideration for longitudinal sleep duration from 2.5 to 6 years, dietary intake, and eating behaviour, included: 1) Being classified as overweight or obese at age 2.5 years; 2) having an immigrant mother; and, 3) having a mother who was overweight or obese when the child was

17 months old. Whereas, coming from a family with a household income of $30,000 - $49,999 in comparison less than $30,000 was associated with a significantly lower prevalence of overweight/obesity in boys at age 6 and 7 years.

Lastly, although an association between longitudinal sleep duration pattern from 2.5 to 6 years and overweight/obesity at either age 6 or age 7 years was not found in girls, results from bivariate analyses showed that, in comparison to girls who had an *'11-hour persistent'* longitudinal sleep duration pattern from 2.5 to 6 years, a greater proportion of girls who had a *'short persistent* or *short increasing'* longitudinal sleep duration pattern had less favorable 'consumption frequencies' ('once per day or less' versus 'more than once per day') of vegetables, fruits (not including juices), and milk and alternatives, and consumed significantly more soft drinks ('once per day or more' versus 'less than once per day') than their longer sleeping female counterparts. However, contrary to what was found in boys, in girls, no association was found between longitudinal sleep duration pattern and any of the eating behaviours examined in the present study.

6.2 *Interpretation*

The findings from this study are intriguing at multiple levels and differ from findings reported in a prior study conducted by Touchette and colleagues on this same cohort of children (Touchette et al., 2008). In Touchette and colleagues' study, a sex-difference in the sleep duration pattern–overweight/obesity association was not reported, nor was a significant relationship found between a *'10-hour persistent'* longitudinal sleep duration pattern and overweight/obesity at age 6 years once the authors controlled for baseline weight at 2.5 years of age (among other factors) in a multivariate analysis. This appears to be due to the fact that the authors did not thoroughly explore a sex-difference as an interaction variable to the sleep duration pattern–overweight/obesity association; rather, the authors simply verified whether a relationship existed between sex of the child and BMI at the bivariate level, with none being found (Touchette et al., 2008). Finding no association between sex of the child and BMI, Touchette and colleagues did not report having pursued an examination of the sleep duration pattern–overweight/obesity association stratified by sex, possibly obtaining muted results of the true association present in boys, as observed in the present study.

Firstly, the present study's finding that a significant inverse association between sleep duration and overweight/obesity at age 6 years was present even in boys who persistently maintained as much as an average of 10 hours of sleep per night from age 2.5 to 6 years (in comparison to boys who had an *'11-hour persistent'* longitudinal sleep duration pattern) is noteworthy. Even though this association between a *'10-hour persistent'* longitudinal sleep duration pattern and overweight/obesity did not persist to age 7 years, the finding suggests that, up to the age of 6 years, boys may be highly sensitive to the effects of even slight amounts of chronic sleep deprivation such that they may require greater than an average of 10-hours of sleep duration per night, persistently from age 2.5 to 6 years, in order to lessen the risk of being overweight/obese at age 6 years. However, to date, much of the literature has generally applied a cut-off of '10 hours or less of sleep (on average)' to examine the association between sleep duration and overweight/obesity in children aged 5 to 10 years, implying that this is the recommended number of hours of sleep duration required for children in this age group, regardless of their sex (Amschler & McKenzie, 2005; Chen et al., 2008; Liu et al., 2005; Sekine et al., 2002a). As seen from the results of the present study, applying such a cut-off when examining this association in boys up to age 6 years may be overlooking a large number of children who are maintaining 'recommended' levels of sleep duration yet, unbeknownst to parents and health practitioners, may be at an increased risk of overweight/obesity. It is therefore suggested that future studies re-examine the appropriate guidelines for 'recommended hours of sleep duration' required to age 6 years, in boys and girls separately, taking into consideration how sleep duration may associate with risks of overweight/obesity (and possibly other comorbidities) differently across the sexes.

The present study's finding that a sex-difference exists in the relationship between longitudinal sleep duration pattern and overweight/obesity corresponds with findings obtained in other studies of children and adolescents that report a stronger association between short sleep duration and overweight/obesity in boys in comparison to a weak or non-existent relationship in girls (Chen et al., 2008; Eisenmann et al., 2006; Knutson, 2005; Sekine et al., 2002a). In fact, a meta-analysis conducted by Chen and colleagues on children and adolescents aged 0 to 18 years found that the odds for overweight/obesity in boys with shorter sleep duration was 2.50, while the odds in girls with shorter sleep duration was 1.24, each, respectively, in comparison to their longer sleeping male and female counterparts; however, this meta-analysis was mainly based on results from cross-sectional studies (Chen et al., 2008). Results from the present study revealed that the association between sleep duration and overweight/obesity in boys may be even more pronounced when looking at pattern of sleep duration over time. Using a longitudinal measure of sleep duration pattern from 2.5 to 6 years, the present study found that the odds for overweight/obesity in boys who had a *'short persistent* or *short increasing'* longitudinal sleep duration pattern were much higher than in Chen and colleagues' meta-analyses, with odds for overweight/obesity at age 6 years ranging between 3.6 to 5.3 (range from all models explored to age 6 years), and between 3.4 to 4.2 at age 7 years (range from all models explored to age 7 years), in comparison to boys who had an *'11-hour persistent'* longitudinal sleep duration pattern. On the other hand, the association was non-existent in girls, whether examined cross-sectionally (data not shown) or longitudinally in the present study.

As reviewed in Chapter 2, insufficient sleep duration is proposed to contribute to the development of overweight and obesity through several biological pathways that regulate appetite, eating behaviour, food selection, and patterns of energy expenditure. These pathways include: decreased levels of leptin, growth hormone (GH), and serotonin, impaired glucose tolerance and insulin resistance, elevated levels of ghrelin and cortisol, increased sympathetic activity, alterations in basal metabolic rate, the thermic effect of food, and non-exercise activity thermogenesis (NEAT) (Crispim et al., 2007; Eisenmann, 2006; Knutson et al., 2007; Rosmond and Bjorntorp, 2000; Spiegel et al., 2004a; Spiegel et al., 1999; Taheri, 2006; Taheri, 2004). Such hormonal and metabolic changes may promote increased selection of calorie-dense foods, excessive food intake, and reduced physical activity resulting from daytime fatigue. Thus, insufficient sleep duration is suggested to promote overweight and obesity by affecting both sides of the energy balance equation.

The reason for a sex-difference in the relationship between sleep duration and overweight/obesity is not well understood. From an evolutionary perspective, certain researchers have hypothesized that girls may be biologically more resilient to environmental stressors and may require greater sleep deprivation to be negatively affected in comparison to boys (Eisenmann et al., 2006; Wells, 2000). On the other hand, studies in adults provide some evidence for differences in the physiology and behavioural manifestations of sleep architecture across the sexes (Huupponen et al., 2002; Manber & Armitage, 1999; Roehrs et al., 2006). Even though few studies have examined whether such sex-differences in sleep are also present in childhood, of those that exist, findings in children and adolescents suggest that girls perform better than boys on sleep indicators measured through an actigraph (a wristwatch-style device that, through software, objectively records movement and several sleep variables), with boys' sleep being more inefficient and more interrupted by awakenings, and girls having a longer, more motionless sleep (Gaina et al., 2005; Sadeh, Raviv, & Gruber, 2000). Such sex-differences in sleep, which may impact hormonal regulation and metabolic functions, can affect the way inadequate sleep duration impacts the underlying metabolic functions and behavioural practices (e.g. diet, eating behaviour, and physical activity) of boys differently from girls (Knutson, 2005). In fact, results from the present study support such a notion. It was seen that, although boys and girls showed similar unfavorable patterns of dietary intake in response to shorter longitudinal sleep duration patterns, the relationship between longitudinal sleep duration pattern and eating behaviour was notably different across the sexes. In girls, longitudinal sleep duration pattern did not associate with any of the three problematic eating behaviours examined; whereas, in boys, having a shorter longitudinal sleep duration pattern (a *'short persistent* or *short increasing'* or a *'10-hour persistent'* longitudinal sleep duration pattern, in comparison to an *'11-hour persistent'* longitudinal sleep duration pattern) from 2.5 to 6 years was significantly associated with a higher prevalence of exhibiting both the problematic eating behaviours 'eating at irregular hours in the day' and 'eating too much or too fast' at 6 years of age. These two eating behaviours also significantly related to overweight/obesity and, in turn, acted as mediators to the sleep duration – overweight/obesity association found in boys. This finding suggests that obesity-promoting eating behaviours may be easily induced in boys when they do not receive adequate levels of sleep duration over long periods of time, even if receiving as much as 10 hours of sleep per night (on average), persistently from age 2.5 to 6 years. On the other hand, girls may not be as easily susceptible to altering their eating behaviours in response to insufficient levels of sleep duration or may require more severe levels of chronic sleep deprivation.

Touchette and colleagues' study on this same cohort of children briefly examined the potential mediating role of 'perception of the child overeating' in the sleep duration – overweight/obesity association; however, as the authors did not examine the main association as stratified by sex, muted results were obtained as to the importance of this variable (as was seen for boys in the present study) and only mild support was provided for considering this eating behaviour variable as a potential mediator to the association in 6 year old children (Touchette et al., 2008). Furthermore, in Touchette and colleagues' study, 'perception of the child overeating' and overweight/obesity were both examined only at age 6 years, leaving reverse-causality at question. In the present study, however, it was found that 'eating too much or too fast' at age 6 years persisted to have mediating effects on the association between longitudinal sleep duration pattern (2.5 to 6 years) and overweight/obesity in boys even to age 7 years, providing support for a possible causal chain of effects.

It is important to note, however, that although eating behaviour played an important role as a mediator in the sleep duration – overweight/obesity association found in boys in the present study, the mediating effects were only *partial* in boys who had a *'short persistent* or *short increasing'* pattern of longitudinal sleep duration. Thus, additional factors must underlie a sex-difference in the sleep duration – overweight/obesity association. Although the 'frequency of consumption' of various foods was not found to mediate the association present in boys, it is possible that diet quality (macronutrient value and caloric intake) may act as an additional mediator to the association (Nedeltcheva et al., 2009; Schmid et al., 2008); however, this requires further study. Other behavioural factors that may mediate a sleep duration – overweight/obesity association in is level of energy expenditure (Knutson et al., 2007). Inadequate sleep duration may negatively affect levels of energy expenditure more severely in boys than in girls. Although little is known about sex-differences in the association between sleep duration and energy expenditure, generally, research in adults has found that inadequate sleep duration is associated with decrease levels of energy expenditure and decreased level of physical activity due to daytime fatigue (Schmid et al., 2008; Spegel et al., 1999; Taheri, 2006), even though the opportunity for physical activity is increased with longer waking hours. Some cross-sectional studies in children also found an association between short sleep duration, increased television viewing, and reduced participation in organized sports (Locard et al., 1992; von Kries et al., 2002). However, epidemiological studies that considered these factors did not find that the association between sleep duration and overweight/obesity could be explained by either level of physical activity or television viewing (Nixon et al., 2008; Patel & Hu, 2008). Furthermore, results from the present study did not find that longitudinal sleep duration pattern was associated with differences in hours of television viewing or level of physical activity in boys. Nonetheless, it is possible that other underlying metabolic processes that regulate energy expenditure, such as resting energy expenditure (REE), may be at play (Hitze et al., 2009).

Future research is needed to substantiate these longitudinal findings in other populations and further examine the biological and behavioural mechanisms underlying sex-differences in the association between sleep duration and overweight/obesity in young children.

6.3 *Limitations*

The results of the present study must be considered in light of certain limitations. Firstly, the results cannot be generalized to other populations or to the subpopulations excluded from the study design (e.g. persons living in Cree and Inuit regions, Indian reserves, and Northern Québec). Secondly, the findings rely on a subjective, parent-reported measure of sleep duration; this may have overestimated children's true sleep time. Although the validity of parent-reported sleep duration of younger children is less well established, certain studies have shown that parental reports of children's sleep duration are similar to results obtained through wrist actigraphy (Sadeh, 1994; Sekine et al., 2002b). Furthermore, there is no evidence to suggest that any potential misclassification for sleep duration would have been differential; thus, the results obtained are likely to have underestimated the strength of the true association.

The measures utilized to monitor dietary intake (the frequency of consumption of various foods) and eating behaviour in the present study also have some limitations. These measures were based on parental reports and, in the case of the FFQ, did not measure actual portion sizes of the various foods consumed. Thus, no conclusions can be made about differences in the *quantity* of foods consumed by children according to longitudinal sleep duration pattern, but rather only in the *frequency* of foods consumed, which may have overlooked differences in caloric or macronutrient intake. However, this may have produced more conservative findings as to the importance of dietary intake in the sleep duration – overweight/obesity association. Using data obtained through a more detailed measure of dietary intake (a 24-recall interview) utilized in a sub-study of the QLSCD when children were 4.5 years old, a prior study with this same cohort of children found that children who were reported to 'eat too much or too fast' ('overeaters') consumed more total energy, more of each macronutrient, and more servings of grain products, meats and alternatives per day than did children who were never reported as being 'overeaters' (Dubois et al., 2007c). Thus, as the eating behaviour 'eating too much or too fast' was found to play an important mediating role in the sleep duration – overweight/obesity association examined in the present study, it is likely that if a more detailed measure of dietary intake were used to monitor caloric and macronutrient intake at age 6 years, dietary intake may play a more significant role in mediating the association between longitudinal sleep duration and overweight/obesity at age 6 and 7 years. Nonetheless, an indication of the validity of the FFQ utilized in the present study is presented in Figure 2 (Chapter 4) of this manuscript.

Certain covariates were also parent-reported. In particular, children's 'level of physical activity' was based on a single-item question which asked the PMK to rate their child's level of physical activity in comparison to other children on a Likert-type scale. Such an item may introduce some bias (e.g. recall, social desirability, etc.) and does not empirically measure a child's level of energy expenditure, nor does it provide information pertaining to the time spent being physically active or the type of physical activity (Goran, 1998; Miller, 2004; Sirard & Pate, 2001; Sithole & Veugelers, 2008). In the present study, 'level of physical activity' did not significantly relate to any of the main variables studied (longitudinal sleep duration pattern, dietary intake/eating behaviour, and/or overweight/obesity) and, thus, was excluded from final multivariate analyses. It is possible that if a more objective measure of physical activity were used, children's level of physical activity may have been found to play an important role in the sleep duration – overweight/obesity association. Future studies may consider using a stronger and more objective measure of physical activity to substantiate the findings observed in the present study. Nonetheless, a study by Sithole and Veugelers showed that parent reports of children's level of physical activity provided adequate information to replicate the well established association between increased physical activity and a healthy body weight (Sithole & Veugelers, 2008). It is also well recognized that there are several advantages to self-/parent- reports for physical activity in large population-based surveys: They are more convenient, less costly, they retain a greater number of participants, and data on physical activity obtained through self-reports are more easily implemented into public health policy recommendations (Sithole & Veugelers, 2008).

Limitations also lie in the use of BMI as a measure of adiposity to classify children as overweight/obese. Other measures, such as waist circumference or skinfold thickness, may provide a more precise measure of total body fat or fat distribution. However, studies have shown that BMI is associated with other measures of adiposity in children of both sexes (Lindsay et al, 2001; Pietrobelli et al., 1998). Furthermore, BMI is also widely used as a measure of relative adiposity and as a weight classification system for overweight and obesity in Canada and by the World Health Organization (WHO) (WHO, 2006).

Another limitation of the present study is the lack of a formal statistical test to examine the *strength* and *amount* of mediation (a test of the indirect effect) observed from eating behaviours on the sleep duration – overweight/obesity association found in boys. Mediation is a topic that has been studied for numerous years and is increasingly being explored as a way to understand the mechanisms through which a predictor variable affects a specified outcome (Hyman, 1955; MacCorquodale & Meehl, 1948). Although mediation is not defined statistically, some formal statistical tests have been formulated to evaluate hypothesized mediational models (e.g. Sobel test) (Baron & Kenny, 1986; Goodman, 1960; Jasti, Dudley, & Goldwater, 2008; MacKinnon, Warsi, & Dwyer, 1995; Preacher & Hayes, 2008; Preacher & Hayes, 2004; Preacher & Leonardelli, 2003; Sobel, 1982); however, to date, no program was found to accommodate logistic regression modelling with a multilevel categorical predictor variable (e.g. longitudinal sleep duration pattern), while also taking into consideration multiple categorical covariates (as is the case for the present study). After a consultation with experts on the topic of mediation analyses, it was suggested that a future study may attempt to explore mediation testing using Structural Equation Modeling (SEM) and a software called M*plus* (Muthén & Muthén, 1998–2007) that uses latent growth curve modeling to deal with multiple covariates and multilevel categorical variables (*personal communication* with: Kristopher J. Preacher, *Assistant Professor in the Department of Psychology, University of Kansas*; Srichand Jasti, *Statistician II at Duke University Medical Center*; and, William N. Dudley, *Associate Dean for Research at the School of Health and Human Performance Office of Research, University of North Carolina at Greensboro*, August-September 2008). As this method had not been explored by the experts consulted and developing such a program was beyond the scope of the present project, producing a program to test mediation with the variables examined in this study will be pursued at a later date. For this reason, the present study used a qualitative approach (described in section 4.4.2 of this document) to evaluate the mediating effects examined in the present study. Similar methods have been used to examine the potential mediating role of various variables in several other studies (e.g. Nixon et al., 2008; Touchette et al., 2008;).

Limitations to the present study's findings may also include potential selection bias that may have been introduced with the large number of children that were excluded from analyses from the original QLSCD cohort due to missing information on body weight and height, dietary intake/eating behaviour, or sleep duration. Differences between the sample included and excluded from analyses at age 6 and 7 years are reviewed in section 5.1 of this document. Nonetheless, in spite of these differences, it is important to note that all analyses conducted with the QLSCD dataset take into account 'non-responders' through the use of survey weights, making it less likely that the results were subjected to selection bias.

Finally, the present study's findings may be limited by the possibility of residual confounding. Although several child, parent, and family demographic/socio-economic characteristics were taken into consideration in the analyses, it is possible that the associations observed between longitudinal sleep duration pattern and overweight/obesity in boys and the mediating role of eating behaviour may be further explained by other variables not accounted for in the present study.

6.4 *Strengths*

Despite the limitations reviewed in the previous section, the present study has many strengths. First, results are based on data obtained from a large sample of boys and girls, representative of children born in 1998, in the province of Quebec, Canada; this provides high power and, thus, high confidence in the study results. The large representative sample also allows the study results to be highly generalizable to this population. Many other studies on the association between sleep duration and overweight/obesity have been limited to specific cities, regions, or subgroups within a specified population.

A second and more important strength of this study is that, not only was the association between sleep duration and overweight/obesity examined prospectively, but the hypothesized mediating roles of dietary intake and eating behaviour were also examined longitudinally. Furthermore, sleep duration was determined by observing longitudinal patterns of sleep duration established throughout early childhood rather than measuring sleep duration at only one point in time. Although causation cannot fully be inferred by the findings of the present study, this study design provides strong support for causality. Prior systematic reviews and meta-analyses concluded that the causal effect of inadequate sleep duration on overweight/obesity could not yet be inferred due to the lack of prospective studies providing evidence of a temporal sequence and a lack of repeated measures of sleep duration (Cappuccio et al., 2008; Patel & Hu, 2008). Reverse causality remained in question, suggesting that short sleep duration may be a consequence of overweight/obesity. In fact, some studies have shown an association between obesity and sleep-disordered breathing (e.g. sleep apnea), which may lead to shorter sleep duration (Redline et al., 2007; Redline et al., 1999). However, the present study not only supports a temporal sequence, but also examined the role of 'snoring' in boys and found that, although 'snoring' was associated with longitudinal sleep duration pattern at the bivariate level, it did not associate with overweight/obesity in boys at either age 6 or 7 years, neither when examined at the bivariate nor at the multivariate level. Consequently, although some of the literature indicates that obesity may be a cause of shorter sleep duration, the findings of the present study strongly suggest that the causal direction is likely to be in the opposite direction, with a closed loop in the association occurring perhaps only for the very obese (Amin & Daniels, 2002; Hitze et al., 2009).

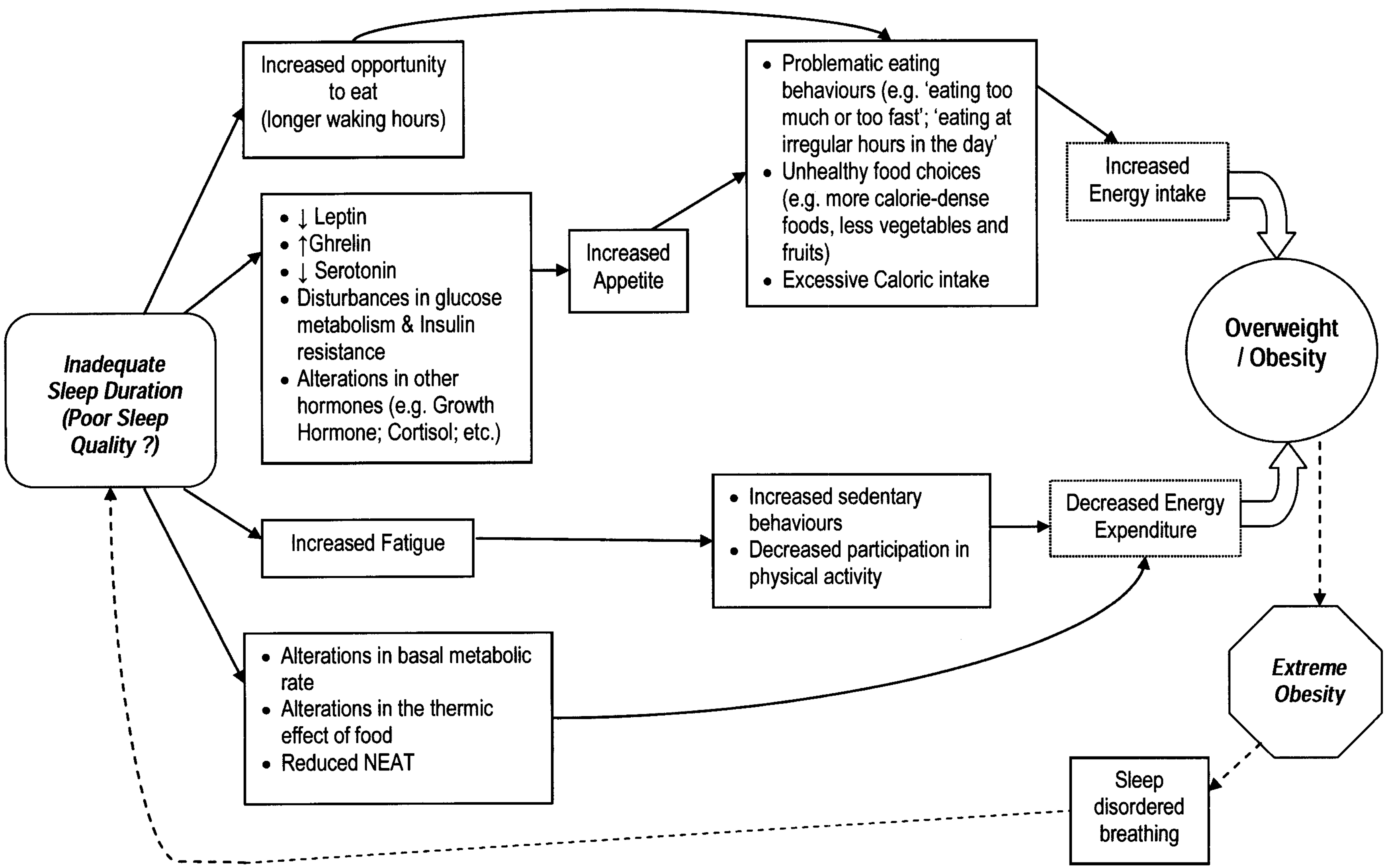
Third, the present study also utilized measured, rather than parent-reported, indices of height and weight to determine children's BMI. A previous study with the QLSCD cohort showed that using parental reports of children's heights and weights overestimated the prevalence of overweight by over 3% in this study population and by 5% specifically for boys; this was due to mothers overestimating their children's weights more than their heights, especially for boys (Dubois & Girard, 2007). Another study showed that parental reports tend to underestimate the prevalence of overweight in young children (Scholtens et al., 2007). These studies underscore the importance of using measured weight and height to obtain more accurate and reliable estimates of children's BMIs.

Finally, the present study took into consideration several important child, parent, and family demographic/socio-economic characteristics to account for potentially confounding variables to the association between sleep duration, dietary intake/eating behaviour, and overweight/obesity. Furthermore, as the relationship between longitudinal sleep duration pattern and overweight/obesity was only found to be significant for boys, a sex-specific covariate selection process was conducted to ensure that the factors deemed most pertinent to boys were included in the final multivariate models to control for potential confounding.

6.5 *A proposed model for future research*

This study confirms the existence of a strong, longitudinal association between sleep duration and overweight/obesity in young, male children, and provides some answers as to how this association is partially mediated; however, the findings of this study also raise many questions. Figure 6 outlines the hypothesized pathways by which inadequate sleep duration has been proposed to influence BMI and increase the prevalence of overweight/obesity, as is reviewed in the literature presented throughout this manuscript and by the present study's findings. Yet, if the findings of this study are replicated in other child populations, questions remain: Why is this association present in boys and not in girls? How come boys with a shorter longitudinal sleep duration pattern exhibit problematic eating behaviours ('eating too much or too fast' or 'eating at irregular hours in the day'), which in turn mediate part of the association with overweight/obesity, whereas longitudinal sleep duration pattern does not associate with these problematic eating behaviours in girls? Do differences lie at the biological level, such that inadequate sleep duration does not produce the same metabolic and hormonal changes in girls as in boys? Or, are the sex-differences in this association exacerbated in boys simply as a result of sleep-quality itself? Further, high quality prospective and intervention epidemiological studies are needed to thoroughly dissect the underlying factors driving sex-differences in the sleep duration – overweight/obesity association, and to confirm the remaining factors mediating this association in young boys (e.g. possible caloric/macronutrient intake differences; snacking habits; unhealthy obesogenic meal practices such as breakfast skipping (Dubois et al., 2009) and eating in front of the television (Dubois et al., 2008); and factors related to energy expenditure).

Figure 6: Hypothesized pathways by which sleep duration is proposed to affect overweight/obesity



6.6 *Conclusion*

With the obesity epidemic spreading to all ages and genders, it is increasingly important to understand every underlying factor driving this epidemic in order to properly create effective, multifaceted strategies and interventions to counter this trend. Although, diet (energy intake) and physical activity (energy expenditure) are the main factors responsible for overall energy regulation, to date, dietary and exercise interventions to reduce the prevalence of overweight and obesity have not been very successful (Deshmukh-Taskar et al., 2006; McManus et al., 2001). Other measures must be taken to address the factors that may *lead* an individual to regulate his or her energy balance more effectively. In concordance with the literature, this study indicates that sleep duration is one important factor that may promote proper energy regulation to counter the overweight/obesity epidemic in young boys.

Our findings suggest that the effect of inadequate sleep duration on the prevalence of overweight/obesity in young boys is likely to be cumulative over time and is partially mediated through poor eating behaviours such as ‘eating at irregular hours in the day’ and ‘eating too much or too fast’. This finding underscores the importance of addressing sleep duration patterns in early childhood, making sure that boys regularly receive greater than 10 hours of sleep per night to reduce the prevalence of overweight/obesity. Even though no association was found between sleep duration pattern and overweight/obesity in young girls, this finding does not imply that the importance of sleep duration should be overlooked in young girls. Firstly, sleep duration is shown to associate with many other health problems and in both sexes; these include, all-cause mortality, cardiovascular disease, and Type 2 diabetes (Ayas et al., 2003a; Ayas et al., 2003b; Gangwisch et al., 2006; Kripke et al., 2002; Patel et al., 2004; Tamakoshi & Ohno, 2004; Yaggi, Araujo, & McKinlay, 2006). Secondly, the sex-differences observed in the present study must be replicated in prospective epidemiological studies from other child populations.

Providing healthy food choices, healthy eating behaviours, and having an environment that promotes physical activity are key factors in the fight against overweight/obesity. However, with an awareness of how adequate sleep duration may promote such healthy eating behaviours and overall energy regulation, thereby reducing the prevalence of overweight/obesity in young boys, interventions can be made to encourage adequate sleep duration along with healthy dietary practices and physical activity to have greater success in countering the current obesity epidemic. Schools and health practitioners should ensure that parents are reminded to pursue measures to promote sleep hygiene (Box 4) to help children receive adequate amounts of sleep duration (Taheri, 2006).

Box 4: Measures to promote Sleep Hygiene

- Create a regular bedtime routine
- Keep strict bed and wake times
- Ensure sleeping areas are quiet, dark, and relaxing, and have a comfortable temperature
- Make sure the bed is comfortable, is only used for sleeping and not other activities (such as reading, playing games, watching television or listening to music)
- Promote physical activity during the day, but not within a few hours of bedtime
- Do not keep televisions, computers and distracting gadgets in the bedroom
- Avoid large meals near bedtime
- Avoid activities that may be arousing around bedtime (such as computer games or arguments)
- Dim the lights in the evening
- Provide exposure to bright light upon awakening in the morning

Finally, future intervention studies are needed to examine the impact of promoting longer sleep duration in children on caloric and macronutrient intakes, eating behaviours, and physical activity to prevent overweight/obesity and other related diseases, while taking into consideration possible sex-differences and other potential confounding factors.

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Appendices

Appendix A: 'With-'analyses at age 6 years - includes boys with missing values on covariates.

Unadjusted and adjusted† odds ratios£ and 95% confidence intervals for overweight/obesity in boys at 6 years of age, according to longitudinal sleep duration pattern (2.5 to 6 years) alone, or with adjustments for dietary intake and eating behaviour at 6 years of age.

	BOYS			
	Overweight *or* obese at 6 years (15.9%)			
Base Model 1: Longitudinal sleep duration pattern *only – Adjusted and unadjusted for potential confounders*				
Variable	**Unadjusted OR§**	**95% CI§**	**Adjusted for other covariates † OR**	**95% CI**
Longitudinal sleep duration pattern (average sleep at night from age 2.5 to 6yrs)				
Short persistent *or* short increasing pattern (14.6%)	7.07**	3.22, 15.52	6.61**	2.75, 15.90
10-hour persistent pattern (52.4%)	2.86*	1.43, 5.75	3.06*	1.43, 6.56
11-hour persistent pattern (32.9%) ‡	1.00	--	1.00	--
Model 2: Longitudinal sleep duration pattern and Vegetable consumption – *Adjusted and unadjusted for potential confounders*				
Variable	**Adjusted for the model's main variables only OR**	**95% CI**	**Adjusted for additional covariates † OR**	**95% CI**
Longitudinal sleep duration pattern (average sleep at night from age 2.5 to 6yrs)				
Short persistent *or* short increasing pattern (14.6%)	6.24**	2.82, 13.84	6.45**	2.67, 15.58
10-hour persistent pattern (52.4%)	2.87*	1.43, 5.78	3.11*	1.45, 6.68
11-hour persistent pattern (32.9%) ‡	1.00	--	1.00	--
FFQ: Vegetables (times per day)				
≤1/day (56.2%)	1.65	0.96, 2.82	1.20	0.66, 2.19
> 1/day (43.8%)‡	1.00	--	1.00	--
Model 3: Longitudinal sleep duration pattern and Fruit consumption (excluding juices) – *Adjusted and unadjusted for potential confounders*				
Variable	**Adjusted for the model's main variables only OR**	**95% CI**	**Adjusted for additional covariates † OR**	**95% CI**
Longitudinal sleep duration pattern (average sleep at night from age 2.5 to 6yrs)				
Short persistent *or* short increasing pattern (14.6%)	6.52**	2.95, 14.39	6.49**	2.67, 15.77
10-hour persistent pattern (52.4%)	2.82*	1.40, 5.56	3.22*	1.48, 6.96
11-hour persistent pattern (32.9%) ‡	1.00	--	1.00	--
FFQ: Fruits (only) (times per day)				
≤1/day (52.0%)	1.57	0.94, 2.62	1.64	0.94, 2.86
> 1/day (48.0%) ‡	1.00	--	1.00	--

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(continued)

	BOYS			
	Overweight *or* obese at 6 years (15.9%)			

Model 4: Longitudinal sleep duration pattern and Eating Behaviour Pattern (Eats at irregular hours in the day) – *Adjusted and unadjusted for potential confounders*

Variable	Adjusted for the model's main variables only OR	95% CI	Adjusted for additional covariates † OR	95% CI
Longitudinal sleep duration pattern (average sleep at night from age 2.5 to 6yrs)				
Short persistent *or* short increasing pattern (14.6%)	6.06**	2.72, 13.49	5.79**	2.38, 14.12
10-hour persistent pattern (52.4%)	2.71*	1.35, 5.46	3.00*	1.40, 6.45
11-hour persistent pattern (32.9%) ‡	1.00	--	1.00	--
Eats at irregular hours in the day				
No (89.8%)‡	1.00	--	1.00	--
Yes – Irregular eater (10.2%)	2.24*	1.15, 4.39	2.19*	1.01, 4.74

Model 5: Longitudinal sleep duration pattern and Eating Behaviour Pattern (Eats too much *or* too fast) – *Adjusted and unadjusted for potential confounders*

Variable	Adjusted for the model's main variables only OR	95% CI	Adjusted for additional covariates † OR	95% CI
Longitudinal sleep duration pattern (average sleep at night from age 2.5 to 6yrs)				
Short persistent *or* short increasing pattern (14.6%)	5.58**	2.48, 12.57	5.19**	2.08, 12.97
10-hour persistent pattern (52.4%)	2.59*	1.27, 5.28	2.67*	1.21, 5.86
11-hour persistent pattern (32.9%) ‡	1.00	--	1.00	--
Eats too much or too fast				
No (60.4%)‡	1.00	--	1.00	--
Yes – Eats too much or too fast (39.6%)	4.33**	2.53, 7.42	5.05**	2.72, 9.40

Model 6: Longitudinal sleep duration pattern and *both* Eating Behaviour Patterns – *Adjusted and unadjusted for potential confounders*

Variable	Adjusted for the model's main variables only OR	95% CI	Adjusted for additional covariates † OR	95% CI
Longitudinal sleep duration pattern (average sleep at night from age 2.5 to 6yrs)				
Short persistent *or* short increasing pattern (14.6%)	4.59**	2.00, 10.53	4.47*	1.76, 11.32
10-hour persistent pattern (52.4%)	2.40*	1.17, 4.92	2.59*	1.17, 5.72
11-hour persistent pattern (32.9%) ‡	1.00	--	1.00	--
Eats at irregular hours in the day				
No (89.8%)‡	1.00	--	1.00	--
Yes – Irregular eater (10.2%)	2.63*	1.28, 5.40	2.39*	1.06, 5.42
Eats too much or too fast				
No (60.4%)‡	1.00	--	1.00	--
Yes – Eats too much or too fast (39.6%)	4.56**	2.64, 7.88	5.19**	2.77, 9.71

* Significantly different from the reference category (two-sided $p \leq 0.05$)
** Significantly different from the reference category (two-sided $p \leq 0.001$)
†Adjusted for all variables in the model as well and the following covariates: 'Child overweight *or* obese at 2.5yrs'; 'mother's immigrant status'; 'mother classified as overweight *or* obese'; and, 'household income'.
‡Reference category
§ OR, odds ratio; CI, confidence interval
£ Weighted.

Appendix B: 'With-'analyses at age 7 years - includes boys with missing values on covariates.

Unadjusted and adjusted† odds ratios£ and 95% confidence intervals for overweight/obesity in boys at age 7 years, according to longitudinal sleep duration pattern (2.5 to 6 years) alone, or with adjustments for dietary intake and eating behaviour at 6 years of age.

	BOYS			
	Overweight *or* obese at 7 years (14.8%)			
Base Model 1: Longitudinal sleep duration pattern *only – Adjusted and unadjusted for potential confounders*				
Variable	**Unadjusted OR§**	**95% CI§**	**Adjusted for other covariates † OR**	**95% CI**
Longitudinal sleep duration pattern (average sleep at night from age 2.5 to 6yrs)				
Short persistent *or* short increasing pattern (13.1%)	4.34**	1.91, 9.90	4.60**	1.87, 11.31
10-hour persistent pattern (53.1%)	2.23*	1.13, 4.42	2.23*	1.07, 4.65
11-hour persistent pattern (33.9%) ‡	1.00	–	1.00	--
Model 2: Longitudinal sleep duration pattern and Vegetable consumption				
Variable	**Adjusted for the model's main variables only OR**	**95% CI**	**Adjusted for additional covariates † OR**	**95% CI**
Longitudinal sleep duration pattern (average sleep at night from age 2.5 to 6yrs)				
Short persistent *or* short increasing pattern (13.1%)	3.63*	1.57, 8.37	4.14*	1.66, 10.28
10-hour persistent pattern (53.1%)	2.21*	1.11, 4.40	2.30*	1.10, 4.82
11-hour persistent pattern (33.9%) ‡	1.00	–	1.00	--
FFQ: Vegetables (times per day)				
≤1/day (54.8%)	2.06*	1.15, 3.70	1.88*	1.01, 3.51
> 1/day (45.2%)‡	1.00	–	1.00	--
Model 3: Longitudinal sleep duration pattern and Eating Behaviour Pattern (Eats too much *or* too fast)				
Variable	**Adjusted for the model's main variables only OR**	**95% CI**	**Adjusted for additional covariates † OR**	**95% CI**
Longitudinal sleep duration pattern (average sleep at night from age 2.5 to 6yrs)				
Short persistent *or* short increasing pattern (13.1%)	3.40*	1.45, 7.96	3.73*	1.47, 9.49
10-hour persistent pattern (53.1%)	2.03*	1.01, 4.08	1.96	0.92, 4.18
11-hour persistent pattern (33.9%) ‡	1.00	–	1.00	--
Eats too much or too fast				
No (61.1%)‡	1.00	--	1.00	--
Yes – Eats too much or too fast (38.9%)	4.04**	2.29, 7.15	4.94**	2.60, 9.39

* Significantly different from the reference category (two-sided $p \leq 0.05$)

** Significantly different from the reference category (two-sided $p \leq 0.001$)

†Adjusted for all variables in the model as well and the following covariates: 'Child overweight *or* obese at 2.5yrs'; 'mother's immigrant status'; 'mother classified as overweight *or* obese'; and, 'household income'.

‡Reference category

§ OR, odds ratio; CI, confidence interval

£ Weighted.

Appendix C: Authorization to use copyright material for "Box 1: IOTF schematic of the determinants of obesity" -- (*Paste of email communication*)

-----Original Message-----
From: Rachel Jackson Leach [mailto:rleach@iaso.org]
Sent: December 14, 2009 3:16 AM
To: Fabiola Tatone
Subject: RE: Requesting permission to use copyright material (urgent request, please)

Dear Fabioloa

Providing you fully reference the source you are welcome to reproduce the figure.

Good luck with your thesis.

Kind regards

Rachel

Rachel Jackson-Leach
Senior Policy Officer
International Association for the Study of Obesity (IASO)
28 Portland Place, London W1B 1LY, UK
Tel: + 44 (0) 20 7467 9612
Fax: + 44 (0) 20 7636 9258
Web: www.iaso.org <http://www.iaso.org/>

From: Fabiola Tatone [mailto:ftatone@uottawa.ca]
Sent: Fri 11/12/2009 18:53
To: Obesity
Subject: Requesting permission to use copyright material (urgent request, please)

Dear IOTF Secretariat,

I am writing to request permission to include a figure from one of your well respected articles into my Master's Thesis (MSc in Epidemiology).

The figure I am referring to is Figure 9 (Societal policies and processes with direct and indirect influences on the prevalence of obesity and under-nutrition) from your article:

Kumanyika S, Jeffery RW, Morabia A, Ritenbaugh C, Antipatis VJ, Public Health Approaches to the Prevention of Obesity (PHAPO) Working Group of the International Obesity Task Force (IOTF). Obesity Prevention: The Case for Action. Int J Obes, 2002;26(3):425-36.

My Master's Thesis is entitled: "Examining the association between sleep duration, diet and body mass index in Québec children". The figure would be included as part of my literature review on the determinants of obesity and will not be altered in any way. You can rest assured that the reprint of your work will not be used to mislead, slander, or bring the author into disrepute, and the figure will be properly sourced and attributed. I do not plan to sell this work. The thesis will be kept in the University's library (University of Ottawa, Canada), and a microfilmed version will be stored at the National Library of Canada.

Should you agree to grant me permission to use your material, kindly, would it be possible to obtain your written permission to include your figure into my Thesis?

My name and contact information is:

Fabiola Tatone-Tokuda
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Canada
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Email: ftatone@uottawa.ca

Thank you for taking the time to review my request. I look forward to hearing from you soon.

Sincerely,

Fabiola Tatone-Tokuda