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Diet Quality and Body Mass Index in 4 and 6 Year Old Children:
A Prospective Study Using Data from the Québec Longitudinal Study of Child Development

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Diet quality and Body Mass Index in 4 and 6 year old children: A prospective study using data from the Québec Longitudinal Study of Child Development

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ABSTRACT

The prevalence of childhood obesity is increasing at an alarming rate worldwide. The diets of children have shifted from nutrient-dense foods to energy-dense, nutrient-dilute foods.

Using data from the Québec Longitudinal Study of Child Development, this study aims to identify the nutritional factors related to BMI at 4 and 6 years and weight change from 4 to 6 years. This study also compares the diets of normal and overweight/obese children according to the DRI standards set by Health Canada. Associations were examined using chi-square tests, and multivariate linear and logistic regressions.

The nutrition variables which appear to consistently be associated with overweight and/or BMI are linolenic acid, saturated fat and grain products. A significant difference in linolenic acid, phosphorous and iron was found between healthy weight and overweight/obese children. Also, meeting the DRI recommendations of various nutrients differs among children from various demographic and socioeconomic groups.

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Table of Contents

List of Tables

List of Footnotes

List of Appendices

Chapter 1: Introduction

The prevalence of childhood obesity is increasing at an alarming rate worldwide. Globally, there are approximately 1 billion overweight adults with 300 million of them that are obese (World Health Organization, 2006). Social and behaviour changes over decades have facilitated the growth of this epidemic and as a result, the epidemic is also present in children (Murray and Battista, 2009; Markovic and Natoli, 2009). Both short-term and long-term effects of obesity have significant physical, mental and emotional repercussions (Children's Food in Canada, 2009; Engeland et al., 2003; Guo et al., 2002). Childhood obesity sets the stages for numerous health complications and diseases in adulthood. As a result, tremendous direct and indirect health care costs are associated with obesity.

This chapter reviews: 1) The definition and classification of overweight and obesity, 2) childhood obesity statistics in the United States and Canada, 3) the etiology of the disease and lastly, 4) the rationale for examining the relationship between diet and body mass index in children.

1.1 Background

1.1.1 Definition and Classification

Obesity is defined as an "abnormal or excessive fat accumulation" (WHO, 2006) and poses as a risk factor for numerous debilitating conditions. Childhood obesity is a multi-factorial disease convoluted in genetic, psychological, behavioural and environmental risk factors (Sorensen & Echwald, 2001; Wang & Brownell, 2005). Although this condition is complex in terms of causality, consumption of energy-dense foods with high-sugar levels or high-saturated fats and reduced physical activity are the leading contributors to this disease

(WHO, 2006). Basically, it is believed that obesity is a result of an energy input that exceeds energy output.

Ideally, the most precise estimates of total body fat are taken through direct measures of body composition such as underwater weighing (hydro-densitometry), air-displacement plethysmography, magnetic resonance imaging (MRI), computerized tomography (CT), or bioelectrical impedance analysis (BIA); however, these methods are costly and unsuitable for children and large population studies (Lobstein et al., 2004; Lobstein and Leach, 2007). Body mass index (BMI) is the most practical indirect measure of body fatness and is most commonly used for population-based studies (WHO, 2000). BMI is calculated by dividing the weight (in kilograms) by height squared (in meters). At the individual level, BMI may not accurately measure body fatness in people that are muscular, short, tall, or those of old age with degenerative muscle loss (Lobstein et al., 2004). BMI, however, is considered by the World Health Organization as the most useful population-level measure of obesity in adults and in children when taking into account age and sex (WHO, 2000).

Currently, the most common classification systems, which use BMI as an indicator of body fatness, are the International Obesity Task Force (IOTF) and the U.S.A. Centers for Disease Control and Prevention (CDC) growth charts. The IOTF was developed in 2000 by Cole et al. (2000) based on six large nationally representative cross-sectional surveys conducted in Brazil, Great Britain, Hong Kong, the Netherlands, Singapore and the United States. Age- and gender specific IOTF cut-off points for overweight and obesity children were determined by extrapolated backwards from adult cut-off points for 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). Thus, this method strongly predicts children's likelihood of being overweight or obese at 18 years of age, and allows for both interprovincial and international comparisons (Cole et al., 2000). *Table 1* summarizes the IOTF cut-off points for overweight and obesity by sex and age in children aged 2-18 years.

Table 1. International BMI classification according to IOTF standards based on sex and age for children between 2-18 years

	Overweight Defined as body mass index ≥25 kg/m²		Obesity Defined as body mass index ≥30 kg/m²	
Age (years)	Males	Females	Males	Females
2	18.41	18.02	20.09	19.81
2.5	18.13	17.76	19.80	19.55
3	17.89	17.56	19.57	19.36
3.5	17.69	17.40	19.39	19.23
4	17.55	17.28	19.29	19.15
4.5	17.47	17.19	19.26	19.12
5	17.42	17.15	19.30	19.17
5.5	17.45	17.20	19.47	19.34
6	17.55	17.34	19.78	19.65
6.5	17.71	17.53	20.23	20.08
7	17.92	17.75	20.63	20.51
7.5	18.16	18.03	21.09	21.01
8	18.44	18.35	21.60	21.57
8.5	18.76	18.69	22.17	22.18
9	19.10	19.07	22.77	22.81
9.5	19.46	19.45	23.39	23.46
10	19.84	19.86	24.00	24.11
10.5	20.20	20.29	24.57	24.77
11	20.55	20.74	25.10	25.42
11.5	20.89	21.20	25.58	26.05
12	21.22	21.68	26.02	26.67
12.5	21.56	22.14	26.43	27.24

13	21.91	22.58	26.84	27.76
13.5	22.27	22.98	27.25	28.20
14	22.62	23.34	27.63	28.57
14.5	22.96	23.66	27.98	28.87
15	23.29	23.94	28.30	29.11
15.5	23.60	24.17	28.60	29.29
16	23.90	24.37	28.88	29.43
16.5	24.19	24.54	29.14	29.56
17	24.46	24.70	29.41	29.69
17.5	24.73	24.85	29.70	29.84
18	25	25	30	30

Data source: Cole et al., 2000

The second method commonly used as a classification system for childhood obesity uses BMI-for-age and sex-specific reference charts to classify overweight and obesity by BMI percentiles. To classify weight status, BMI is plotted on growth charts set up by the CDC in 2000, which rank weight by height, age and sex (National Health and Nutrition Examination Survey, (NHANES), 2009). These charts were developed by the national center for Health Statistics (NCHS) and have been revised as a result of recent data collections and advances in statistical procedures (NHANES, 2009). The latest revision occurred in 2000 where most of the data came from the National Health and Nutrition Examination Survey (NHANES, 2009). Initially, this committee recommended the use of the 85th and 95th percentiles for age and sex to define at "risk of overweight" and "overweight" respectively, to avoid the stigma associated with the term obesity (Kuczmarski et al., 2000). However, more recently, the term overweight replaced "at risk of overweight" and obesity replaced "overweight" (Bradford, 2009). The CDC revised growth charts for US children and adolescents include BMI-for-age charts for males and females aged 2-20 years, which can be used clinically or epidemiologically (Ogden et al., 2002). 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 sex-specific reference charts appropriate to their study population.

Studies have shown that the CDC obesity estimates produce a greater prevalence of obesity (Flegal et al, 2001 & Chinn, 2006). Additionally, the CDC obesity definitions can also be used in children under 2 years of age, unlike the IOTF definitions, which examine children between 2-18 years of age. The CDC estimates can be used for continuous and categorical BMI measures; however, the IOTF cut-offs only define overweight and obesity alone (Chinn, 2006). Despite the downfalls of the IOTF-cut offs, it is recommended that prevalence based on this method be given in addition to national reference data, since it allows for international comparisons (Barlow and Dietz, 1998).

Table 2 summarizes the classification of weight status according to BMI percentiles as set up by the CDC.

Table 2. BMI percentile classifications according to the CDC growth charts

BMI percentile classification	Range of BMI percentile
Underweight	1st to 10th percentile
Normal weight	10th to 84 9th percentile
Overweight	85th to 94.9th percentile
Obesity	95th to 100th percentile

Source NHANES (2009) and Bradford (2009)

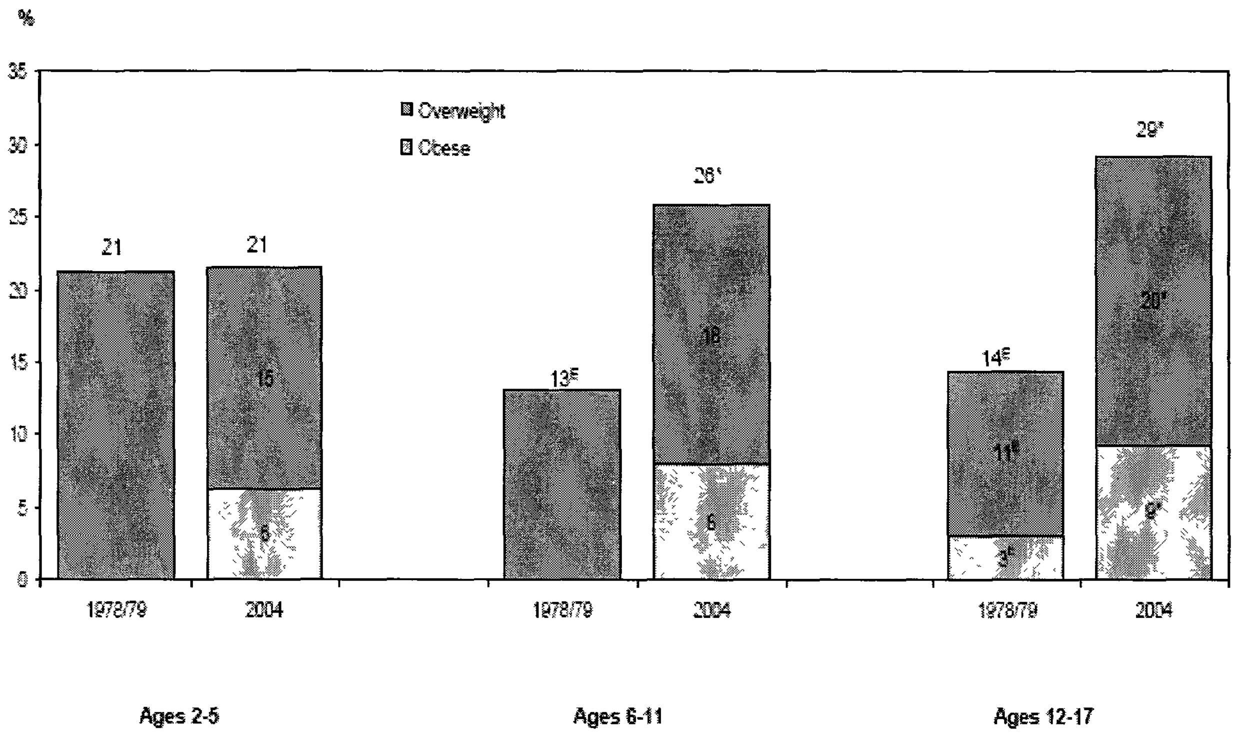
1.1.2 Childhood Obesity Statistics in the United States of America

The CDC and the NHANES collaborate every few years to collect data regarding the weight status of children. From 1960 to 1980, the prevalence of childhood obesity was stable.

However, “from the 1976 to 1980 period to the 2003-to 2004 period, the prevalence of obesity (defined as BMI ≥ the 95th percentile) increased dramatically in all age groups. The prevalence of obesity doubled in 2- to 5- year olds from 7.2% to 13.9%. In 6 to 11 years old, the prevalence went from 11% to 19%, and in 12- to 19- years old from 11% to 17%. Overall, in the 2003-to-2004 survey, 17% of the children and adolescents were obese” (Bradford, 2009).

1.1.3 Childhood Obesity Statistics in Canada

In Canada, the prevalence of obesity (BMI above the 95th percentile for age and sex) in children more than doubled between 1981-1996, from 5% to 16.6% for boys and from 5% to 14.6% for girls (Gillis and Gillis, 2005). The prevalence of overweight at this time (BMI above the 85th percentile for age and sex) among boys has increased from 15% to 35.4% and among girls from 15% to 29.2% as well (Gillis and Gillis, 2005). In 2004, the Canadian Community Health Survey (CCHS) found that 26% of children and adolescents between 2-17 years of age were overweight or obese, where approximately 8% were classified as obese (Statistics Canada, 2005). Between 1979 and 2004 (Figure 1), overweight and obesity doubled among 12-17 year olds from 14% to 29%) and tripled among 12-17 year olds (from 3% to 9%) (Statistics Canada 2005; Statistics Canada 2008). During 1979-2004, the percentage of children aged 2 to 5, who were overweight or obese remained stable, however, the prevalence of obesity itself rose 6% (Statistics Canada, 2005).



Data sources: 2004 Canadian Community Health Survey: Nutrition; Canada Health Survey 1978/79
Note: The obesity rates for the 2-5 and 6-11 age groups from the 1978/79 Canada Health Survey have coefficients of variation greater than 33.3%, therefore, the estimates are not releasable.
E Coefficient of variation between 16.6% and 33.3% (interpret with caution)
* Significantly different from estimate for 1978/79 ($p < 0.05$)

Figure 1. A comparison of the prevalence of overweight and obesity for Canadian children aged 2-5, 6-11, and 12-17 from 1978/79 to 2004.
*

1.1.4 Health complications associated with Obesity

Childhood obesity is associated with numerous physiological and psychological health disorders. These disorders include short-term health risks such as the development of "glucose intolerance and insulin resistance, type II diabetes, hypertension, sleep apnea, impaired balance, orthopedic problems, low self-esteem, negative body image, depression, negative stereotyping, teasing and bullying, and social marginalization" (Children's Food in Canada, 2009). In addition to these short-term effects, childhood obesity is related to long-terms effects,

* http://www.statcan.gc.ca/pub/82-620-m/2005001/article/child-enfant/8061-eng.htm

which continue into adolescence and adulthood. Long-term effects include type II diabetes mellitus, hypertension, hyperlipidemia, metabolic syndrome, polycystic ovarian syndrome or hyperandrogenism, obstructive sleep apnea, mental health, and neurological disorders, adult obesity and mortality (Engeland et al., 2003 & Guo et al., 2002).

Both the short and long-term effects of childhood obesity have imposed a direct and indirect economic burden on the health-care system of Canada (Katzmarzyk & Janssen, 2004; Lobstein et al., 2004; Wolf, 1998). Direct medical costs include diagnostic and treatment services related to obesity and obesity-related comorbidities (Lobstein et al., 2004). Indirect costs are related to the morbidity and mortality associated with the disease (Lobstein et al., 2004). Without sustainable prevention and management strategies, the economic impact of obesity will continue to grow and subsequently, drain the health-care and social systems of Canada.

1.2 Rationale

Over the last few decades there has been a shift in diet and activity patterns, which have propagated an epidemic of obesity among children and adolescents (Murray and Battista, 2009). This shift is a global transition – "from a period of famine, heavy physical activity patterns that are among the causes of non-communicable diseases" (Murray and Battista, 2009) to a period of poor diets and sedimentary lifestyles since 1980. These changes have caused the prevalence of obesity in all regions of the world to significantly increase (Murray and Battista, 2009).

Many factors seemed to rise during this time period, which has contributed, to this epidemic. This includes the use of soft drinks instead of water and milk, the development of video games, computers and home movies and changes in urban design which has allowed for fast food, long drives and eating in cars (Murray and Battista, 2009). Active lifestyles were replaced with sedimentary lifestyles (Markovic and Natoli, 2009). The diets of children and adults shifted from whole, nutrient-dense foods to energy-dense, nutrient-dilute foods. This has led to a paradoxical nutritional deficiency in overweight and obese individuals (Markovic and Natoli, 2009).

Good quality diets tend to be energy-dilute and nutrient-rich and thus contain a sufficient intake of energy, macronutrients, micronutrients, and other important nutrients such as fiber (Darmon and Drewnowski, 2008). For example, a diet high in whole grains, fish, fresh vegetables, and fruits is indicative of a good quality diet. A poor quality diet tends to be high in refined grains, sugar and fat (Darmon and Drewnowski, 2008). Consumption of these unhealthy foods suppresses satiety and provokes overeating and weight gain (Darmon and Drewnowski, 2008).

Despite speculation that both carbohydrate quantity and quality have contributed significantly to excess weight gain, the relationship between carbohydrate intake and body mass index is controversial. Although prospective observational studies performed in adults have found that a higher dietary glycemic index or lower intakes of fiber and whole grain are independently associated with weight gain (Hare-Brunn et al., 2006, Koh-Banerjee et al., 2004, Liu et al., 2003, Ludwig et al., 1999, Ma et al., 2005, Nooyens et al., 2005), these observations are not conclusive (Cheng et al., 2008, Iqbal et al, 2006) and minimal research exists in children.

Mixed findings have also been observed with protein intake and childhood obesity as well. The link between protein intake and childhood obesity is a relatively recent finding. A cross-sectional study conducted in Italy found that protein intake was not significantly different between obese and non-obese children (Rocandio et al., 2001). However, longitudinal studies have demonstrated a positive link between protein intake and overweight in children (Skinner et al., 2004; Scaglioni et al., 2000; Gunther et al., 2007). It has also been suggested that the type of protein consumed, whether animal, plant or dairy, is associated with obesity rather than protein intake as a whole (Gunther et al., 2007). Due to the novelty of these findings, it is important to investigate the relationship between this macronutrient and childhood obesity.

Additionally, little research exists as to whether the quality of dietary fats, not just the quantity, is related to overweight and obesity. Studies have demonstrated that a diet high in saturated fats causes weight gain and obesity in adults (Soares, 2003) since saturated fats are stored in adipose tissue rather than being subjected to oxidation (Piers, 2003). Monounsaturated fats, on the other hand, have shown to have significant health benefits (Soares, 2003). They increase fat oxidation and induce greater thermogenesis of food, which prevents weight gain (Soares, 2003). Diets high in monounsaturated fats also improve insulin sensitivity (Riccardi, 2004) and have a low energy density (Soares, 2003). Soares et al. (2003) observed that men following a diet high in monounsaturated fats have lower body weight and greater fat loss than those consuming a diet high in saturated fats. A similar study found that men had a greater weight loss when they consumed a diet high in monounsaturated fats than those with a diet high in saturated fats with similar energy intakes (Piers, 2003). This suggests that monounsaturated fats can induce significant losses in body weight without significant changes in energy intake. Additionally, saturated fatty acids, and polyunsaturated fatty acids are positively associated with the prevalence of obesity in adults (Moussavi, 2007). A strong negative association also exists between monounsaturated fats and the prevalence of obesity (Moussavi, 2007). In contrast, polyunsaturated fats (especially those found in fish oil) in addition to monounsaturated fats (especially those found in olive oil) have been found to promote weight loss (Moussavi, 2007) and have health benefits, which protect against heart disease. However, studies of these types of fats in children are minimal.

In our study, we assessed the association of diet quality in relation to body mass index in pre-school children. Diet quality will be assessed by examining carbohydrate, protein, and fat intake of children between 4 and 6 years of age. Additionally, the diets of children from various demographic and socioeconomic groups will be compared and contrasted. These findings may suggest hidden social inequalities present in society and promote new research to improve nutrition as a means of preventing childhood obesity.

Chapter 2: Literature Review

This chapter presents 1) the covariates that are common to both diet quality and overweight/obesity, 2) a description of how different covariates relates to diet quality and overweight/obesity in children and lastly, 3) a literature review which investigates the relationship between diet quality and overweight/obesity.

2.1 Common covariates of diet quality and overweight/obesity in children

Diet quality and overweight/obesity in children have several common covariates, which are significantly related to both of these variables (see Table 4). This relationship can be confounded by several covariates and thus controlling for these cofounders is imperative. A confounder is defined as "the mixing of effects between an exposure, an outcome, and a third extraneous variable known as a confounder" (Achengrau and Seage III, 2003). Confounders distort the relationship between an outcome and exposure variable since a relationship is present between the confounder and outcome and confounder and exposure. Controlling for the influences of extraneous factors is necessary in order to ensure the study is valid and the findings are accurate.

An indictor of overall diet quality can be measured by energy density; energy available from foods per unit weight (Darmon and Drewnowski, 2008). Good quality diets tend to be energy-dilute and nutrient-rich, thus, they have sufficient intakes of energy, macronutrients, micronutrients, and other important nutrients such as fiber (Darmon and Drewnowski, 2008). For example, diets high in whole grains, fish, fresh vegetables, and fruits are indicative of good diet quality. Diets of poor quality tend to be high in refined grains, sugar and fat (Darmon and Drewnowski, 2008). These types of foods suppress satiety, provoke overeating and in turn cause weight gain (Darmon and Drewnowski, 2008). Diet quality is strongly influenced by a child's physical and social environment. A discussion regarding the child, parent, demographic and socioeconomic factors related to a child's diet quality are presented below.

2.1.1 Relationship between child characteristics and diet quality

It is well known that poor diet quality and a sedimentary lifestyle highly influence body weight in children. However, several other child characteristics are associated with poor diet quality as well. Veugelers et al. (2005) found that girls who are 10-11 years of age have diets of better quality than boys of the same age. Specifically, it was found that boys have a 7% higher risk of poor diet quality in comparison to girls. Skipping breakfast has also been shown to be significantly associated with a poor diet as well (Dubois et al., 2005; Dubois et al., 2007; Veugelers et al., 2005). Skipping breakfast puts children at an 18% higher risk of poor diet quality (Dubois et al., 2007). Meals eaten in front of televisions, sedentary activities (TV, computer, video games), and low physical activity levels have also been linked to poor diets in children (Patrick and Nicklas, 2005; Boumtje et al., 2005; Veugelers et al., 2005). Additionally, child-care centres have an impact on children's diet quality (Pollard, 2001). Regulations or policies that ensure proper nutrition and physical activity are not mandatory in many child-care centres. Child-care providers have a significant impact on children's health practices (Pollard, 2001), thus, the importance of educated instructors which ensure good diet quality and physical activity levels can impact children obesity rates.

Chronic disease has also been linked to poor diet quality in children. Feeding problems in children with chronic illness is a common issue in these children. Children with chronic illnesses tend to be fussy eaters and are prone to malnutrition. Child temperament affects diet quality since food refusal is common in some disease processes (Harris et al., 2000). Dietary restrictions or demands exist with certain chronic diseases such as asthma, diabetes, cystic fibrosis and chronic renal disease (Fielding and Alistair, 1999). Diseases affecting major organs are likely to cause children to have trouble with food acceptance, in addition, to certain minor diseases as well (Harris et al., 2000).

Several demographic and socioeconomic factors are related to diet quality (Patrick and Nicklas, 2005; Darmon and Drewnowski, 2008; Veugelers et al., 2005; Campbell et al., 2002). Specifically, a step-wise gradient between socioeconomic status and diet quality has been observed (Darmon and Drewnowski 2008; Veugelers et al., 2005). Individuals from higher socioeconomic status tend to consume more whole grains, lean meats, fish, low-fat dairy products, and fresh fruits and vegetables (Darmon and Drewnowski, 2008). Poor diets are also more prevalent among children from families of low socioeconomic status. These children tend to consume more refined grains, high-sugar and high-fat in their diets (Darmon and Drewnowski, 2008). A review conducted by Darmon and Drewnowski (2008), found that in the United States, the consumption of refined cereals (white bread), pasta, rice, added fats, and fatty meats were associated with lower socioeconomic status. In contrast, high socioeconomic families consumed more fresh vegetables and fruits, as well in a higher portion, to those from low socioeconomic families. This trend has also been observed in European countries (Irala-Estevez et al., 2000), Australia, (Giskes et al., 2002), the Netherlands (Giskes et al., 2004), and in Canada (Ricciuto and Tarasuk, 2007).

Veugelers et al. (2005) conducted a study in Nova Scotia, Canada, which examined the risk factors associated with poor diet among grade five children. This study found that parental place of origin (other than Canada), martial status of the parents (married or common law, separated or divorced, or single or widowed) and household annual income were not related to diet quality. However, household annual income has been positively associated with overweight among children in other studies conducted in the United States (Boumtje et al., 2005; Patrick and Nicklas, 2005). Children of parents with healthy eating practices, high socioeconomic backgrounds, and high parental education have been observed to have good quality diets (Veugelers et al., 2005; Boumtje et al., 2005; Patrick and Nicklas, 2005). Particularly, in the United States, children of parents with low education tend to consume less fruits and vegetables and have a limited selection of this food group to eat (Kirby et al., 1995). In some cases, children do not meet recommendations for fruits and vegetables by 40% (Neumark-Szatainer, 1998). Low intake of fruits and vegetables and high intake of sweetened beverages has also been observed in children from families of low socioeconomic status in European countries (Serra-Majem et al., 2002; Haapalahti et al., 2003; Laitinen et al., 1995; Vereecken et al., 2005). These children also have high intakes of sweetened beverages as well (Kirby et al., 1995).

Additionally, Patrick and Nicklas (2005) found that children from parents with higher education make healthy food choices and thus have "higher intakes of carbohydrates, protein, fiber, folate, vitamin A, and calcium; higher consumption of vegetables; and greater likelihood of consuming the recommended servings of dairy products" per day. Children from higher income families which have a higher intake of "polyunsaturated fats, protein, folate, calcium, and iron and were more likely to meet the recommended number of daily servings for dairy products" (Patrick and Nicklas, 2005). In the U.S, Crawford et al. 1995 demonstrated an inverse relationship between the percent of kilocalories consumed from fat in children and parental education and family income. A strong negative relationship exists between maternal education and children's consumption of sugar intake, as opposed to paternal education alone (Patrick and Nicklas, 2005; Campbell et al., 2002). Exclusive use of whole milk has been observed in families with parents that had less than a high school education as opposed to reduced fat milk, which was highest among parents who had graduated from college (Patrick and Nicklas, 2005). Mothers who were least educated and youngest also rely more heavily on convenience foods to feed their children (Lowry et al. 1996). Children from mothers with a higher education also tend to watch less television during evening meals (Campbell et al., 2002) and also are more likely to breastfeed their children (Martinez and Nalezienski, 1981). Breastfeeding has been observed to have a protective role against childhood obesity as well (Dubois and Girard, 2006).

Children of single parent homes or of two parents working outside the home tend to have poor diets as well (Patrick and Nicklas, 2005). Since these parents have longer work hours, they rely on convenience foods (i.e. fast foods) to feed their children as a result of time constraints. Mother's who are overweight also make poor food choices for their children, thus mother's behaviour significantly influences the child's diet quality (Khloe-Lehman et al., 2007). Lastly, rural dwelling creates difficultly in obtaining energy-dilute, nutrient-dense foods at reasonable prices. In addition to high costs, fruits and vegetables available in rural setting tend to be of poor quality and limited variety (Campbell et al., 2002). Thus, easy access to energy-dense foods becomes the norm in these locations and perpetuates poor diet in these communities (Darmon and Drewnowski 2008; Campbell et al, 2002).

Birth weight of children, an indicator of socioeconomic status, is indirectly related to diet quality. Low birth weight is associated with low socioeconomic status since an unequal number of low birth weights are found among low socioeconomic families in comparison to high socioeconomic families. Very low birth weight has been associated with increased morbidity in school-aged children, where the effect is amplified in those from low socioeconomic status families (McCormick, et al., 1992). Inequalities in low birth weight have also been observed in England, where a study found that 30% of low birth weights occur among socioeconomically disadvantaged families (Pattenden et al., 1999). Children from low-income families with parents who smoke have been observed to have poor diets as well (Johnson, 1996). Johnson et al., (1996) observed that "children whose parents smoked 11 or more cigarettes per day had lower vitamin A intakes and higher energy and sodium intakes than children whose parents smoked 10 or fewer cigarettes per day." Johnston et al., (1996), also found that "children whose parents smoked more than 20 cigarettes per day had a higher percentage of energy from saturated fat, and children whose parents smoked 11 to 20 cigarettes per day had the highest cholesterol intakes in comparison to the rest of the sample." It is also found that parental smoking is related to low fiber intakes in children (Johnson et al., 1996). Thus, parental smoking status has a significant relationship with children's diet quality, and increases the risk of chronic illness in children.

2.1.2 Relationship between covariates and obesity

Early determinants or risk factors for overweight/obesity have been defined by several studies. A Québec longitudinal study conducted in children 4.5 years of age found various social and behaviours factors to be associated with childhood overweight/obesity (Dubois and Girard, 2006). Maternal smoking (Dubois and Girard 2006; Toschke et al., 2008), weight gain between birth and 5 months (Dubois and Girard, 2006), household annual income (Dubois and Girard, 2006), single-parent households (Strauss and Knight, 1999; Gibson et al., 2007) and parental overweight/obesity (Dubois and Girard, 2006; Toschke et al., 2008; Reilly et al.,

2005) were all deemed early determinants of overweight at 4.5 years of age (Dubois and Girard, 2006). Birth weight as a predictor of childhood obesity, however, has mixed results. Studies suggest that birth weight can predict weight gain later in childhood since it programs the fat accumulation in the intra-abdominal area (Druet et al., 2008). Thus, children born small for gestational age are prone to weight gain later in life (Hokken-Koelega et al., 1995, Ong et al., 2000, Reilly et al., 2005). However, positive associations have also been found between higher birth weights and higher BMI in childhood (Whitaker and Dietz, 1998). Thus, birth weight is believed to be a causal factor that puts children at risk of subsequent childhood obesity (Hokken-Koelega et al, 1995, Karlberg et al., 1997, Ong et al., 2000, Baird et al., 2005, Ong, 2006).

Studies conducted in the United States (Whitaker, 2004) and Germany (Danielzik et al., 2004) found that parental overweight was the most potent risk factor for childhood obesity. A study conducted by Toschke et al. (2008) found that maternal overweight and high weight gain of the child in the first two years of life were significant risk factors for childhood obesity. They found that if all children in a population were exposed to these risk factors equally (and were susceptible to this risk factor), then a shift in BMI distribution would be observed. The mechanism in which maternal overweight is thought to contribute to childhood obesity is not conclusive; however, influences on a child's diet through obesogenic available foods, maternal food habits, maternal food beliefs, and amount of food served are thought to be the main culprits (Agras and Mascola, 2005).

Maternal smoking during pregnancy was deemed an early determinant for overweight/obesity in children as well (Dubois and Girard, 2006; Toschke et al., 2008). It was found that maternal smoking during pregnancy almost doubled the odds of being overweight at

4.5 years of age (Dubois and Girard, 2006). Additionally, children born to non-smoking mothers but with a high birth weight (more than 4000 g) were overweight at 4.5 years. The majority of children, who were more likely to be overweight at 4.5 years, were born to smoking mothers and were of normal birth weight (3000-4000g). These children gained the most weight during the first 5 months of life, compared to children of non-smoking mothers (Dubois and Girard, 2006).

Skipping breakfast has also been associated with overweight/obesity in children at 4.5 years of age (Dubois and Girard, 2006). Dubois and Girard (2006) demonstrated that almost 10% of children do not eat breakfast everyday. A greater proportion of these children have immigrant mothers, mothers with no high-school diploma, and come from families with a low household annual income. Skipping breakfast in the morning nearly doubled the odds of being overweight at 4.5 years of age (Dubois and Girard, 2006) and is associated with a lower diet quality. Dubois et al., (2008) found that children that skipped breakfast would overcompensate by consuming high-energy snacks, carbohydrates and proteins in the afternoon and evening as opposed to a more even distribution of energy intake throughout the day.

In developed countries, there tends to be a negative trend between high socioeconomic status and childhood obesity. This finding had been observed in the United States (Stunkard et al., 2004) Canada, and Germany (Danielzik et al., 2004). However, this trend has not been observed in Brazil (da Viega et al., 2004) or Russia (Wang et al., 2002). A study conducted in the United States found that from 2003 to 2007 the prevalence of obesity increased 10% from 16.4% for all U.S. children (Singh et al., 2009). The prevalence of obesity was about 23-33% for children from low-education, low-income, and unemployed households (Singh et al., 2009). Additionally, the prevalence of obesity grew between these years among single-mother households and various minority groups such as Hispanics, non-Hispanic White, and America Indian children (Singh et al., 2009). Further demonstrating the social inequalities in obesity children, the odds of being obese in children from low-income and low-education families were 3.4-4.3 times higher than those from high socioeconomic families (Singh et al., 2009). Low maternal education, in particular, has been deemed a risk factor for childhood obesity (Saxton et al., 2009). Low maternal education influences poor feeding choices, which impacts the child's diet quality and weight status (Saxton et al., 2009).

Physical inactivity is a well-known risk factor for childhood obesity. Physical inactivity in children has been shown to be inversely associated with BMI (Segal et. al, 2009). However, measuring the activity level of a child is difficult and therefore determining the level of physical activity necessary to combat childhood obesity is complex. Studies using an accelerometer have found that insufficient vigorous physical activity have been linked to childhood obesity (Patrick et al., 2004). The link between reduced physical activity, increased screen time and childhood obesity have been observed as well. Sedentary activities such as computer use, video games, and television viewing have been linked to childhood obesity. Overweight children that par-take the most in sedentary activities tend to be the least physically active (Jannsen et al., 2004).

High frequency of television viewing alone is also a risk factor for childhood obesity (Toschke et al., 2008; Dubois et al., 2008; Manios et al., 2009; Reilly et al., 2005). Dubois et al., 2008 found that roughly one quarter of children in Québec eat in front of the television at least twice daily. Children that watched television at this frequency in addition to consuming snacks during this time had higher BMIs than children who watched television at a lower frequency (Dubois et al., 2008). Children who ate snacks in front of the television also consumed "more carbohydrates (total), more fat and less protein, fewer fruits and vegetables, and drank soft drinks more than children who never ate snacks in front of the television" (Dubois et al., 2008). Additionally, television viewing for more than 2 hours per day has been associated with increased consumption of high-energy foods which are of high-fat and high-sugar content in preschool children in Greece (Manios et al, 2009). Thus, television-viewing behaviour has a significant impact on children food habits. It increases the risk of overweight and obesity among children since it reduces physical activity and increases energy intake.

Breastfeeding has been thought to have a protective role against childhood obesity (Toshcke et al., 2008, Agras and Mascola, 2005). A dose-dependent response was found between duration of breastfeeding and childhood obesity, however, this relationship was only present if the child was breastfed for 3 or more months (Grummer-Strawn and Mei, 2004). The negative association between breastfeeding and childhood obesity is thought to be a result of greater self-regulation of the child's diet later in life. It was found that the longer a mother breastfeeds, the less likely they are to restrict a child's diet at 1 year of age. This is linked to controlling a child's feeding style, which is associated with childhood obesity (Agras and Mascola, 2005).

In addition to behavioural and parental influences, neighbourhood characteristics also have an impact on childhood obesity. Living in rural areas can restrict access to stores with reasonably priced fruits and vegetables, parks, and recreational facilities. This in turn increases sedentary behaviour and reduces physical play. A study conducted in Nova Scotia, Canada, found that children from neighborhoods that have access to grocery stores had diets of higher quality and were less likely to be overweight or obese (Veugelers, 2008). It was also found that children with access to parks and recreational facilities were more physically fit (Veugelers, 2008). This trend was also observed in neighborhoods deemed safe by the parent (Veugelers, 2008).

Childhood obesity can also have short-term and long-term health effects on chronic illness. Obese children are more likely to develop orthopedic disorders (Barlow and Dietz, 1998), sleep disorders (Barlow and Dietz, 1998), gall bladder disease (Barlow and Dietz, 1998), insulin resistance (Barlow and Dietz, 1998; Reilly, 2005), and cardiovascular disease risk factors (Reilly, 2005) such as hypertension, dyslipidaemia, and left ventricular abnormalities. Short-term health consequences also include psychological ill-health (Reilly, 2005), such as behavioural problems and low self-esteem, which may result from bullying, and lack of popularity/friendship (Reilly, 2005). Asthma and chronic inflammation are additional short-term health consequences of childhood obesity (Reilly, 2005). Persistence of obesity into adulthood is commonly seen in addition to the health consequences that accompany the disease. The persistence of obesity in later life is significantly associated with parental obesity and the length and severity of obesity during childhood (Reilly, 2005).

2.1.3 Conclusion

In conclusion, diet quality and overweight/obesity in children share many covariates that are necessary to control for in statistical modeling. *Table 3* summaries the relationship between various covariates, diet quality and overweight/obesity.

Table 3. Relationship between various covariates and diet quality and overweight/obesity

	Poor diet quality	Overweight/obesity
Child/Birth Characteristics		
Low birth weight (yes vs. no)	Positive	Positive or negative
Mother smoked during pregnancy (yes vs. no)	Positive	Positive
Breastfeeding (yes vs. no)	Negative	Negative
Chronic health illness (yes vs. no)	Positive	Positive
Level of physical activity (high vs. low)	Negative	Negative
Screen time (television watching, computer use) (high vs. low)	Positive	Positive
Child care/day care (yes vs. no)	Negative or positive	Negative or positive
Parent Characteristics		
Mother's level of education (high vs. low)	Negative	Negative
Mother's immigrant status (immigrant vs. non-immigrant)	Positive	Positive
Mother overweight/obese (obese vs. normal)	Positive	Positive
Demographic and Socioeconomic Characteristics		
Household annual income (high vs. low)	Negative	Negative
Family structure (single parent vs. intact)	Positive	Positive

Table 3. Relationship between various covariates and diet quality and overweight/obesity		
	Poor diet quality	**Overweight/obesity**
Urban dwelling (Rural vs. urban)	Positive	Positive

2.2 The Relationship Between Diet and Body Weight in Childhood: A Critical Appraisal of the Literature

This section details the critical appraisal of the literature that was conducted to determine what is currently known about the relationship between diet quality and overweight/obesity in children. The review was conducted prior to the initiation of the study described in the paper (November 2009) and updated upon completion of the study (June 2010).

2.2.1Literature Review Objective

The objective of this literature review was to use observational studies to assess the relationship between diet quality and childhood obesity in order to verify previous findings and propose methods to control childhood obesity.

2.2.2 Eligibility criteria

Studies were included if the relationship of diet quality (carbohydrate, protein, and dietary fats) was examined in association with overweight/obesity or BMI in children. The target population consisted of children between 1-15 years of age. This age group was chosen since it contained the age group examined in this study (4 and 6 years of age) and was presented as a limit using the main search engines. Studies conducted in under-developed or developing countries were excluded since the gap between the rich and the poor is greater in these countries and thus, socioeconomic inequalities are not comparable to Canada. Additionally, in contrast to developing countries, studies conducted in developed countries have found that the prevalence of overweight/obese children is greater in low socioeconomic groups.

The independent variable of interest (exposure) was diet quality. Studies were included if diet quality was measured by one or all macronutrients (carbohydrates, protein, fats) and studies that described individual intake of foods categories. Papers concerning only the temporal aspects of food intake (meal patterns, eating behaviours, etc.) were excluded since our study did not examine this type of relationship. Studies that focused solely on one or more micronutrients were excluded as well since our study focused on the relationship between macronutrients and childhood obesity.

The dependent variable of interest (outcome) was BMI or overweight/obesity. BMI or overweight must also be defined either by the IOTF, the CDC revised growth charts or another comparable growth chart. Studies that calculated BMI based on self-reported or measure height and weight measurements were included. Studies using skin fold thickness or waist circumferences alone were excluded. These studies were excluded to allow for meaningful comparison between populations.

Observational study designs were included in this review with the exception of randomized control trials. However, considering the unethical nature of randomized control trials, it is unlikely that these types of studies exist except in studies that focus on weight loss. Only studies published in English were included in this review.

2.2.3 Search Strategy

The electronic databases used to conduct this literature review include MEDLINE, EMBASE, CINHAL, Psych Info and In-process/non-indexed MEDLINE using the Ovid version 10.2.1 interface. The search strategy employed in MEDLINE is available in Appendix A. Search strategies for the other databases were adapted from the detailed search strategy used in MEDLINE. Only one reviewer was available to assess inclusion/exclusion criteria.

Search terms were based on the independent variable (diet quality, carbohydrates, proteins, fats), dependent variable (BMI or overweight/obesity), target population (children between 1-15 years of age), to the English language, and studies conducted in the last 10 years (2000-current) in developed countries. The exposure terms were grouped using the "OR" command and the outcome terms were grouped using the "OR" command as well. The findings of these commands were then grouped using the "AND" command.

The reference lists of all relevant articles were explored for additional studies relevant to this literature review. Additionally, manual searches were conducted between each exposure and each outcome using MEDLINE to ensure no relevant articles were left out.

All potential relevant studies were imported using a reference database (RefWorks). Duplicate and triplicate publications were removed from the initial search. After duplicate and triplicate publications were removed from the initial search, the titles and abstracts of 1333 potential studies were screened for inclusion. Full articles of the 153 remaining studies were obtained in order to thoroughly assess inclusion and exclusion criteria. This was based on the relevance of these articles to the objectives of this study and excluding articles, which investigate other diseases in conjugation with obesity (such as diabetes). After full articles were examined, 12 studies were consequently included in this review.

2.2.2 Results and Discussion

Study characteristics of the included studies are presented in Table 3.1. Five studies were conducted in the United States, 1 in Italy, 1 in Spain, 1 in New Zealand, 1 in France, 1 in Australia, 1 in Sweden and 1 in Germany.

Majority of studies were based on data collected from larger population studies while others were community-based studies. Measures of body mass index were comparable among the 12 included studies, where BMI was either based on the IOTF standards or CDC reference standards. Only the study from Italy used the French Rolland-Cachera curves to define overweight/obesity.

All of the 12 studies included both boys and girls, none focused on one sex alone. The age groups investigated in the included studies did vary significantly and the range in age from all the studies included was between 1-15 years of age. Cut-points for overweight/obesity were similar among all studies with the exception of the study conducted in Italy, which used the 90^{th} percentile as opposed to the 85^{th} percentile.

Table 3.1: Study Characteristics

Author(s), Year, & Country	Publication Type	Study Design & Objectives	Study Population & Age Range & Sex	Sample Size	Independent Variable of Interest Modeled (Exposure) & Measurement	Dependent Variable of Interest Modeled (Outcome) & Measurement
Field et al , 2003 United States	Journal article	Prospective cohort study "To assess whether intake of fruits and vegetables was associated with change in body mass index (BMI) among a large sample of children and adolescents in the United States "	Data were obtained from the 1996-1999 Growing Up Today Study (GVTS) Age 9-14 years of age Boys & Girls	8203 girls 6715 boys	Fruit, fruit juice (servings/day) and vegetable intake (servings/day) were evaluated using a validated food frequency questionnaire	Change in BMI z-scores over 3 years based on self-reported data BMI was based on age- and gender- (CDC reference standards) BMI between 85^{th} and 95^{th} percentile for age and gender were classified as obese
Grant et al , 2004 New Zealand	Journal article	Cross-sectional study in collaboration with the Pacific Island Advisory Council To determine whether dietary factors are associated with high levels of obesity in preschool children	Children were recruited by "Pacific community workers through personal networks and local churches " Age 2-5 years old Boys & Girls	60 children	Energy intake (kJ/d) Protein (g/d) Total energy from fat (%) Total energy from carbohydrates (%) Dietary intake was assessed using a 2-day weighed dietary record	Z-scores for BMI based on CDC reference data Trained examiners determined BMI for each child
Gunther et al , 2007 Germany	Journal article	Prospective cohort study To determine whether a high protein intake in early life predicts obesity in later life	Data were obtained from the Dortmund Nutritional and Longitudinally Designed Study Age 12 months – 7 years of age Boys & Girls	203 children – 102 males, 101 females	Energy (kcal/d) Total protein (g x kg-1 x d-1) Protein from animals (% of energy) Protein from vegetables (% of energy) Protein from dairy (% of energy) Meat protein (% of	Body mass index (BMI) based on IOTF criteria Trained nurses determined BMI for each child according to standard procedures

					energy) Cereal protein (% of energy) A 3-day weighted-diet record was used to obtain children's dietary intake Parents weighed all foods and beverages and recorded intake of foods to the nearest 1 g	
Lin and Morrison, 2002 United States	Journal article	Cross-sectional study To determine the relationship between fruit and/or vegetable consumption and body weight	Data were obtained from USDA's 1994-1996 Continuing Survey of Food Intakes by Individuals (CSFII) Age 5-12 years Boys & Girls	2181 children	Fruits (servings) Vegetables (servings) Food intake in grams was converted into servings Diet was assessed using two 24-hour recalls	BMI based on age- and gender- CDC reference standards BMI was calculated based on self-reported height and weight data Normal weight (BMI <85th percentile) Risk of overweight (BMI $\geq$ 85th and <95th percentile) Overweight BMI $\geq$ 95th percentile)
Magarey et al , 2001 Australia	Journal article	Prospective observational study To examine the relationship between food energy and macronutrient intake and body weight	Community-based study Age 2-15 years old Boys & Girls	143-243 children	Energy (MJ) Protein (g in) Energy from protein (%) Energy from fat (g) Carbohydrates (g) Energy from carbohydrates (%) Dietary intake was assessed using a 3-4 day diet diary	Body mass index (BMI) BMI was determined was weight and height measurements which were taken by the author (except at 2 years of age)

Maillard et al , 2000 France	Journal article	Cross-sectional study To determine the relationship between food intake and adiposity in non-obese children	Data were obtained from the Fleurbaix Ville Sante Study, with a focus on non-obese prepubertal children Age 5-11 years Boys & Girls	826 children	Energy intake (kcal) Percentage of energy intake from carbohydrates (%) Percentage of energy intake from complex carbohydrates (%) Percentage of energy intake from fats (%) Percentage of energy intake from proteins (%) Dietary intake was assessed using a single 24-hr diet record	Body mass index (BMI) Trained examiners determined BMI for each child
Nicklas, et al , 2003 United States	Journal article	Cross-sectional study To determine the association between eating patterns and overweight status in children	Data were obtained from the 1973-1994 Bogalusa Heart Study Age 10 years of age Boys & Girls	1562 children	Fats/oils (servings/day) Fruit, fruit juice, vegetable (servings/day) Breads/grains (servings/day) Meats (servings/day) Dietary intake was assessed using a 24-hour dietary recall	BMI based on age- and gender- CDC reference standards Trained examiners determined BMI for each child Normal weight (BMI <85th percentile) Risk of overweight (BMI $\geq$ 85th and <95th percentile) Overweight BMI $\geq$ 95th percentile)
Newby et al , 2003 United States	Journal article	Prospective cohort study To determine the association between nutrient and food group intake and annual weight change	Data were obtained from the North Dakota Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) Age 2-5 years of age Boys & Girls	1379 children	Total fat (% of energy, and intake g/day) Predefined food groups breads and grains, "fat foods", fruits and vegetables (servings/day) Dietary intake was assessed using a semi quantitative validated food frequency	Annual change in BMI based on CDC growth curves Trained examiners determined BMI for each child Change in annual weight (BMI)= weight at visit 2- weight at visit 1 x 12 months (to estimate an

					questionnaire	annual change in weight)
Ohlund et al , 2010 Sweden	Journal article	Cross-sectional study To determine whether current macronutrient intake is associated with BMI in children This study, however, did focus on the child's protein intake	Age 4 years Boys & Girls	127 children	Energy intake (MJ) Carbohydrate (grams and % of total energy) Protein (grams and % of total energy) Fat (grams and % of total energy) Monounsaturated fat (% of total energy) Polyunsaturated fat (% of total energy) n-6 fatty acids (grams and % of total energy) n-3 fatty acids (grams and % of total energy) Dietary intake was assessed using monthly 5-day food records	BMI was calculated based on weight and height measurements Height was measured (to the nearest mm) using a CMS stadiometer Weight was measured (to the nearest 0 1kg) using a Seca 835 digital adult scale Overweight/obesity in children was defined using Cole's criteria
Rocandio et al , 2001 Spain	Journal article	Cross-sectional study To compare the dietary intake of overweight and non-overweight children	School-children were selected at random Age 11 years old Boys & Girls	32 children – 16 males and 16 females	Carbohydrate intake (% of total energy) Protein intake (% of total energy) Fat intake (% of total energy) Saturated fat intake (% of total energy) Cholesterol intake (% of total energy) Monounsaturated and polyunsaturated fat intake (% of total energy) Dieticians trained parents on how to use a food	Body mass index (BMI) Trained examiners determined BMI for each child Children were considered overweight if their BMI was higher than the 90^{th} percentile

					weighing method to determine their child's diet intake for 7 days Parents recorded dietary intake of children for 1 week using the food weighing method	
Scaglioni et al , 2000 Italy	Journal article	Prospective observational study To examine the relationship between micronutrient intake and the development of overweight	Children were recruited randomly from live births that occurred at the maternity ward of San Paolo Hospital Age 1-5 years of age Boys & Girls	147 children – 67 females and 80 males	Daily energy • Total (kJ) • Total (kcal) • Per kg body weight (kJ/kg) • Per kg body weight (kcal/kg) Nutrient (energy %) • Proteins • Carbohydrates • Fats - Saturated - Monounsaturated - Polyunsaturated Age-adjusted FFQ and 24hr recalls were used to obtain the children's dietary intake	Body mass index (BMI) Weight was measured using an electronic Sartorious scale and height was measured using a Harpenden stadiometer A child was defined as overweight if their BMI was over the 90th centile according to the Rolland-Cachera curves
Skinner et al , 2004 United States	Journal article	Prospective observational study To determine predictors of body mass index in children 2-8 years of age (longitudinal study)	Community-based study Age 2-8 years Boys & Girls	70 white children – 37 males and 33 females	Longitudinal dietary variables (between 2 to 8 years of age) • Energy (kJ) (kcal) • Fat (g) • Protein (g) • Carbohydrate (g) A 24-h recall and 2 days of food records were used to obtain the children's dietary intake	Body mass index (BMI) based on CDC growth curves Trained examiners determined BMI for each child

Results of Individual Studies

The studies included in this literature review are those deemed relevant by the reviewer's opinion and which meet the inclusion criteria stated above. Detailed study results from each individual study are presented in Table 3.2.

Of the 12 studies included in this review, 10 used multivariate regression models to examine the relationship between dietary intake and BMI, all of which modeled BMI or overweight as the main outcome of interest. Of the 12 included studies, 7 used linear regression models (BMI as the main outcome), 1 did not specify the type of regression used for their statistical analysis (Lin and Morrison, 2002), and 2 used logistic regression models (overweight as the main outcome). The remaining 2 studies used chi-square tests or student's t-test to determine the relationship between dietary intake and BMI. Dietary intake, whether defined as a particular macronutrient or pre-defined food group, was used as the independent variable in all the included studies.

Field et al., (2003) focused their regression analysis on children and adolescent between 9-14 years of age. No relationship was found for either boys or girls in regards to fruit, fruit juice and vegetable intake and a change in BMI over a 3-year period (β=0.003). A significant negative relationship was present among boys between vegetable intake and change in BMI. However, this relationship was no longer significant when the model was adjusted for caloric intake (β=0.003). Conversely, Lin and Morrison (2002) conducted a cross-sectional analysis in 2181 children between 5-12 years of age. They found that overweight/obese boys ate less fruits ($p \leq 0.01$) and vegetables ($p \leq 0.01$) than healthy-weight children. Furthermore, they found that overweight/obese and at risk of overweight girls ate less fruit than healthy weight children as well ($p \leq 0.05$).

Nicklas et al. (2003) found no significant relationship between fats/oils, fruits, fruit juice, vegetables and breads/grains consumption and overweight status in 10-year-old children. However, a positive relationship was found between consumption of meats (mixed meats, poultry, seafood, eggs, pork, and beef) and overweight status ($p<0.051$) (Nicklas et al., 2003). Newby et al., (2005) also found no significant relationship between total fat intake, fruits or vegetables and weight change among children 2-5 years of age. Weight change was determined by examining the difference in weight on two separate visits, which were scheduled 6 to 12 months apart. Newby et al., (2004) did find that for each additional serving of breads and grains, there was a 0.16-kg lower weight change per year (95% CI, -0.20 to -0.12kg, $p\leq0.01$). Additionally, for each additional serving of fats, there was a 0.05-kg greater weight change per year (95% CI, 0.1-0.09kg, $p<0.05$).

No significant difference between macronutrient intake (protein, fat, carbohydrates) and obesity in children was found cross-sectionally (Grant et al., 2004) or longitudinally (Magarey et al., 2001). In a longitudinal study conducted by Magarey et al., (2001), no relationship was observed between any energy-adjusted macronutrient intakes (protein, fat, carbohydrates) at previous ages and BMI at subsequent ages (across 2-15 years of age). In a cross-sectional study conducted by Grant et al., (2004), obese children did have a significant higher intake of energy ($p=0.01$), despite finding a null relationship between macronutrient intake and obesity in children. Nonetheless, this finding is not consistent with Rocandio et al., (2001) whom found that the percentage of energy intake was significantly lower in the overweight group compared to the non-overweight children ($p<0.01$). However, the study conducted by Rocandio et al., (2001) did have a different definition of obesity than the other studies included in this review.

Studies also found a relationship between carbohydrates and BMI (Maillard et al., 2000, Skinner et al., 2004) or overweight status (Rocandio et al., 2001; Scaglioni et al., 2000). Maillard et al., (2000) found a significant relationship between a high percentage of energy intake from carbohydrates and BMI in girls ($p < 0.02$). It was also found that children who were overweight at 5 years old had a lower percentage intake of energy from carbohydrates at 1 year old than non-overweight children ($p = 0.031$) (Scaglioni et al., 2000). Mean carbohydrate intake (which was recorded between 2 and 8 years) were negatively associated with children's BMI at 8 years of age as well (Skinner et al., 2004). These results contradict the finding presented by Rocandio et al., (2001) where carbohydrate intake was significantly greater in the non-overweight group compared to overweight group ($p < 0.01$). Again, the study conducted by Rocandio et al., (2001) did have a different definition of obesity than the other studies included in this review.

Mixed results were found for the association between fat and protein and overweight status. Rocandio et al., (2001) found that fat and protein intake was not significantly different between obese and non-obese children. However, Scaglioni et al., (2000) found that children who were overweight at 5 years old had a higher percentage intake of energy from protein at 1 year old than non-overweight children ($p = 0.024$). Skinner et al., (2004) found that mean protein and fat intake (which was recorded between 2 and 8 years of age) were positively associated with children's BMI at 8 years of age. Similarly, Ohlund et al., (2010) conducted a cross-sectional analysis that demonstrated that protein intake at 4 years of age is also associated with BMI ($p = 0.01$). Gunther et al., (2007) looked at particular types of proteins and their association with BMI. They observed that higher animal protein intake at 12 months was associated with a higher BMI at 7 years of age ($p = 0.003$). Higher vegetable protein intake at 12 months or 5-6 years was not associated with a higher BMI at 7 years of age ($p=0.80$ and $p=0.20$ respectively). Lastly, they observed that higher dairy protein intake at 12 months was associated with a higher BMI at 7 years of age as well ($p=0.02$).

From the data provided in this review, it appears that obese children tend to consume more protein, carbohydrates and energy. The link between fruits, vegetables, fat intake and BMI is not consistent and, thus, subject to question.

Table 3.2: Individual Study Results

Study	Main statistical analyses conducted and presented	Reported measures of association & associated measure of statistical stability (where possible, only Odds Ratios (OR) are presented)	Methods used to control for confounding during data analysis
Field et al , 2003	Multivariate linear regression Multivariate linear regressions were re-run to control for caloric intake	No relation among girls between fruit, fruit juice and vegetable intake and change in BMI (either an increase or decrease in BMI) (β=0 003) A significant relationship was present among boys between vegetable intake and change in BMI However, this relationship was no longer significant when the model was adjusted for caloric intake (β=0 003)	Variables controlled for • Tanner stage of pubic health development • Age and gender specific z-score of BMI at the beginning of the 1 year interval • Age • Age squared • Height change • Activity/inactivity Adjusted for caloric intake
Grant et al , 2004	Pearson's chi-square test	Obese children had higher energy intakes than non-obese children (p=0 01) No difference was observed between obese and non-obese children in regards to macronutrient intakes (fat, protein, carbohydrates)	Age and/or gender
Gunther et al , 2007	Multivariate linear regression	Higher animal protein intake at 12 months is associated with a higher BMI at 7 years of age (p=0 03) Higher vegetable protein intake at 12 months or 5-6 years was not associated with a higher BMI at 7 years of age (p=0 80 and p=0 20 respectively) Higher dairy protein intake at 12 months is associated with a higher BMI at 7 years of age (p=0 02)	Variables controlled for • Maternal overweight (BMI ≥ 25, yes or no) • Maternal education status (12 years of schooling, yes or no) • Breastfeeding (full breastfeeding for ≥ 4 months, yes or no) • Firstborn status (yes or no) • Siblings in the dataset (yes or no)
Lin and Morrison, 2002	Regression analysis – does not specify the type	Overweight/obese boys ate less fruits (p≤0 01) and vegetables (p≤0 01) than healthy weight children Overweight/obese and at risk of overweight girls ate less fruit than healthy weight children (p≤0 05)	Variable controlled for • Age • Sex • Race/ethnicity

Magarey et al , 2001	Generalized linear estimating equations evaluated the longitudinal relationship between body fatness and macronutrient intake Regression analyses estimated the relationship between body fatness at specific age and macronutrient intake at previous ages	Across 2-15 years, no relationship was found between any macronutrient intake and BMI No relationship was observed between any energy-adjusted macronutrient intakes at a previous age and BMI at subsequent ages A single 24-hour dietary recall was used to collect the children's dietary intake	Variables controlled for • Sex • Maternal BMI • Paternal BMI • Gender • Total energy intake • Level of fatness at the beginning of the interval
Maillard et al , 2000	Multivariate linear regression Analyses were performed for all children and for boys and girls separately	A significant relationship exists between a high percentage of energy intake ascribed to carbohydrates and BMI in girls (p <0 02)	None reported
Nicklas, et al , 2003	Multivariate logistic regression	No significant relationship exists between fats/oils, fruits, fruit juice, vegetables and breads/grains and overweight status Fats/oils (OR 0 99, 95% CI 0 92-1 06) Fruit, fruit juice, vegetable (OR 0 96, 95% CI 0 81-1 13) Breads/grains (OR 1 05, 95% CI 0 87-1 25) Meats (OR 1 21, 95% CI 1 00-1 46) * *P<0 051, significant result A positive relationship exists between consumption of meats (mixed meats, poultry, seafood, eggs, pork, and beef) and overweight status (p<0 051)	Variables controlled for • Calorie intake • Age • Study year • Ethnicity • Gender • Ethnicity x gender
Newby et al , 2003	Multivariate linear regression	No significant relationship between total fat intake, fruits or vegetables and weight change For each additional serving of breads and grains, there was a 0 16-kg lower weight change per year (95% CI, -0 20 to -0 12kg, p<0 01) For each additional serving of fats, there was a 0 05-kg greater weight change per year (95% CI, 0 1-0 09 kg, p<0 05)	Variables controlled for • Baseline weight • Change in height during the time interval • Age • Sex • Total energy intake • Birth weight • Maternal education • Race/ethnicity • Residence • Poverty level
Ohlund et al , 2010	Univariate regression analyses Multivariate linear regression	*Univariate regression* Significant univariate associations between nutrient intake and BMI at 4 years	None reported

		• Energy at 4 years (p=0 014) • Protein at 4 years (g/day) (p=0 002) • Protein at 4 years (% energy) (p=0 023) • n-6 fatty acids at 4 years (g/day) (p=0 022) • Carbohydrates at 4 years (g/day) (p=0 009) _Multivariate stepwise linear regression_ Energy (p=0 003) and protein intake (p=0 01) at 4 years of age is also associated with BMI	
Rocandio et al , 2001	Chi-square and student's t-test	Percentage energy intake was significantly lower in the overweight group compared to the non-overweight children (p<0 01) Carbohydrate intake was significantly greater in the non-overweight group compared to overweight group (p<0 01) Fat and protein intake was not significantly different between both groups of children There was no significant difference in fatty acid intake between both groups of children as well	None reported
Scaglioni et al , 2000	Multivariate logistic regression	Children who were overweight at 5 years old had a higher percentage intake of protein at 1 years old than non-overweight children (p=0 024) Children who were overweight at 5 years old had a lower percentage intake of carbohydrates at 1 years old than non-overweight children (p=0 031) Intake of protein at 1 year of age was associated with overweight at 5 years of age (p=0 05)	Variables controlled for • Infant's gender • Weight and length at birth and 1 year • Parental age
Skinner et al , 2004	Multivariate linear regression (forward stepwise regression)	Mean protein (p=0 0167) and fat intake (p=0 0039 for fat in grams and p=0 0095 for fat as % energy), which was recorded between 2 and 8 years, were positively associated with children's BMI at 8 years of age Mean carbohydrate intake (which was recorded between 2 and 8 years) were negatively associated with children's BMI at 8 years of	Variables controlled for • Gender • Birth weight • Breastfeeding duration • Age that cereal was introduced • BMI at age 2yr • Longitudinal dietary energy intake • Mother's perception of child as a

		age (p=0 0099)	picky eater at age 6 years • The number of foods liked at age 8 years • Average daily time spent watching television at 6 and 7 yrs old • Average dietary variety score at ages 3 5-7 years • BMI of both parents

2.2.3 Limitations of Review

Limitations of this review included the age range of the target population of the articles retrieved for this review. The age groups presented in the 12 included studies were not equivalent to the age used in this study, thus the comparability between studies is compromised. Several age groups are presented in the limitation section in MEDLINE. By choosing the groups relevant for this study in this search engine (Preschool child: 2-5 years and Child: 6-12 years), it significantly expanded the number of articles retrieved for this literature review. An age range between 1-15 years of age was then set to allow for relevant articles to be included based on search results. Thus, the articles explored may be less relevant to the narrow age group under investigation in this study (children 4 and 6 years of age).

Additional limitations include the use of 24-hour diet recalls or food frequency questionnaires in many studies, which can introduce recall and response bias. The use of published literature only could have also have produced publication bias. Additionally, one reviewer examined the articles that were included in this review and this reviewer was not blinded to the names of authors, journal, or institution. It would be more accurate to have two or more reviewers to assess the articles for inclusion in order to prevent bias in article selection and the possible loss of relevant articles.

CHAPTER 3: Study Objectives and Conceptualizing Variable Relationships

3.1 Goal

The overarching aim of this project is to evaluate associations between diet quality and overweight/obesity and BMI at 4 and 6 years, as well as changes in BMI from 4 to 6 years. Assessment of diet quality includes macronutrient intake and food group intake according to Canada's Food Guide to Healthy Eating.

3.2 Objectives and Hypotheses

1. To assess the association between diet quality and overweight/obesity at 4 and 6 years;
2. To assess the association between diet and body mass index at 4 and 6 years;
3. To assess the association between diet and the change in BMI from 4 to 6 years.

- *Hypotheses: Children who have lower dietary fiber and fruits and vegetable intake are more likely to be overweight/obese at 4 and 6 years of age than normal weight children. The change in BMI from 4 to 6 years will be greatest for those who have low intake of these dietary elements as well.*
- *Hypotheses: Children who have lower monounsaturated fat & polyunsaturated fat, linolenic acid, and linoleic acid intake are more likely to be overweight/ obese at 4 and 6 years of age than normal weight children. The change in BMI from 4 to 6 years will be greatest for those who have low intake of these types of fats.*

- *Children who have higher saturated fat and cholesterol intake are more likely to be overweight/ obese at 4 and 6 years of age. The change in BMI from 4 to 6 years will be greatest for those who have high intake of these types of fats.*
- *Hypothesis: Those who consume more carbohydrates, proteins and fats will have higher body mass indexes at both 4 and 6 years old, and greater changes in BMI from 4 to 6 years old.*

4. To examine and compare the diets of normal and overweight /obese children from different socioeconomic groups to the new DRI standard for total fiber intake, linoleic acid, linolenic acid, total protein intake, total carbohydrate intake, zinc, calcium, magnesium, phosphorous, iron, vitamin A, vitamin B_{12}, and vitamin C at 4 years (since this is the only time point in which nutrition information was gathered).

- *Few children will meet the DRI requirement for fiber*
- *Children who are overweight/obese will be more likely to meet the DRI requirement for various micronutrients due to nutrient- dilute diets (such as vitamin A, C, B_{12} etc.)*
- *More children who are overweight/obese will exceed the DRI for total carbohydrate and protein intake in comparison to normal weight children.*
- *Children from families with low socioeconomic status will be less likely to meet the DRI for all variables outlined in the objective.*

3.3 Conceptualizing Variable Relationships

Data from the Québec Longitudinal Study of Child Development (QLSCD) was reviewed following the literature search presented in the previous chapter. This investigation aimed to determine variables that would be added during model development to control for potential cofounders. These variables are listed in Table 4.

Table 4: Potential confounders identified in the QLSCD

Child/Birth Characteristics	Parent Characteristics	Family Demographic and Socioeconomic Characteristics
• Sex of child • Category of birth weight • Born premature • Breastfed (partial or exclusive for first 4 months) • Chronic illness (excluding allergies, but including asthma) at age 6 years • Level of physical activity in comparison to other children • Type of child care • Television viewing for 3 or more hours/day (weekdays and weekends) • Initial BMI at 2 years (mother's report) • Frequency of computer use at 6 years	• Mother's age when the child was born • Mother's level of education (highest diploma obtained when child was 4 years) • Mother smoked during pregnancy • Mother's employment status (when child was 4 years) • Mother's smoking status • Mother overweight or obese (BMI $\geq 25 kg/m^2$) when the child was 1.5 years	• Household annual income • Socioeconomic status • Family structure • Urban dwelling • Mother's immigrant status

A conceptual framework was developed to illustrate the relationship between diet quality and childhood obesity in accordance to the data from the QLSCD. See Figure 2 for this framework.

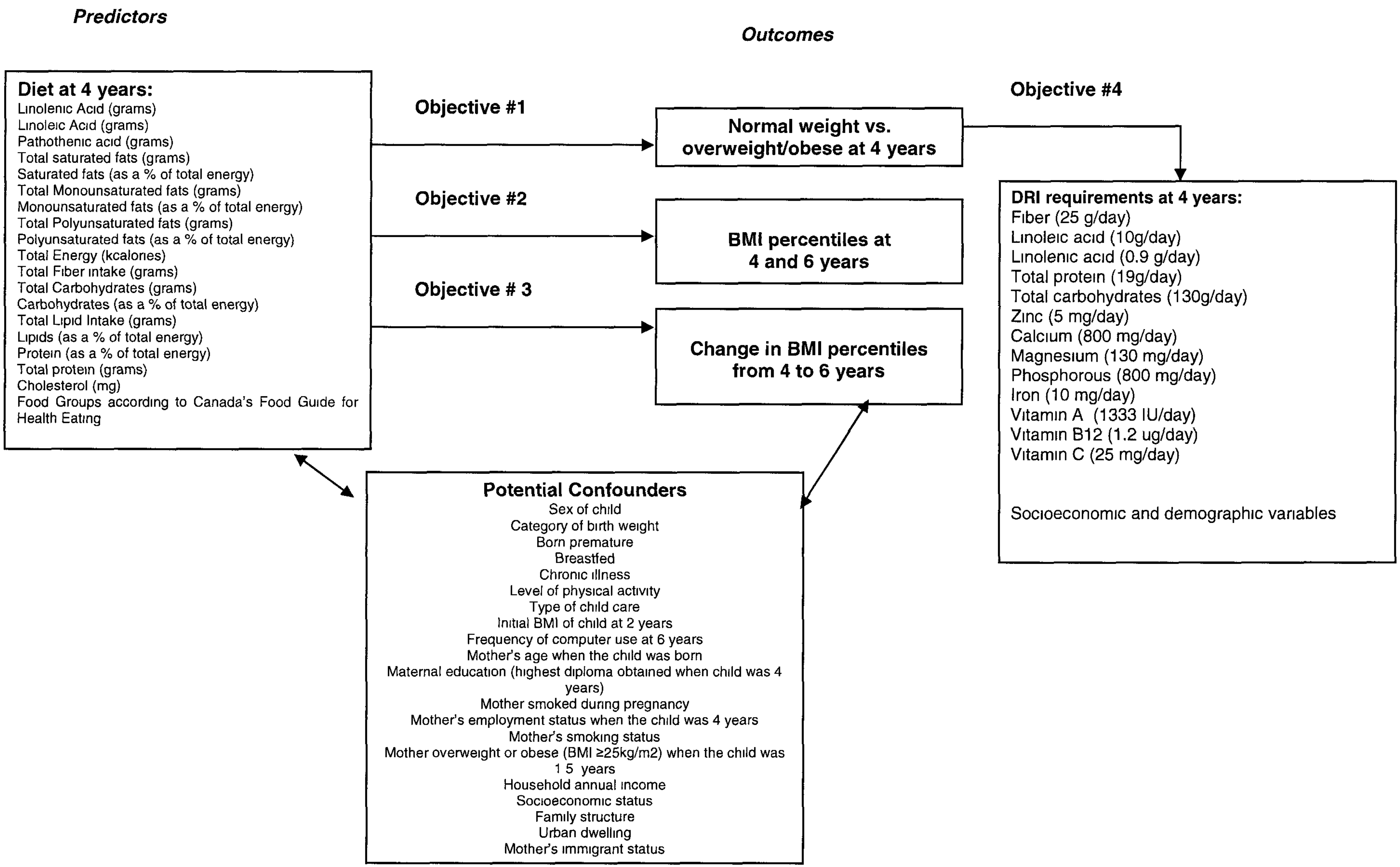


Figure 2. Conceptual framework outlining the potential relationships between the variables proposed in study

CHAPTER 4: Methods

4.1 Data source: The Québec Longitudinal Study of Child Development (QLSCD)

This study was conducted with data from the Québec Longitudinal Study of Child Development (QLSCD, 1998-2010). The QLSCD is a provincially representative, prospective longitudinal study conducted by Santé Québec (**Institut de la statistique du Québec)*. It began in 1998 and was designed to advance our knowledge of child development. "It's main objective had been to identify factors that, coming into play during early childhood, affect the social adjustment and academic performance of young Québeckers" ([†]*Institut de la statistique du Québec website*). Ethical approval from the Ministry of Health Ethics Committee (Comité d'Ethique de Santé Québec) and consent from participants were obtained. [†]

4.2 Study Sample

A representative sample (n=2103) of children born in 1998 in the province of Québec was obtained (total population over 7 million, with approximately 70,000 newborns per year) by the QLSCD. Children were 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). A randomized 3-level stratified survey design was used to obtain a representative sample of children. Children born throughout the year in each geographic area of the province were included in order to minimize the effect of seasonality and to ensure geographic representation. Twins and children with major disease or disabilities at birth were excluded from the study.

[†] http://www.jesuisjeserai.stat.gouv.qc.ca/etude_an.htm

The children and their parents were first seen in 1998, when the children were approximately 5 months of age (adjusted for gestational age), and each year after that for data collection. At each data collection time point, information was collected about the child's weight, height, health and development, as well as demographic and socioeconomic characteristics that pertained to that child. The information pertaining to the child and parents were collected through the child's medical birth records, face-to-face paper and computer-based interviews, and computer-based and self-administered questionnaires. Questionnaires aimed at collecting information regarding demographic and socioeconomic characteristics include the *Interviewer Completed Paper Questionnaire (ICPQ), the Interviewer Completed Computerized Questionnaire (ICCQ) and the Self-Administered Questionnaire for the Mother (SAQM)*. Questionnaires pertaining to the child, including diet and eating behaviour, were addressed by the person deemed most knowledgeable (PMK) of the child, generally the mother. Further information regarding the construction and validation of these instruments can be found from the technical documentation available on the QLSCD's Website (Jette & DesGroselliers, 2000; Thibault et al., 2003; Thibault, Jette & Desrosiers, 2001).

The sample of 2103 children reduced to 1944 at 4-5 years of age in 2002 as a result of subjects that dropped out of the study, or families that could no longer be reached. During 2002, 1549 children volunteered to take part in a nutrition sub-study. This nutrition sub-study included a 24-hour dietary recall interview, a self-administered eating behaviour and television viewing questionnaire, and measurement of the children's height and weight. This recall was performed in order to collect nutrition data and to analyze the children's food consumption patterns.

4.2.1 Energy/macronutrient intake and food consumption analysis

The single 24-hour dietary recall was administered in the home of the children by a trained nutritionist in order to analyze the child's food consumption patterns. Mothers were asked to indicate the type, quantity, and recipes eaten by the child during the 24-hour period preceding the interview. The nutritionist then recorded this information during the interview. Volume food models were used to determine portion sizes and the verification of nutrition labels was used to ensure accuracy.

A second 24-hour recall was administered to 50% of the children seven days later in order to adjust recall data for random intra-child variability. Thus, all nutritional variables used in this study were based on the adjusted data. This double sampling method was used to validate that the first recall was not conducted on a day in which the child would consume foods different from their regular pattern of consumption (such as a birthday). If the child attended day-care, the nutritionist questioned the administrative staff regarding the child's food intake (e.g., time, meal, quantity) for the same 24-hour period.

The 24-hour recall was administered evenly across all days in the week. Energy, macronutrient and micronutrient intake, and food portion size were evaluated according to The Canadian Nutrient File (Cole at al., 2000). Dietary data collected were managed using a validated nutrient analysis software package from Micro Gesta (Québec, Canada; version 73). Final consumption and serving estimates were adjusted to minimize within-child variability (Dubois et al., 2007).

Anthropometric measurements of the child were measured at home at 4 and 6 years of age. A standardized protocol consisting of a measuring tape, a ruler, and a scale were used to take the anthropometric measurements of the child. Children were asked to wear light clothing and no shoes.

4.3 Measures

Data analyses were performed from data collected through the responses to the 24-hour dietary recall, anthropometric measurements and various questionnaires in regards to demographic and socioeconomic characteristics such as the *Self-Administered Questionnaire for the Mother (SAQM), and the Interviewer Completed Paper Questionnaire (ICPQ),* and the child's medical birth records.

4.3.1 Outcome

Three BMI outcome measures are examined in this study: 1) IOTF definition of overweight/obesity at 4 and 6 years of age, 2) BMI percentile at 4 and 6 years of age according to the CDC growth curves and 3) change in BMI from 4 to 6 years of age according to the CDC growth curves. Overweight/obesity and BMI at 4 years of age were used as outcomes since nutritional data was collected during this year. Overweight/obesity and BMI at 6 years of age were also used as outcomes since this was the most recent data available from the QLSCD, which contained important potential confounders required for this study (level of physical activity and television viewing for 3 or more hours/day).

4.3.1.1 IOTF definition of overweight/obesity

By using the IOTF definition of overweight/obesity, interprovincial and international comparisons are possible due to the structure of this variable. The relationship between this outcome and the nutritional predictors has been investigated in this study. According to the IOTF definition, girls and boys at 4 years of age are classified as 'overweight or obese' if their

BMI percentile is ≥17.2 kg/m^2 and ≥17.5 kg/m^2 respectively (Cole et al., 2000). At 6 years of age, girls and boys are classified as 'overweight or obese' if their BMI percentile is ≥17.3 kg/m^2 and ≥17.6 respectively (Cole et al., 2000). This dichotomous variable is categories into two subcategories, children of normal weight or children who are overweight or obese.

4.3.1.2 BMI percentile based on CDC growth curves

Investigating BMI percentile at 4 and 6 years of age aims to find an association between the nutrition predictors and food groups of interest and BMI. It is a continuous variable based on the CDC growth curves. Change in BMI from 4 to 6 years of age is a continuous variable as well, which was created by taking the raw difference in BMI from 4 to 6 years of age.

Change in BMI from 4 to 6 years of age was used to create models, which aimed to determine whether diet at 4 years of age would predict weight change at 6 years of age. It would be ideal to have information about dietary intake at more than one time point; however, this information was not present in the Québec Longitudinal Study of Child Development.

4.3.2 Main Predictors

There were four groups of main predictors, which were examined in this study. The four groups were:

1) Nutrition predictors in quintiles

2) Nutrition predictors dichotomized into high and low intake levels (quintiles 1-2 and quintile 3-5 were grouped in order to dichotomize the nutrition predictors)

3) Continuous nutrition predictors

4) Food groups (milk and alternatives, grains, meats and alternatives, fruits and vegetables) split in categories based on Canada's Food Guide to Healthy Eating for children 4-8 years of age.

The nutritional predictor variables and food groups, which were investigated in this study, are presented in *Figure 2* and *Table 5* respectively.

Table 5: Nutritional predictor food groups

Variable	Category
Grain products	0-2 servings/day 3 servings/day 4 servings/day ≥ servings/day
Grain products	< 4 servings/day ≥ 4 servings/day
Dairy products	0-1 serving/day ≥ 2 servings/day
Fruits and vegetables	0-2 servings/day 3 servings/day 4 servings/day ≥ 5 servings/day
Fruits and vegetables	0-1 serving/day ≥ 2 servings/day
Meats and alternatives	0-1 serving/day ≥ 2 servings/day

The nutritional predictor variables in quintiles were created from their corresponding continuous nutritional variables available in the QLSCD.

Nutrition predictor variables in quintiles were used when looking at overweight/obese since it provided further information in regards to the relationship between diet quality and overweight/obesity at 4 and 6 years of age in order to look for a gradient effect. The continuous nutrition variables were used for all outcomes since it suggested whether an association existed between these variables and BMI at 4 and 6 years, a change in BMI from 4 and 6 years, and overweight/obesity at 4 and 6 years. Nutrition variables in quintiles were not used for linear regression models since the models would be too complex to interpret. Instead, the quintiles were dichotomized into low and high subcategories and were run in the automated linear models.

Linear regression models were created when the outcome of interest was BMI at 4 and 6 years and change in BMI from 4 to 6 years (since these outcomes are continuous). Logistic regression models were created when the outcome of interest was overweight/obesity. Therefore, fifteen regression models are presented in total. See *Section 4.4.3 Multivariate Analyses* for details of the fifteen regression models in this study.

4.3.3 Covariates

A covariate, for the scope of this study, is defined as a predictor variable, which is a potential confounder in the association between diet quality and BMI. Therefore, the covariates included in the study were based on the literature and on the best available variables in the QLSCD. All covariates were categorical, as provided by the QLSCD database. Section 4.3.3.1 – 4.3.3.3 presents a description of each covariate that was used in this study.

4.3.3.1 Child Characteristics

These characteristics were obtained from different survey years since some years had a large number of missing data or since a particular characteristic of interest was only available at a particular year.

- Sex of the child
    - Categories: Male/Female
- Category of birth weight
    - <2.5kg (low birth weight)

    - ≥2.5kg to ≤4kg (normal birth weight)
    - >4 kg (high birth weight)

- Born premature
    - No/yes

- Maternal smoking during pregnancy
    - No/yes

    The variable maternal smoking during pregnancy was created based on the following question:
    "Did you smoke during your pregnancy with ... (name)?"
    YES (GO TO MED-Q4)
    NO
    DON'T KNOW
    REFUSAL

    MED-Q4 How many cigarettes per day did you smoke during your pregnancy with ... (name)? (QLSCD, 1998-2010)

- Breastfed (partial or exclusive) for first 4 months
    - Never breastfed, breastfed <4 months, breastfed 4 months or more

- Chronic illness (excluding allergies, but including asthma) at 6 years of age
    - No/yes

The definition for chronic illness was based on the following question:

Now I'd like to ask about any chronic health conditions you/... (name) may have. "Long-term conditions" refer to conditions that have lasted or are expected to last 6 months or more and have been diagnosed by a health professional.

Do you does he/she have any of the following long-term conditions? (Read list. Mark all that apply)
FOOD ALLERGIES
OTHER ALLERGIES
ASTHMA
ARTHRITIS OR RHEUMATISM
BACK PROBLEMS EXCLUDING ARTHRITIS
HIGH BLOOD PRESSURE
MIGRAINE HEADACHES

CHRONIC BRONCHITIS OR EMPHYSEMA
SINUSITIS
DIABETES
EPILEPSY
HEART DISEASE
CANCER
STOMACH OR INTESTINAL ULCERS
EFFECTS OF STROKE
ANY OTHER LONG TERM CONDITION (SPECIFY
NONE
DON'T KNOW
REFUSAL (QLSCD, 1998-2010)

- Level of physical activity in comparison to other children
  - No ('same as other children/lower or much lower)
  - Yes ('Higher/Much higher')
- Television viewing for 3 or more hours/day (weekdays and weekends)
  - No (<3hrs/day)
  - Yes (3 or more hrs/day)
- Type of child care
  - Not in day-care or being taken care of at home
  - Being taken care of at someone else's home
  - In a day-care centre
- Frequency of computer use at 6 years
  - Quintile 1, 2, 3, 4, 5 (1=lowest frequency, 5=highest frequency)
- Initial BMI of child at 2 years of age
  - Normal weight
  - Overweight
  - Obese

4.3.3.2 Parent Characteristics

Parent characteristics were only taken from the mother for this study in order to avoid multicollinearity and since more than 10% of the data for many of the covariates of interest from the father were missing. These characteristics were obtained from different survey years since some years had a large number of missing data or since a particular characteristic of interest was only available at a particular year.

- Mother's age when the child was born
    - 29 years or less, 30-34 years, 35-39 years, 40+years
- Mother's level of education (highest diploma obtained when the child was 4 years old)
    - No secondary school diploma
    - Secondary school diploma
    - College or professional school diploma
    - University diploma
- Mother's employment status (when the child was 4 years of age)
    - No (not employed)/Yes (employed)
- Mother's smoking status when the child was 4 years of age
    - Non-smoker/smoker

The variable maternal smoking when the child was 4 years of age was created based on the following question:

"At the present time do you / does he/she smoke cigarettes daily, occasionally or not at all?"

DAILY (GO TO HLA-Q3)
OCCASIONALLY
NOT AT ALL
DON'T KNOW
REFUSAL

"HLA-Q3 How many cigarettes do/does you/he/she smoke each day now?"

(QLSCD, 1998-2010)

- Mother's immigrant status
    - Not an immigrant/an immigrant

    The definition of an immigrant was based on the following question: "Are you/is ... (name) now, or have/has you/he/she ever been a landed immigrant? "
    YES
    NO
    DON'T KNOW
    REFUSAL (QLSCD, 1998-2010)

- Mother's overweight or obesity ($\geq 25kg/m^2$) when the child was 1.5 years
    - No (not overweight or obese)/ Yes (overweight or obese)

4.3.3.3 Demographic and Socioeconomic Characteristics

Demographic and socioeconomic characteristics were obtained from different survey years since some years had a large number of missing data or since a particular characteristic of interest was only available at a particular year.

- Household annual income
    - Less than $30,000
    - $30,000-$49,999
    - $50,000-$79,999
    - $80,000-more
- Socioeconomic status
    - Quintile 1,2,3,4,5 (1=lowest, 5 highest)

The socioeconomic status indicator combines measures describing occupational prestige, educational level and financial situations of parents based on the method developed by Willms and Shields, (1996).

- Family structure
    - Intact
    - Recomposed
    - Single parent
- Urban dwelling
    - Rural
    - Urban

4.4. Statistical Analysis

4.4.1 Analysis of Baseline Characteristics

Statistical analyses were conducted using the SAS statistical software package version 9.1 (SAS Institute; Cary, NC). Simple descriptive statistics such as proportions, means and standard deviations were used to assess the distribution and fit of the data to statistical assumptions, and to find outliers or missing values.

Univariate analyses examined each variable individually. Categories present within a particular variable were collapsed if the sample in each category was too small. For example, the predictor, total fiber intake, is presented in three quintiles since quintiles 1 and 2 and quintiles 4 and 5 were collapsed. This was also repeated for the variable initial BMI recorded for the child at 2 years of age regrouping quintiles 1 and 2 and quintiles 4 and 5.

4.4.2 Bivariate Analyses

Single linear regressions were used to examine the crude associations between two outcomes (BMI at 4 and 6 years and change in BMI from 4 to 6 years) and predictor variables, covariates and predictors and covariates and outcome. The level of significance was set to $P \leq 0.05$.

Single logistic regressions were used to examine the crude association between IOTF definition of overweight/obesity at 4 and 6 years (normal vs. overweight/obesity) and predictor variables (in continuous form). Chi-square tests of association were used to examine associations between overweight/obesity and covariates, overweight/obesity and predictors (in quintiles) and covariates and predictors.

4.4.3 Modeling Strategy

Automated logistic regression analyses were performed with the IOTF definition for overweight/obesity at 4 and 6 years (normal vs. overweight/obesity) as supported by previous published literature, *see Objective #2&3*. Automated linear regression analyses were performed for models with continuous outcomes; BMI at 4 and 6 years old (objective 2), and for change in BMI from 4 to 6 years (objective 3).

Predictor variables and covariates for each model were selected in correspondence with literature (*see Main Predictors in Methods section*). These variables were included in the automated models when there was a significant association with the outcome based on the bivariate analyses mentioned in Section 4.4.2 and Section 4.4.3.

An automated model chose which predictor variables were included in the final models based on the statistical significance of these variables. In the forward procedure, one variable is added one at a time with the most significant variable added first. The backwards procedure starts with all the predictor variables in the model at once, and deletes those that are insignificant. The stepwise model uses a combination of both the forward and backward approach and was chosen as the method of choice for this study. Below are the detail steps for a stepwise selection procedure using SAS:

Step 1: If any significant variable can be added to the model (at the 0.05 significance level), add the most significant variable.

Step 2: If any variable in the model becomes insignificant based on the 0.05 significance level, drop the least significant one.

Step 3: Repeat step 2 until all variables are significant.

Step 4: Return to step 1 until unable to add another significant variable.

For the linear regression models, four covariates, which were categorical, were dichotomized. The covariates were: initial BMI when the child was two years of age, category of birth weight, family structure, and type of child care. Initial BMI of child at 2 years was dichotomized by merging underweight with normal weight and overweight with obese children. The final categories for initial BMI of child were normal weight (including underweight) and overweight/obese. Category of birth weight was dichotomized by merging the last two categories, ≥2.5kg to ≤4kg (normal birth weight) and >4 kg (high birth weight). The final variable categories for category of birth weight were <2.5kg (low birth weight) and ≥2.5kg >4kg (normal to high birth weight). Family structure was dichotomized by merging the last two categories, recomposed and single parent families. The final variable categories for family structure were intact family and recomposed/single parent families. Lastly, type of child care was dichotomized by merging the first two categories, not in day-care/being taken care of at home and being taken care of at someone else's home. The final categories for type of child care were not in day-care/being taken care of at home/being taken care of at someone else's home or in a day-care centre. The aim of dichotomizing these multilevel covariates for the linear regression models was to simplify the interpretability of the final results since there was a natural logic to condensing these particular variables.

Suspected interactions between predictors and predictors, or predictors and covariates, were included in the automated models. If an interaction was present in the model, then a manual backwards regression determined whether the interaction and its components were included in the final model based on a significance level of 5%. Odds ratios estimates, including confidence intervals, were determined through logistic regression analyses.

Energy intake (in kilocalories) was forced in all models in order to control for this variable. This is based on the rationale that a child with a high-energy intake will consume more of every food group and macronutrient.

Multicollinearity was investigated after all final models were produced. Evidence of multicollinearity using variance inflation factors (*VIF*s) was used. Multicollinearity was considered to be present if betas had *VIF*s of 10 or more.

All statistical tests included sample weights to adjust for any variations in the population.

4.4.3.1 Model Fit for Logistic and Linear Models

Model fit was assessed using the Hosmer and Lemeshow Goodness of Fit statistic for the logistic regression models. If the chi-square $P \geq 0.05$, then the model was judged to be a good fit. The linear regression models were assessed for fit by examining the residual and predictor plots of the final models. If the residuals were evenly dispersed without any trend present, then the model was deemed to have good fit.

4.4.3.2 Testing Linearity for Linear Models

The linearity of continuous variables was determined by examining the plots of continuous outcomes (BMI at 4 years of age, change in BMI from 4 to 6 years) against continuous predictors. If the bivariate relationship was non-linear, the covariate was categorized. Lastly, the normality of linear regression was examined using the Kernel density method. The final density plot was observed to determine the normality of the final models.

4.4.3.3 Influence and Outlier Detection for Logistic Regression Models

For the logistic regression, standardized Pearson residuals plots and DFBETA plots of each predictor variable were used to identify outliers.

Residuals are based on comparing observed values of the outcome variables with predicted values from a fitted model. Since logistic outcomes are binary, the values of the residuals cluster into the two outcome groups. Graphical displays are difficult to interpret compared to linear model residuals. However, it is possible to look at the residuals considering this cluster effect and identify outliers. Thus, standardized Pearson residual plot were used for each logistic model against the ordered observation number. Absolute standardized Pearson residuals cut-offs were determined based on analyses of this plot.

DFBETA measures how much the estimated coefficient for a fitted model would change if the observation were deleted. DBETA plot for each variable were plotted against the estimated outcome probabilities. All predictor variables were assessed using DFBETA plots. Outliers were identified by examination of these plots.

4.4.3.4 Influence and Outlier Detection for Linear Regression Models

A detailed influence analysis was carried out on the final weighed models. Studentized residuals (*rstudents*) from each of the models and one summary measure of influence, Cook's D, were examined in detail. The *rstudent* is sensitive to both an observation's distance from the fitted line and to its degree of leverage, therefore, the larger the *rstudent* value, the greater the leverage of the observation. Internal scaling was used to specify *rstudent* cut-offs based on influence statistic graphical analysis.

The absolute cut-off value for Cook's D (D_t) is based on statistical theory and was set to $D_t > 1$ (Dupont, 2002).

Lastly, scatter bubble plots of *rstudents* by predicted value were used to detect influential observations for linear regression analyses. The bubbles in the plot represent the D_t of each observation, where the larger the bubble, the larger the D_t value.

4.4.3.5 Missing Data Analysis

The impact of missing data in the covariates was taken in consideration for all models. If less than 5% of the data were missing, then it was considered as having no impact and the missing data was removed from the analyses. Otherwise, with- or 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.

4.4.3.6 Final Models

The logistic regression models that were examined in this analysis are:

Model # 1: Nutrition predictor variables (in quintiles) in association with overweight/obesity at 4 years

Model # 2: Nutrition predictor variables (in quintiles) in association with overweight/obesity at 6 years

Model # 3: Nutrition predictor variables (continuous) in association with overweight/obesity at 4 years

Model # 4: Nutrition predictor variables (continuous) in association with overweight/obesity at 6 years

Model # 5: Food groups (according to Canada's Food in association with overweight/obesity at 4 years

Model # 6: Food groups (according to Canada's Food in association with overweight/obesity at 6 years

The linear regression models that were examined in this analysis are:

Model # 7: Nutrition predictor variables (quintiles were dichotomized) in association with BMI at 4 years

Model # 8: Nutrition predictor variables (quintiles were dichotomized) in association with BMI at 6 years

Model # 9: Nutrition predictor variables (continuous) in association with BMI at 4 years

Model # 10: Nutrition predictor variables (continuous) in association with BMI at 6 years

Model # 11: Food groups (according to Canada's Food Guide for Healthy Eating) in association with BMI at 4 years

Model # 12: Food groups (according to Canada's Food Guide for Healthy Eating) in association with BMI at 6 years

Model # 13: Nutrition predictor variables (quintiles were dichotomized) in association with change in BMI from 4 to 6 years in association

Model # 14: Nutrition predictor variables (continuous) in association with change in BMI from 4 to 6 years in association

Model # 15: Food groups (according to Canada's Food Guide for Healthy Eating) in association with change in BMI from 4 to 6 years in association

4.4.4 Statistical analysis for DRI comparison (Objective #4)

The diets of normal weight and overweight/obese children at 4 years of age was compared to the new DRI standard for total fiber (grams), linoleic acid(grams), linolenic acid (grams), total protein (grams), total carbohydrate intake (grams), zinc (mg), calcium (mg), magnesium (mg), phosphorous (mg), iron (mg), vitamin A (IU), vitamin B_{12} (ug), and vitamin C (mg). *Table 6* presents the DRI summary of each nutritional variable under investigation for Objective #4.

Table 6. Summary of DRI's Presented in Study	
Fiber	25 g/day
Linoleic acid	10g/day
Linolenic acid	0.9 g/day
Total protein	19g/day
Total carbohydrates	130g/day
Zinc	5 mg/day
Calcium	800 mg/day
Magnesium	130 mg/day
Phosphorous	800 mg/day
Iron	10 mg/day
Vitamin A	1333 IU/day
Vitamin B_{12}	1.2 ug/day
Vitamin C	25 mg/day

These variables were chosen for examination since they are available from the QLSCD and have a DRI outlined by Health Canada. These DRI's are specific for children between 4-8 years of age and were retrieved from the 2007 Canada's Food Guide for Healthy Eating. This analysis refers to the children at 4 years of age when the QLSCD conducted a 24-hour dietary recall. Each of the variables was dichotomized into two groups: "meets the DRI" or "does not meet the DRI". This division was based on the most current DRI's outlined by Health Canada. The IOTF definition of overweight/obesity was the outcome of interest used to assess the diet of children at 4 years of age for this objective. Chi-square tests of association were used to determine whether overweigh/obese children were different from normal weight children in terms of their likelihood of meeting the DRI.

Bivariate analyses were conducted using the chi-square test of association in order to determine whether a significant relationship exists between various demographic and socioeconomic variables and the DRI standards for the nutrients listed above (*Table 6*). The demographic and socioeconomic factors that were examined included household annual income, socioeconomic status, urban dwelling, family structure, and mother's level of education.

Bivariate analyses were also conducted using the chi-square test of association in order to determine whether each nutrient was associated with overweight/obesity at 4 years. A multivariate model was not conducted for this objective since it would be redundant in this study. For example, some of these nutrients are part of the nutrition predictors and food groups examined in previous objectives, thus, chi-square tests of association were used instead to determine whether a significant relationship exists between different nutrients and overweight/obesity at 4 years of age.

Chapter 5: Results

5.1 Characteristics of the study sample

From the initial 2103 children sampled in cycle 1, 1549 children were included in the nutrition sub-study when the children were 4 years of age. There was no missing data regarding the nutritional predictor variables of these 1549 children at 4 years. Missing data does exist in regards to height and weight measures of each child, thus, BMI at 4 and 6 years of age do have missing values. *Table 7* presents the descriptive characteristics of the children included (n=1134) and excluded in the analyses at age 4 and 6 years (n=415).

5.1.1 Descriptive analysis for included sample at 4 years of age

There are more males than females included in the sample at 4 years of age. The majority of mothers did not smoke during pregnancy and breastfed their child (partial or exclusive) 4 months or more. The majority of the children did not have a chronic illness (excluding allergies, but including asthma) at 4 years of age and their level of physical activity was the same, lower or much lower than other children. The majority of the children included at 4 years of age also watched television for less than 3 hours per day and attended child care outside of the home.

In terms of parent characteristics, mothers of the children included in the analysis were generally between 30-34 years of age when the child was born, had a college or professional school diploma, were employed when the child was 4 years of age, do not smoke, were not an immigrant, and were not overweight or obese.

Children included in the study at 4 years of age tended to come from families with a household annual income between $50,000-$79,999, had an intact family structure and lived in urban dwellings.

5.1.2 Descriptive analysis for excluded sample at 4 years

There are more males than females excluded in the study at 4 years of age. The majority of mothers did not smoke during pregnancy and breastfed their child (partial or exclusive) 4 months or more. The majority of the children did not have a chronic illness (excluding allergies, but including asthma) at 4 years of age and their level of physical activity was the same, lower or much lower than other children. The majority of the children excluded at 4 years of age also watched television for less than 3 per day and attended child care at a day care centre.

In term of parent characteristics, mothers of these children were generally between 35-39 years of age when the child was born, had a college or professional school diploma, were employed when the child was 4 years of age, do not smoke, were not an immigrant, and were not overweight or obese.

The majority of children excluded in the study at 4 years of age came from families with a household annual income less than $30,000, had an intact family structure and lived in urban dwellings.

A significant difference ($P \leq 0.05$) exists between children included and excluded in the study at 4 years of age for mother's level of education (lower for excluded) and household annual income (lower for excluded).

5.1.3 Descriptive analysis for included sample at 6 years

There are more females than males included in the study at 6 years of age. The majority of mothers did not smoke during pregnancy and breastfed their child (partial or exclusive) 4 months or more. The majority of the children did not have a chronic illness (excluding allergies, but including asthma) at 6 years of age and their level of physical activity was the same, lower or much lower than other children. The majority of children included at 4 years of age watch television for less than 3 hours per day and attended child care outside of the home.

In term of parent characteristics, mothers of these children were generally between 35-39 years of age when the child was born, had a college or professional school diploma, were employed when the child was 6 years of age, do not smoke, were not an immigrant, and were not overweight or obese.

The majority of children included in the study at 6 years of age came from families with a household annual income of $50,000-$79,999, had an intact family structure and lived in urban dwellings.

5.1.4 Descriptive analysis for excluded sample at 6 years

There are more males than females excluded in the study at 6 years of age. The majority of mothers did not smoke during pregnancy and breastfed their child (partial or exclusive) 4 months or more. The majority of the children did not have a chronic illness (excluding allergies, but including asthma) at 6 years of age and their level of physical activity was the same, lower or much lower than other children. The majority of the children excluded at 6 years of age also watched television for less than 3 hours per day and attended child care at a day care centre.

In term of parent characteristics, mothers of these children were generally between 35-39 years of age when the child was born, have a college or professional school diploma, were employed at the survey time-point (when the child was 4 years of age), do not smoke, were not an immigrant, and were not overweight or obese.

The majority of children excluded in the study at 6 years of age came from families with a household annual income less than $30,000, had an intact family structure and lived in urban dwellings.

A significant difference (P≤0.05) exists between children included and excluded in the study at 6 years of age for the following variables: sex of the child (lower for males and higher for females in the included), chronic illness (higher for excluded), frequency of computer use (lower for excluded), mother's level of education (lower for excluded) and mother's immigrant status (higher for excluded).

Table 7: Descriptive characteristics† of the sample included and excluded from analyses

Characteristics of the children	Children included in analyses at 4 years	Children excluded from analyses (Missing data on BMI at 4 years)	Children included in analyses at 6 years	Children excluded from analyses (Missing data on BMI at 6 years)
Variable	(%)	(%)	(%)	(%)
Child/Birth Characteristics				
Sex of child				
Male	50.59	52.50	47 27	55.28**
Female	49.41	47.50	52.73	44 72
Category of birth weight				
<2.5 kg	3.22	3.71‡	3.62	3.12
≥2.5 kg to ≤4kg	84.69	84.74	85.36	84 02
>4kg	10.84	9.13	10.49	10.10
Missing	1.25	2.43	0.53	2.75
Born premature (<37 weeks)				
No	96.12	95 15‡	95.59	96.05
Yes	3.42	3.99	3 97	3 21
Missing	0.46	0 86	0.44	0.73
Mother smoked during pregnancy				
No	75.69	72.04	75.49	73.55

Table 7: Descriptive characteristics† of the sample included and excluded from analyses				
Characteristics of the children	Children included in analyses at 4 years	Children excluded from analyses (Missing data on BMI at 4 years)	Children included in analyses at 6 years	Children excluded from analyses (Missing data on BMI at 6 years)
Yes (smoked during pregnancy)	23.98	27.10	23.99	25.99
Missing	0.33	0.86	0.53	0.46
Breastfed (partial or exclusive) for first 4 months				
Never breastfed	25 36	34.81	25.75	31.04
Breastfed <4 months	32.06	29.81	30.42	32 32
Breastfed 4 or months or more	42.58	35 38	43 83	36.64
Chronic illness (excluding allergies, but including asthma) at 6 years of age				
No	91.13	96.43‡	89.24	96.51**
Yes (child has a chronic illness)	8.87	3.57	10 76	3.49
Level of physical activity in comparison to other children ('Higher' or 'Much higher')				
No ('Same as other children/lower/or much lower')	79.17	31.10‡	95.59	31.13
Yes ('Higher/Much higher')	3.29	2.43	4.32	1.65
Missing	17.54	66.48	0.09	67 22
Television viewing for 3 or more hours per day (weekdays and weekends)				
No (<3hrs/day)	78.25	31.24‡	95 24	30.3
Yes (3 or more hours/day)	4.20	2.43	4.67	2.57
Missing	17.54	66.33	0.09	67.13
Type of child care				
No in daycare/at home	28.58	19.12	27.95	23 14
Outside of home	37.52	20.40	36.68	27.36
Day care centre	33.71	20.68	34.66	24.33
Missing	0 20	39.80	0.71	25.16
Frequency of computer use at 6 years				
Quintile 1	14 13	6.56‡	16.23	7.07*
Quintile 2	31 01	10.70	37.30	11.39

Table 7: Descriptive characteristics† of the sample included and excluded from analyses				
Characteristics of the children	Children included in analyses at 4 years	Children excluded from analyses (Missing data on BMI at 4 years)	Children included in analyses at 6 years	Children excluded from analyses (Missing data on BMI at 6 years)
Quintile 3	16.29	99	21.08	5.97
Quintile 4	8.48	3.57	10.93	2.75
Quintile 5	12.61	4.85	14.46	5.69
Missing	17.48	66.33	0	67.13
Parent Characteristics				
Mother's age (when the child was born)				
29 years or less	21.55	23.68	20.99	23.51
30-34 years	32.39	29.81	32.28	30.85
35-39 years	32.26	33.95	32.36	33.24
40+ years	13.80	12.41	14 37	12.30
Missing	0	0 41	0	0.09
Mother's level of education (highest diploma obtained when the child was 4 years old)				
No secondary school diploma	13.27	11 27‡ *	13 32	11.94**
Secondary school diploma	20 83	13.69	20.37	16.71
College or professional school diploma	35.55	19.26	32.72	28.01
University diploma	29.63	15.55	32.28	17.81
Missing	0.72	40.23	1.32	25 53
Mother's employment status (when the child was 4 years old)				
No (not employed)	33.64	18.97	32.63	25.25
Yes (employed)	65.57	40.80	65.96	49 22
Missing	0 79	40 23	1.41	25.53
Mother's smoking status				
No (non-smoker)	77.27	73 61	77.25	74.93
Yes (Smoker)	22.73	26.11	22 66	24.98
Missing	0	0.29	0.09	0 09
Mother's immigrant status (is the mother an immigrant?)				
No (not immigrant)	91.39	81.31‡	93 21	83.01**

Table 7: Descriptive characteristics† of the sample included and excluded from analyses				
Characteristics of the children	Children included in analyses at 4 years	Children excluded from analyses (Missing data on BMI at 4 years)	Children included in analyses at 6 years	Children excluded from analyses (Missing data on BMI at 6 years)
Yes (immigrant)	8.61	18.40	6.70	16.90
Missing	0	0.29	0.09	0.09
Mother overweight or obese (BMI≥25 kg/m^2) when the child was 1.5 years				
No (not overweight/obese)	69.71	51.78	69.31	58.59
Yes (overweight/obese)	28.45	21.54	28.92	23.51
Missing	1.84	26.68	1.76	17.91
Family Demographic and Socioeconomic Characteristics				
Household annual income				
Less than $30,000	26.74	33.10‡*	25.40	32 23
$30,000-$49,999	29.37	25 39	28.92	27.27
$50,000-$79,999	28.25	25.82	29.37	25.53
$80,000-more	14 59	12.13	15.52	12.03
Missing	1 05	3.57	0 79	2.94
Family structure				
Intact	81.93	80.31‡	82.89	79.89
Recomposed	11.50	10 13	11.29	10 84
Single parent	6.44	9 13	5.64	9.00
Missing	0.13	0.43	0.18	0.28
Urban dwelling				
Rural	34 69	33.74	35 36	32.05
Urban	63.07	63.92	61.99	65.93
Missing	2.23	2 34	2.65	2.02

*Significant difference between those excluded and included (Chi-square, two-sided p≤0 05),
** Significant difference between those excluded and included (Chi-square, two-sided p≤0 01)
† Weighed data
‡ 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 Québec Institute of Statistics, QLSCD 1998-2010

5.1.5 Descriptive Statistics for IOTF definition of overweight/obesity

Using the IOTF BMI definition for overweight/obesity in boys and girls at age 4 and 6 years, approximately 13% (11% of boys; 14% of girls) of the sample was classified as overweight/obese at age 4 years, and 16% (13% of boys; 15% of girls) at 6 years of age. *Table 8* presents the distribution of BMI by overweight/obesity status (IOTF definition) in boys and girls at 4 and 6 years. No significant difference in overweight/obesity exists between boys and girls at 4 or 6 years of age.

Table 8: Mean† BMI (kg/m^2) by overweight/obesity status in boys and girls at age 4 and 6 years

	BMI (Body Mass Index kg/m^2) at 4 years of age		
	Total	**Boys**	**Girls**
Overweight/Obese at age 4 years (IOTF definition)	*Mean (SD) and Range (lowest-highest value)*	*Mean (SD) and Range (lowest-highest value)*	*Mean (SD) and Range (lowest-highest value)*
Non-overweight/Obese at age 4 years	15 22 (1 32) (3 70-17 62)	15 26 (1 41) (3 69-17 62)	15 17 (1 22) (6 52-17 40)
Overweight/Obese at age 4 years	19 03 (1 86) (17 25-27 08)	19 36 (2 06) (17 56-26 15)	18 74 (1 64) (17 25-27 08)
	BMI (Body Mass Index kg/m^2) at 6 years of age		
	Total	**Boys**	**Girls**
Overweight/Obese at age 6 years (IOTF definition)	*Mean (SD) and Range (lowest-highest value*	*Mean (SD) and Range (lowest-highest value*	*Mean (SD) and Range (lowest-highest value*
Non overweight/Obese at age 6 years	15 18 (1 13) (11 10-17 53)	15 28 (1 13) (11 10-17 53)	15 10 (1 11) (11 96-17 32)
Overweight/Obese at age 6 years	19 41 (2 08) (17 22-28 45)	19 56 (2 15) (17 58-27 14)	19 21 (2 00) (17 22-28 45)

†Weighted data
Source Data courtesy of the Quebec Institute of Statistics QLSCD 1998 2010

5.1.6 Descriptive Statistics of the Included Sample by Sex and Prevalence of Overweight/Obesity at 4 and 6 years

The descriptive characteristics of the sample by sex and prevalence of overweight/obesity at 4 and 6 years are presented in *Table 9*. At 4 years of age, boys who were classified as overweight or obese using the IOTF criteria were more likely to have a mother that was overweight/obese (Chi-square, $p \leq 0.05$), as opposed to mother of normal weight.

Boys that were overweight or obese at 6 years of age were more likely to have a mother which was not an immigrant and were more likely to come from a family with a lower household annual income (Chi-square, $p \leq 0.05$).

Girls who were considered overweight or obese at 4 years of age were more likely to come from mothers with higher education in comparison to girls of normal weight (Chi-square, $p \leq 0.05$), however, again, due to a large number of cells having an expected count less than 5, a chi-square test may not valid to determine whether this difference is statistically significant (see *Table 9*).

Girls who were considered overweight or obese at 6 years of age were more likely to have a chronic illness (excluding allergies but including asthma), where more likely to have the same/lower/or much lower physical activity levels, watch television for 3 or more hours/day (weekdays and weekends), and use the computer more frequently in comparison to girls of normal weight (Chi-square, $p \leq 0.05$). More girls who were overweight or obese were more likely to have a mother who was an immigrant and a mother with higher education in comparison to girls of normal weight (Chi-square, $p \leq 0.05$).

Table 9: Descriptive characteristics† of the sample by sex and prevalence of overweight/obesity (IOTF cut-offs) at age 4 and 6 years

Variables	Sample included in analyses to age 4 years				Sample included in analyses to age 6 years			
	Boys		Girls		Boys		Girls	
	% for all	Proportion (%) of overweight /obese	% for all	Proportion (%) of overweight /obese	% for all	Proportion (%) of overweight /obese	% for all	Proportion (%) of overweight /obese
Child/Birth Characteristics								
Category of birth weight								
<2 5kg	4 57	3 50 ‡	4 05	2 92‡	5 13	3 92‡	4 05	5 13‡
≥2 5kg to ≤4kg	81 20	82 10	86 79	87 38	81 56	82 09	86 79	81 56
>4kg	13 20	13 36	7 87	8 23	12 56	13 25	7 87	12 56
Missing	0 95	1 04	1 29	1 46	0 75	0 75	1 29	0 75
Born premature (<37 weeks or with low birth weight (<2 5kg)								
No	95 04	96 11‡	95 31	96 15‡	95 04	95 71‡	95 31	95 48‡
Yes (born premature or with low birth weight)	4 70	3 63	3 98	3 19	4 70	4 10	3 98	3 85
Missing	0 25	0 26	0 71	0 66	0 25	0 19	0 71	0 67
Mother smoked during pregnancy								
No	75 47	75 88‡	73 55	75 43‡	76 99	77 61	73 55	73 58‡
Yes (smoked during pregnancy)	24 40	23 99	25 89	24 04	23 01	22 20	25 89	25 59
Missing	0 13	0 13	0 56	0 53	0	0 19	0 56	0 84
Breastfed (partial or exclusive) for first 4 months								
Never breastfed	24 69	24 77	26 66‡	25 90	24 18	25 56	26 66	25 92
Breastfed <4 months	30 27	31 13	33 39	33 20	27 70	27 80	33 39	32 78
Breastfed 4 or more months	45 04	44 10	39 96	40 90	48 11	46 64	39 96	41 30
Chronic illness (excluding allergies but including asthma) at age 6 years								
No	89 85	90 01	91 90	92 30‡	86 96	88 25	91 90	90 13**
Yes	10 15	9 99	8 10	7 70	13 04	11 75	8 10	9 87
Level of physical activity in comparison to other children ('higher' or 'much higher')								
No ('Same as other children/lower/ or much lower')	75 09	77 17‡	80 22	81 14‡	95 05	95 52‡	80 22	95 65**
Yes	3 62	3 37	2 89	3 32	4 95‡	4 48	2 98	4 18
Missing	21 29	19 46	16 89	15 54	0	0	16 89	0 17
Television viewing for 3 or more hours/day (weekdays and weekends)								
No (<3hrs/day)	74 37	76 65‡	78 27	79 95‡	94 35	95 34‡	78 27	95 15**
Yes (3 or more hrs/day)	4 26	3 76	5 02	4 65	5 52	4 48	5 02	4 85
Missing	21 37	19 58	16 71	15 41	0 12	0 19	16 71	0
Type of child care								

Table 9: Descriptive characteristics† of the sample by sex and prevalence of overweight/obesity (IOTF cut-offs) at age 4 and 6 years

Variables	Sample included in analyses to age 4 years				Sample included in analyses to age 6 years			
	Boys		Girls		Boys		Girls	
	% for all	Proportion (%) of overweight /obese	% for all	Proportion (%) of overweight /obese	% for all	Proportion (%) of overweight /obese	% for all	Proportion (%) of overweight /obese
No in daycare/at home	29 94	27 76	31 59	29 48‡	27 56	27 43*‡	31 59	28 43‡
Outside of home	34 31	36 96	35 59	37 98	34 36	36 75	35 59	26 62
Daycare centre	35 50	35 02	32 68	32 40	37 67	35 07	32 68	34 28
Missing	0 25	0 26‡	0 14	0 13	0 41	0 75	0 14	0 67
Frequency of computer use at 6 years								
Quintile 1	16 08	16 47	11 54	11 69‡	18 16	20 15	11 54	12 71**
Quintile 2	29 05	30 61	29 96	31 34	38 27	37 50	29 96	37 13
Quintile 3	15 31	15 43	16 86	17 13	20 28	20 34	16 86	21 74
Quintile 4	6 29	6 10	10 15	10 89	9 00	8 02	10 15	13 55
Quintile 5	11 98	11 93	14 78	13 55	14 29	13 99	14 78	14 88
Missing	21 29	19 46	16 71	15 41	0	0	16 71	0
Parent Characteristics								
Mother's age (when the child was born)								
29 years or less	22 53	21 53	23 28‡	21 65	23 28‡	22 57	23 28	19 57
30-34 years	31 41	32 30	30 19	32 40	30 19	31 16	30 19	33 28
35-39 years	30 94	32 17	32 54	32 40	32 54	30 97	32 54	33 61
40+ years	15 12	14 01	13 99	13 55	13 99	15 30	13 99	13 55
Missing	0	0	0	0	0	0	0	0
Mother's level of education (highest diploma obtained when the child was 4 years old)								
No secondary school diploma	14 75	12 32	16 56	14 21*‡	11 70	11 01	16 56	15 38*
Secondary school diploma	22 00	20 75	21 83	20 98	23 31	21 64	21 83	19 23
College or professional school diploma	35 60	36 71	33 79	34 40	34 33	34 51	33 79	31 10
University diploma	26 62	29 18	27 10	30 61	29 43	31 34	27 10	33 11
Missing	1 03	1 04	0 72	0 40	1 24	1 49	0 72	1 17
Mother's employment status (when the child was 4 years old)								
No (not employed)	36 72	33 59‡	36 27	33 73‡	36 71	33 21	36 27	32 11‡
Yes (employed)	62 25	65 37	62 93	65 74	62 05	65 30	62 93	66 56
Missing	1 03	1 04	0 80	0 53	1 24	1 49	0 80	1 34
Mother's smoking status when child is 4 years old								
No (non-smoker)	76 52	77 43	75 32	77 16‡	78 70	79 85	75 32	74 92
Yes (smoker)	23 48	22 57	24 68	22 84	21 30	20 15	24 68	24 92
Missing	0	0	0	0	0	0	0	0 17
Mother's immigrant status								
No (not an immigrant)	85 13	90 66	87 78	92 03‡	88 68	93 10**	87 78	93 31**
Yes (an	14 87	9 34	12 22	7 97	11 32	6 90	12 22	6 52

Table 9: Descriptive characteristics† of the sample by sex and prevalence of overweight/obesity (IOTF cut-offs) at age 4 and 6 years								
Variables	**Sample included in analyses to age 4 years**				**Sample included in analyses to age 6 years**			
	Boys		**Girls**		**Boys**		**Girls**	
	% for all	**Proportion (%) of overweight /obese**	**% for all**	**Proportion (%) of overweight /obese**	**% for all**	**Proportion (%) of overweight /obese**	**% for all**	**Proportion (%) of overweight /obese**
immigrant)								
Missing	0	0	0	0	0	0	0	0 17
Mother overweight or obese (BMI ≥ 25 kg/m²) when the child was 1 5 years								
No (not overweight/obese)	70 90	70 82**	69 49	68 53‡	72 48	70 52**‡	69 49	68 23
Yes (overweight/obese)	27 52	28 02	27 69	28 82	26 68	28 17	27 69	29 60
Missing	1 58	1 17	2 82	2 66	0 84	1 31	2 82	2 17
Family Demographic and Socioeconomic Characteristics								
Household annual income								
Less than $30,000	33 47	26 89	30 20	26 69‡	29 29	24 07*	30 20	26 59
$30,000-$49,999	26 26	28 53	29 58	30 15	28 29	29 85	29 58	28 09
$50,000-$79,999	27 64	30 22	24 60	36 26	29 20	30 60	24 60	28 26
$80,000-more	11 49	13 10	14 62	16 07	12 42	14 55	14 62	16 39
Missing	1 15	1 17	1 01	0 93	0 83	0 93	1 01	0 67
Family Structure								
Intact	80 38	82 23‡	79 86	81 54‡	82 47	84 51	79 86	81 44‡
Recomposed	10 82	11 02	11 95	11 95	10 46	10 45	11 95	12 04
Single parent	8 66	6 61	8 01	6 37	7 07	5 04	8 01	6 19
Missing	0 13	0 13	0 18	0 13	0	0	0 18	0 13
Urban dwelling								
Rural	35 50	35 67	33 62	33 73‡	37 67	36 94‡	33 62	33 95
Urban	62 93	62 39	64 23	63 75	60 75	61 01	64 23	62 88
Missing	1 57	1 95	2 15	2 52	1 57	2 05	2 15	3 18

*Significant difference between all children and proportion of overweight/obese children (Chi square, two sided p≤0 05)
**Significant difference between all children and proportion of overweight/obese children (Chi-square, two sided p≤0 01)
† Weighted data
‡ 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 IOTF definition of overweight/obesity as the Primary Outcome

The purpose of this section aims to assess the association between diet quality and overweight/obesity at 4 and 6 years (Objective #1).

5.2.1 Bivariate associations between nutrition predictors and overweight/obesity

At the bivariate level, chi-square tests of independence showed that the following nutrition predictor (in quintiles) are positively associated with overweight or obesity at 4 years of age: linolenic acid ($p<0.0001$), linoleic acid ($p<0.0001$), pathothenic acid ($p=0.0137$), total saturated fats ($p=0.0069$), total monounsaturated fats ($p=0.0005$), total polyunsaturated fats ($p<0.0001$), energy ($p<0.0001$), total fiber ($p=0.04378$), total carbohydrates ($p<0.0001$), total lipid ($p=0.0004$), and total protein ($p=0.044$). The following nutrition predictor (in quintiles) are positively associated with overweight/obesity at 6 years of age (with the exception of saturated fats where a negative association was observed): linolenic acid ($p<0.0001$), linoleic acid ($p=0.0176$), total saturated fats ($p=0.0293$), total polyunsaturated fats ($p=0.0234$), energy ($p=0.0014$), and total carbohydrates ($p=0.0097$). See *Table 10* for details of the bivariate analysis of the total sample for nutritional predictor variables (in quintiles) by overweight/obesity at 4 and 6 years of age.

Table 10: Bivariate analysis † for nutritional predictor variables (in quintiles) by overweight/obese status at 4 and 6 years

Nutritional variable	Quintiles	4 years of age			6 years of age		
		% normal weight (87%)	% overweight/obesity (13%)	P-value (Chisq.)	% normal weight (87%)	% overweight/obesity (13%)	P-value (Chisq.)
Linolenic Acid (grams)	Quintile 1	95.96 [2,3,4,5]	4.04 [2,3,4,5]		91.77[4,5]	8.23[4,5]	
	Quintile 2	86.81 [1,5]	13.19 [1,5]	<0.0001*	86.24	13.76	<0.0001*
	Quintile 3	90.41 [1]	9.59 [1]		89.57[4]	10.43[4]	
	Quintile 4	84.77 [1]	15.23 [1]		81.66[1,3]	18.34[1,3]	
	Quintile 5	76.28 [1,2,3]	23.72 [1,2,3]		72.50[1]	27.50[1]	
Linoleic Acid (grams)	Quintile 1	91.22 [4,5]	8.78 [4,5]		85.62	14.38	
	Quintile 2	88.01 [5]	11.99 [5]	<0.0001*	87.39	12.61	0.0176*
	Quintile 3	91.79 [4,5]	8.21 [4,5]		90.67	9.33	
	Quintile 4	84.72 [1,3]	15.28 [1,3]		81.17	18.83	
	Quintile 5	78.58 [1,2,3]	21.42 [1,2,3]		71.68	22.32	
Pathothenic acid (grams)	Quintile 1	91.20 [4,5]	8.80 [4,5]		86.55	13.45	
	Quintile 2	87.39	12.61	0.0137*	84.77	15.23	0.3784
	Quintile 3	89.93 [4,5]	10.07 [4,5]		87.94	12.06	
	Quintile 4	83.31 [1,3]	16.69 [1,3]		82.57	17.43	
	Quintile 5	82.38 [1,3]	17.62 [1,3]		80.16	22.25	
Total saturated fats (grams)	Quintile 1	90.64 [2,5]	9.36 [2,5]		85.44	14.56	
	Quintile 2	84.54 [1]	15.46 [1]		81.07[3]	18.93[3]	0.0128*
	Quintile 3	89.50 [5]	10.50 [5]	0.0069*	90.35[2,5]	9.65[2,5]	
	Quintile 4	88.76	11.24		88.32	11.68	
	Quintile 5	80.63 [1,3]	19.37 [1,3]		77.60[3]	22.40[3]	
Saturated fats (as a % of total energy)	Quintile 1	85.11 [5]	14.89 [5]		76.65	23.25	
	Quintile 2	84.58 [5]	15.42 [5]	0.2166	88.99	11.01	0.0293*
	Quintile 3	87.16	12.84		84.56	15.44	
	Quintile 4	86.06	13.94		84.34	15.66	
	Quintile 5	91.23 [1,2]	8.77 [1,2]		87.89	12.11	
Total Monounsaturated fats (grams)	Quintile 1	91.50 [5]	8.50 [5]		85.67	14.33	
	Quintile 2	84.49 [5]	10.51 [5]	0.0005*	86.97	13.03	0.0507
	Quintile 3	87.75	12.25		87.57	12.43	
	Quintile 4	86.86	13.14		85.39	14.61	
	Quintile 5	78.61 [1,2,3]	21.39 [1,2,3]		76.40	23.60	
Monounsaturated	Quintile 1	88.68	11.32		83.09	16.91	

Table 10: Bivariate analysis † for nutritional predictor variables (in quintiles) by overweight/obese status at 4 and 6 years

Nutritional variable	Quintiles	4 years of age			6 years of age		
		% normal weight (87%)	% overweight/obesity (13%)	P-value (Chisq.)	% normal weight (87%)	% overweight/obesity (13%)	P-value (Chisq.)
fats (as a % of total energy)	Quintile 2	87.04	12.96	0.4571	82 82	17.18	0.7559
	Quintile 3	83.39	16.61		83.13	16 87	
	Quintile 4	86.68	13.32		86.34	13.66	
	Quintile 5	88.41	11.59		87.01	12.99	
Total Polyunsaturated fats (grams)	Quintile 1	90.88 $^{4 5}$	9 12 $^{4 5}$		87.12^{5}	12.88^{5}	
	Quintile 2	91.00 $^{4 5}$	9.00 $^{4 5}$		89.15	10.85	0.0234*
	Quintile 3	90.38 ^{5}	9.62 ^{5}	<0.0001*	84.54	15.46	
	Quintile 4	84.63 $^{1 2}$	15.37 $^{1 2}$		85.22	14.78	
	Quintile 5	77.20 $^{1 2,3}$	22 80 $^{1 2,3}$		75.93^{1}	24.07^{1}	
Polyunsaturated fats (as a % of total energy)	Quintile 1	89.47	10.53		83.86	16 14	
	Quintile 2	86 46	13.54	0.5247	84 17	15 83	0.3014
	Quintile 3	86.22	13 78		86.03	13.97	
	Quintile 4	87.86	12 14		88.62	11.38	
	Quintile 5	84.14	15 86		79.72	20.28	
Total Energy (kcalories)	Quintile 1	93.44 $^{3 4 5}$	6.56 $^{3 4 5}$		87 78^{5}	12.22^{5}	
	Quintile 2	90.34 ^{5}	9.66 ^{5}	<0.0001*	89.63^{5}	10 37^{5}	0.0014*
	Quintile 3	85.82 $^{1 5}$	14.18 $^{1 5}$		84.99^{5}	15.01^{5}	
	Quintile 4	88 84 ^{1}	11.16 ^{1}		85.50	14.50	
	Quintile 5	75 61 $^{1 2 3}$	24.39 $^{1 2 3}$		73.55$^{1 2 3}$	26.45$^{1 2 3}$	
Total Fiber intake (grams)	Quintile 1	89.63^{3}	10.37^{3}		83.72	16.28	0 5802
	Quintile 2	86.75	13.25	0 04378*	82.76	17.24	
	Quintile 3	84 10^{1}	15.90^{1}		86 10	13 90	
Total Carbohydrates (grams)	Quintile 1	95.17 $^{2 3,4 5}$	4.83 $^{2 3 4 5}$		89.89$^{4 5}$	10 11$^{4 5}$	0.0097*
	Quintile 2	89.26 $^{1 5}$	10.74 $^{1 5}$	<0.0001*	88.62^{5}	11 38^{5}	
	Quintile 3	87.14 ^{1}	12.86 ^{1}		84 80	15.20	
	Quintile 4	85.39 ^{1}	14.61 ^{1}		81.90^{1}	18.10^{1}	
	Quintile 5	77 08 $^{1 2 3}$	22 92 $^{1 2 3}$		76.61^{1,2}	4.47$^{1 2}$	
Carbohydrates (as a % of total energy)	Quintile 1	88.79	11.21		85 95	14.05	0.4542
	Quintile 2	88.70	12.30	0.8213	87.12	12.88	
	Quintile 3	88.94	14.06		86.06	13 94	
	Quintile 4	85.62	14.38		83 29	16.71	
	Quintile 5	86.08	13.92		80.09	19.91	

Table 10: Bivariate analysis † for nutritional predictor variables (in quintiles) by overweight/obese status at 4 and 6 years

Nutritional variable	Quintiles	4 years of age			6 years of age		
		% normal weight (87%)	% overweight/obesity (13%)	P-value (Chisq.)	% normal weight (87%)	% overweight/obesity (13%)	P-value (Chisq.)
Total Lipid Intake (grams)	Quintile 1	90.64 [5]	9.36 [5]		85.66	14.34	0.0787
	Quintile 2	89.17 [5]	10.83 [5]	0.0004*	85.96	14.04	
	Quintile 3	88.18 [5]	11.82 [5]		88.46	11.54	
	Quintile 4	88.20	11.80		85.06	14.94	
	Quintile 5	78.03 [1,2,3]	21.97 [1,2,3]		76.91	23.09	
Lipids (as a % of total energy)	Quintile 1	84.51	15.49		79.74	20.26	0.4334
	Quintile 2	87.16	12.84	0.5556	84.90	15.10	
	Quintile 3	86.06	13.94		84.57	15.43	
	Quintile 4	86.65	13.35		86.11	13.89	
	Quintile 5	89.75	10.25		87.17	12.83	
Protein (as a % of total energy)	Quintile 1	88.42	11.58		83.68	16.32	0.1908
	Quintile 2	84.07	15.93	0.2134	82.52	17.48	
	Quintile 3	83.81	16.19		79.95	20.05	
	Quintile 4	89.29	10.71		88.83	11.17	
	Quintile 5	88.57	11.43		87.34	12.66	
Total protein (grams)	Quintile 1	92.37 [2,4,5]	7.63 [2,4,5]		86.56	13.44	0.4218
	Quintile 2	85.71 [1]	14.29 [1]	0.044*	85.88	14.12	
	Quintile 3	89.51 [5]	10.49 [5]		86.24	13.76	
	Quintile 4	85.58 [1]	14.42 [1]		83.74	16.26	
	Quintile 5	81.03 [1,3]	18.97 [1,3]		79.38	20.62	
Cholesterol (mg)	Quintile 1	87.19	12.81		82.63	17.37	0.1828
	Quintile 2	84.80	15.20	0.6389	86.67	13.33	
	Quintile 3	87.8	12.20		87.00	13.00	
	Quintile 4	89.02	10.98		87.00	13.00	
	Quintile 5	85.30	14.70		78.49	21.51	

*Significant difference present between nutrition predictors and overweigh/obesity (Chi-square, two-sided $p \leq 0.05$)

[1 2 3 4 5] There is a significant difference (CHISQ $p \leq 0.05$) present in the nutritional predictor variables (in quintiles) according to weight status as marked by variable subgroups with the same superscript letter

† Weighted data

Source Data courtesy of the Québec Institute of Statistics, QLSCD 1998-2010

At the bivariate level, single logistic regressions showed that the following nutrition predictor variables (continuous) are positively associated with overweight or obesity at 4 years of age: linolenic acid (p<0.0001), linoleic acid (p<0.0001), pathothenic acid (p=0.0001), total saturated fats (p=0.0024), total monounsaturated fats (p<0.0001), total polyunsaturated fats (p<0.0001), total energy (p<0.0001), total fiber (p=0.0135), total carbohydrates (p<0.0001), total lipid (p<0.001), and total protein (p<0.001). The following nutrition predictor variables (continuous) are positively associated with overweight/obesity at 6 years of age: linolenic acid (p<0.0001), linoleic acid (p=0.0003), pathothenic acid (p=0.0374), total saturated fats (p=0.0421), total polyunsaturated fats (p<0.0001), total energy (p<0.0001), total carbohydrates (p<0.0001), total lipid intake (p=0.0037), and total protein (p=0.0080). See *Table 11* for details of the bivariate analysis of the total sample for nutritional predictor variables (continuous) by overweight/obesity at 4 and 6 years of age.

Diet quality and Body Mass Index in 4 and 6 year old children:
A prospective study using data from the Québec Longitudinal Study of Child Development

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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 childhood obesity is increasing at an alarming rate worldwide. The diets of children have shifted from nutrient-dense foods to energy-dense, nutrient-dilute foods.

Using data from the Québec Longitudinal Study of Child Development, this study aims to identify the nutritional factors related to BMI at 4 and 6 years and weight change from 4 to 6 years. This study also compares the diets of normal and overweight/obese children according to the DRI standards set by Health Canada. Associations were examined using chi-square tests, and multivariate linear and logistic regressions.

The nutrition variables which appear to consistently be associated with overweight and/or BMI are linolenic acid, saturated fat and grain products. A significant difference in linolenic acid, phosphorous and iron was found between healthy weight and overweight/obese children. Also, meeting the DRI recommendations of various nutrients differs among children from various demographic and socioeconomic groups.

(Word count= 146, 150 allowed)

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Furthermore, I would like to dedicate this thesis to my late uncle, Dr. Goliath Nessan, who passed away during the completion of this study. He encouraged me to be at my best and to always strive to be "excellent." He will forever live in my heart.

Table of Contents

List of Tables

List of Footnotes

List of Appendices

Chapter 1: Introduction

The prevalence of childhood obesity is increasing at an alarming rate worldwide. Globally, there are approximately 1 billion overweight adults with 300 million of them that are obese (World Health Organization, 2006). Social and behaviour changes over decades have facilitated the growth of this epidemic and as a result, the epidemic is also present in children (Murray and Battista, 2009; Markovic and Natoli, 2009). Both short-term and long-term effects of obesity have significant physical, mental and emotional repercussions (Children's Food in Canada, 2009; Engeland et al., 2003; Guo et al., 2002). Childhood obesity sets the stages for numerous health complications and diseases in adulthood. As a result, tremendous direct and indirect health care costs are associated with obesity.

This chapter reviews: 1) The definition and classification of overweight and obesity, 2) childhood obesity statistics in the United States and Canada, 3) the etiology of the disease and lastly, 4) the rationale for examining the relationship between diet and body mass index in children.

1.1 Background

1.1.1 Definition and Classification

Obesity is defined as an "abnormal or excessive fat accumulation" (WHO, 2006) and poses as a risk factor for numerous debilitating conditions. Childhood obesity is a multi-factorial disease convoluted in genetic, psychological, behavioural and environmental risk factors (Sorensen & Echwald, 2001; Wang & Brownell, 2005). Although this condition is complex in terms of causality, consumption of energy-dense foods with high-sugar levels or high-saturated fats and reduced physical activity are the leading contributors to this disease

(WHO, 2006). Basically, it is believed that obesity is a result of an energy input that exceeds energy output.

Ideally, the most precise estimates of total body fat are taken through direct measures of body composition such as underwater weighing (hydro-densitometry), air-displacement plethysmography, magnetic resonance imaging (MRI), computerized tomography (CT), or bioelectrical impedance analysis (BIA); however, these methods are costly and unsuitable for children and large population studies (Lobstein et al., 2004; Lobstein and Leach, 2007). Body mass index (BMI) is the most practical indirect measure of body fatness and is most commonly used for population-based studies (WHO, 2000). BMI is calculated by dividing the weight (in kilograms) by height squared (in meters). At the individual level, BMI may not accurately measure body fatness in people that are muscular, short, tall, or those of old age with degenerative muscle loss (Lobstein et al., 2004). BMI, however, is considered by the World Health Organization as the most useful population-level measure of obesity in adults and in children when taking into account age and sex (WHO, 2000).

Currently, the most common classification systems, which use BMI as an indicator of body fatness, are the International Obesity Task Force (IOTF) and the U.S.A. Centers for Disease Control and Prevention (CDC) growth charts. The IOTF was developed in 2000 by Cole et al. (2000) based on six large nationally representative cross-sectional surveys conducted in Brazil, Great Britain, Hong Kong, the Netherlands, Singapore and the United States. Age- and gender specific IOTF cut-off points for overweight and obesity children were determined by extrapolated backwards from adult cut-off points for 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). Thus, this method strongly predicts children's likelihood of being overweight or obese at 18 years of age, and allows for both interprovincial and international comparisons (Cole et al., 2000). *Table 1* summarizes the IOTF cut-off points for overweight and obesity by sex and age in children aged 2-18 years.

Table 1. International BMI classification according to IOTF standards based on sex and age for children between 2-18 years

Age (years)	Overweight Defined as body mass index ≥25 kg/m²		Obesity Defined as body mass index ≥30 kg/m²	
	Males	Females	Males	Females
2	18.41	18.02	20.09	19.81
2.5	18.13	17.76	19.80	19.55
3	17.89	17.56	19.57	19.36
3.5	17.69	17.40	19.39	19.23
4	17.55	17.28	19.29	19.15
4.5	17.47	17.19	19.26	19.12
5	17.42	17.15	19.30	19.17
5.5	17.45	17.20	19.47	19.34
6	17.55	17.34	19.78	19.65
6.5	17.71	17.53	20.23	20.08
7	17.92	17.75	20.63	20.51
7.5	18.16	18.03	21.09	21.01
8	18.44	18.35	21.60	21.57
8.5	18.76	18.69	22.17	22.18
9	19.10	19.07	22.77	22.81
9.5	19.46	19.45	23.39	23.46
10	19.84	19.86	24.00	24.11
10.5	20.20	20.29	24.57	24.77
11	20.55	20.74	25.10	25.42
11.5	20.89	21.20	25.58	26.05
12	21.22	21.68	26.02	26.67
12.5	21.56	22.14	26.43	27.24

13	21.91	22.58	26.84	27.76
13.5	22.27	22 98	27.25	28.20
14	22.62	23.34	27.63	28.57
14.5	22.96	23.66	27.98	28.87
15	23.29	23.94	28.30	29.11
15.5	23.60	24.17	28.60	29.29
16	23.90	24.37	28.88	29.43
16.5	24.19	24.54	29.14	29.56
17	24.46	24.70	29.41	29.69
17.5	24.73	24.85	29.70	29.84
18	25	25	30	30

Data source Cole et al, 2000

The second method commonly used as a classification system for childhood obesity uses BMI-for-age and sex-specific reference charts to classify overweight and obesity by BMI percentiles. To classify weight status, BMI is plotted on growth charts set up by the CDC in 2000, which rank weight by height, age and sex (National Health and Nutrition Examination Survey, (NHANES), 2009). These charts were developed by the national center for Health Statistics (NCHS) and have been revised as a result of recent data collections and advances in statistical procedures (NHANES, 2009). The latest revision occurred in 2000 where most of the data came from the National Health and Nutrition Examination Survey (NHANES, 2009). Initially, this committee recommended the use of the 85th and 95th percentiles for age and sex to define at "risk of overweight" and "overweight" respectively, to avoid the stigma associated with the term obesity (Kuczmarski et al., 2000). However, more recently, the term overweight replaced "at risk of overweight" and obesity replaced "overweight" (Bradford, 2009). The CDC revised growth charts for US children and adolescents include BMI-for-age charts for males and females aged 2-20 years, which can be used clinically or epidemiologically (Ogden et al., 2002). 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 sex-specific reference charts appropriate to their study population.

Studies have shown that the CDC obesity estimates produce a greater prevalence of obesity (Flegal et al, 2001 & Chinn, 2006). Additionally, the CDC obesity definitions can also be used in children under 2 years of age, unlike the IOTF definitions, which examine children between 2-18 years of age. The CDC estimates can be used for continuous and categorical BMI measures; however, the IOTF cut-offs only define overweight and obesity alone (Chinn, 2006). Despite the downfalls of the IOTF-cut offs, it is recommended that prevalence based on this method be given in addition to national reference data, since it allows for international comparisons (Barlow and Dietz, 1998).

Table 2 summarizes the classification of weight status according to BMI percentiles as set up by the CDC.

Table 2. BMI percentile classifications according to the CDC growth charts

BMI percentile classification	Range of BMI percentile
Underweight	1^{st} to 10^{th} percentile
Normal weight	10^{th} to 84.9^{th} percentile
Overweight	85^{th} to 94 9^{th} percentile
Obesity	95^{th} to 100^{th} percentile

Source NHANES (2009) and Bradford (2009)

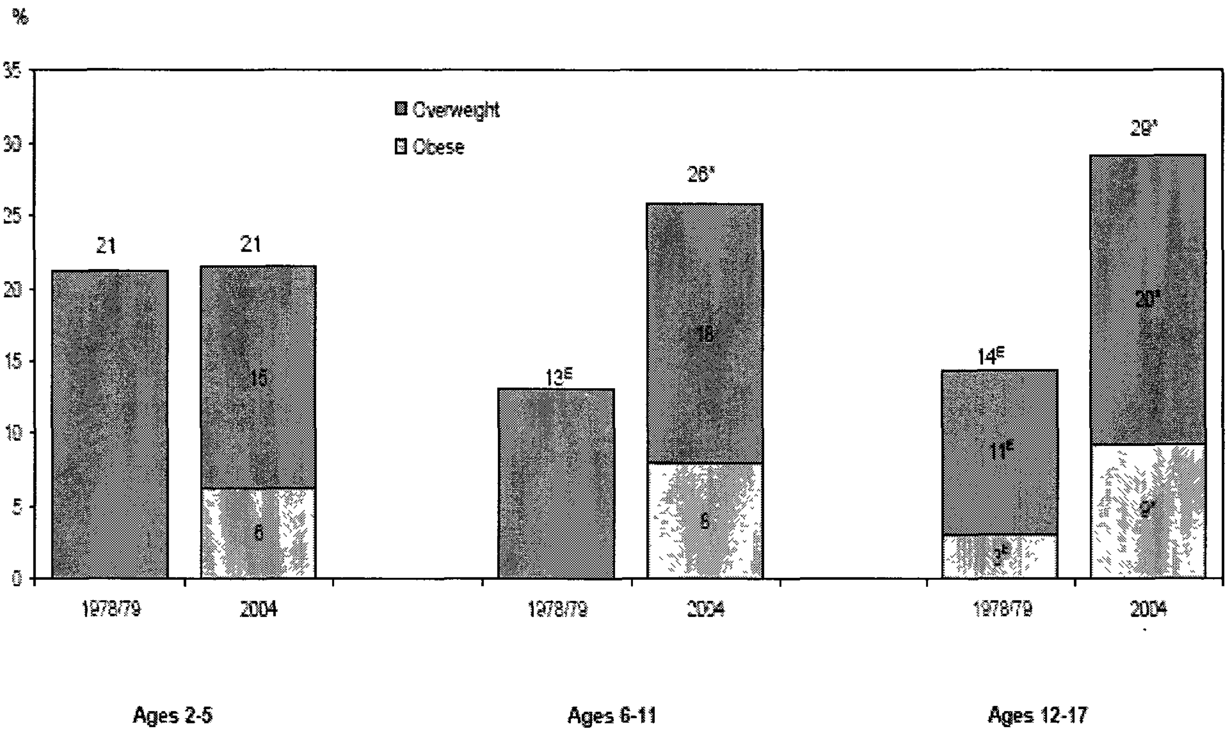
1.1.2 Childhood Obesity Statistics in the United States of America

The CDC and the NHANES collaborate every few years to collect data regarding the weight status of children. From 1960 to 1980, the prevalence of childhood obesity was stable.

However, "from the 1976 to 1980 period to the 2003-to 2004 period, the prevalence of obesity (defined as BMI $\geq$ the 95th percentile) increased dramatically in all age groups. The prevalence of obesity doubled in 2- to 5- year olds from 7.2% to 13.9%. In 6 to 11 years old, the prevalence went from 11% to 19%, and in 12- to 19- years old from 11% to 17%. Overall, in the 2003-to-2004 survey, 17% of the children and adolescents were obese" (Bradford, 2009).

1.1.3 Childhood Obesity Statistics in Canada

In Canada, the prevalence of obesity (BMI above the 95th percentile for age and sex) in children more than doubled between 1981-1996, from 5% to 16.6% for boys and from 5% to 14.6% for girls (Gillis and Gillis, 2005). The prevalence of overweight at this time (BMI above the 85th percentile for age and sex) among boys has increased from 15% to 35.4% and among girls from 15% to 29.2% as well (Gillis and Gillis, 2005). In 2004, the Canadian Community Health Survey (CCHS) found that 26% of children and adolescents between 2-17 years of age were overweight or obese, where approximately 8% were classified as obese (Statistics Canada, 2005). Between 1979 and 2004 (Figure 1), overweight and obesity doubled among 12-17 year olds from 14% to 29%) and tripled among 12-17 year olds (from 3% to 9%) (Statistics Canada 2005; Statistics Canada 2008). During 1979-2004, the percentage of children aged 2 to 5, who were overweight or obese remained stable, however, the prevalence of obesity itself rose 6% (Statistics Canada, 2005).



Data sources: 2004 Canadian Community Health Survey: Nutrition; Canada Health Survey 1978/79
Note: The obesity rates for the 2-5 and 6-11 age groups from the 1978/79 Canada Health Survey have coefficients of variation greater than 33.3%, therefore, the estimates are not releasable.
E Coefficient of variation between 16.6% and 33.3% (interpret with caution)
* Significantly different from estimate for 1978/79 ($p < 0.05$)

Figure 1. A comparison of the prevalence of overweight and obesity for Canadian children aged 2-5, 6-11, and 12-17 from 1978/79 to 2004.
*

1.1.4 Health complications associated with Obesity

Childhood obesity is associated with numerous physiological and psychological health disorders. These disorders include short-term health risks such as the development of "glucose intolerance and insulin resistance, type II diabetes, hypertension, sleep apnea, impaired balance, orthopedic problems, low self-esteem, negative body image, depression, negative stereotyping, teasing and bullying, and social marginalization" (Children's Food in Canada, 2009). In addition to these short-term effects, childhood obesity is related to long-terms effects,

* http://www.statcan.gc.ca/pub/82-620-m/2005001/article/child-enfant/8061-eng.htm

which continue into adolescence and adulthood. Long-term effects include type II diabetes mellitus, hypertension, hyperlipidemia, metabolic syndrome, polycystic ovarian syndrome or hyperandrogenism, obstructive sleep apnea, mental health, and neurological disorders, adult obesity and mortality (Engeland et al., 2003 & Guo et al., 2002).

Both the short and long-term effects of childhood obesity have imposed a direct and indirect economic burden on the health-care system of Canada (Katzmarzyk & Janssen, 2004; Lobstein et al., 2004; Wolf, 1998). Direct medical costs include diagnostic and treatment services related to obesity and obesity-related comorbidities (Lobstein et al., 2004). Indirect costs are related to the morbidity and mortality associated with the disease (Lobstein et al., 2004). Without sustainable prevention and management strategies, the economic impact of obesity will continue to grow and subsequently, drain the health-care and social systems of Canada.

1.2 Rationale

Over the last few decades there has been a shift in diet and activity patterns, which have propagated an epidemic of obesity among children and adolescents (Murray and Battista, 2009). This shift is a global transition – "from a period of famine, heavy physical activity patterns that are among the causes of non-communicable diseases" (Murray and Battista, 2009) to a period of poor diets and sedimentary lifestyles since 1980. These changes have caused the prevalence of obesity in all regions of the world to significantly increase (Murray and Battista, 2009).

Many factors seemed to rise during this time period, which has contributed, to this epidemic. This includes the use of soft drinks instead of water and milk, the development of video games, computers and home movies and changes in urban design which has allowed for fast food, long drives and eating in cars (Murray and Battista, 2009). Active lifestyles were replaced with sedimentary lifestyles (Markovic and Natoli, 2009). The diets of children and adults shifted from whole, nutrient-dense foods to energy-dense, nutrient-dilute foods. This has led to a paradoxical nutritional deficiency in overweight and obese individuals (Markovic and Natoli, 2009).

Good quality diets tend to be energy-dilute and nutrient-rich and thus contain a sufficient intake of energy, macronutrients, micronutrients, and other important nutrients such as fiber (Darmon and Drewnowski, 2008). For example, a diet high in whole grains, fish, fresh vegetables, and fruits is indicative of a good quality diet. A poor quality diet tends to be high in refined grains, sugar and fat (Darmon and Drewnowski, 2008). Consumption of these unhealthy foods suppresses satiety and provokes overeating and weight gain (Darmon and Drewnowski, 2008).

Despite speculation that both carbohydrate quantity and quality have contributed significantly to excess weight gain, the relationship between carbohydrate intake and body mass index is controversial. Although prospective observational studies performed in adults have found that a higher dietary glycemic index or lower intakes of fiber and whole grain are independently associated with weight gain (Hare-Brunn et al., 2006, Koh-Banerjee et al., 2004, Liu et al., 2003, Ludwig et al., 1999, Ma et al., 2005, Nooyens et al., 2005), these observations are not conclusive (Cheng et al., 2008, Iqbal et al, 2006) and minimal research exists in children.

Mixed findings have also been observed with protein intake and childhood obesity as well. The link between protein intake and childhood obesity is a relatively recent finding. A cross-sectional study conducted in Italy found that protein intake was not significantly different between obese and non-obese children (Rocandio et al., 2001). However, longitudinal studies have demonstrated a positive link between protein intake and overweight in children (Skinner et al., 2004; Scaglioni et al., 2000; Gunther et al., 2007). It has also been suggested that the type of protein consumed, whether animal, plant or dairy, is associated with obesity rather than protein intake as a whole (Gunther et al., 2007). Due to the novelty of these findings, it is important to investigate the relationship between this macronutrient and childhood obesity.

Additionally, little research exists as to whether the quality of dietary fats, not just the quantity, is related to overweight and obesity. Studies have demonstrated that a diet high in saturated fats causes weight gain and obesity in adults (Soares, 2003) since saturated fats are stored in adipose tissue rather than being subjected to oxidation (Piers, 2003). Monounsaturated fats, on the other hand, have shown to have significant health benefits (Soares, 2003). They increase fat oxidation and induce greater thermogenesis of food, which prevents weight gain (Soares, 2003). Diets high in monounsaturated fats also improve insulin sensitivity (Riccardi, 2004) and have a low energy density (Soares, 2003). Soares et al. (2003) observed that men following a diet high in monounsaturated fats have lower body weight and greater fat loss than those consuming a diet high in saturated fats. A similar study found that men had a greater weight loss when they consumed a diet high in monounsaturated fats than those with a diet high in saturated fats with similar energy intakes (Piers, 2003). This suggests that monounsaturated fats can induce significant losses in body weight without significant changes in energy intake. Additionally, saturated fatty acids, and polyunsaturated fatty acids are positively associated with the prevalence of obesity in adults (Moussavi, 2007). A strong negative association also exists between monounsaturated fats and the prevalence of obesity (Moussavi, 2007). In contrast, polyunsaturated fats (especially those found in fish oil) in addition to monounsaturated fats (especially those found in olive oil) have been found to promote weight loss (Moussavi, 2007) and have health benefits, which protect against heart disease. However, studies of these types of fats in children are minimal.

In our study, we assessed the association of diet quality in relation to body mass index in pre-school children. Diet quality will be assessed by examining carbohydrate, protein, and fat intake of children between 4 and 6 years of age. Additionally, the diets of children from various demographic and socioeconomic groups will be compared and contrasted. These findings may suggest hidden social inequalities present in society and promote new research to improve nutrition as a means of preventing childhood obesity.

Chapter 2: Literature Review

This chapter presents 1) the covariates that are common to both diet quality and overweight/obesity, 2) a description of how different covariates relates to diet quality and overweight/obesity in children and lastly, 3) a literature review which investigates the relationship between diet quality and overweight/obesity.

2.1 Common covariates of diet quality and overweight/obesity in children

Diet quality and overweight/obesity in children have several common covariates, which are significantly related to both of these variables (see Table 4). This relationship can be confounded by several covariates and thus controlling for these cofounders is imperative. A confounder is defined as "the mixing of effects between an exposure, an outcome, and a third extraneous variable known as a confounder" (Achengrau and Seage III, 2003). Confounders distort the relationship between an outcome and exposure variable since a relationship is present between the confounder and outcome and confounder and exposure. Controlling for the influences of extraneous factors is necessary in order to ensure the study is valid and the findings are accurate.

An indictor of overall diet quality can be measured by energy density; energy available from foods per unit weight (Darmon and Drewnowski, 2008). Good quality diets tend to be energy-dilute and nutrient-rich, thus, they have sufficient intakes of energy, macronutrients, micronutrients, and other important nutrients such as fiber (Darmon and Drewnowski, 2008). For example, diets high in whole grains, fish, fresh vegetables, and fruits are indicative of good diet quality. Diets of poor quality tend to be high in refined grains, sugar and fat (Darmon and Drewnowski, 2008). These types of foods suppress satiety, provoke overeating and in turn cause weight gain (Darmon and Drewnowski, 2008). Diet quality is strongly influenced by a child's physical and social environment. A discussion regarding the child, parent, demographic and socioeconomic factors related to a child's diet quality are presented below.

2.1.1 Relationship between child characteristics and diet quality

It is well known that poor diet quality and a sedimentary lifestyle highly influence body weight in children. However, several other child characteristics are associated with poor diet quality as well. Veugelers et al. (2005) found that girls who are 10-11 years of age have diets of better quality than boys of the same age. Specifically, it was found that boys have a 7% higher risk of poor diet quality in comparison to girls. Skipping breakfast has also been shown to be significantly associated with a poor diet as well (Dubois et al., 2005; Dubois et al., 2007; Veugelers et al., 2005). Skipping breakfast puts children at an 18% higher risk of poor diet quality (Dubois et al., 2007). Meals eaten in front of televisions, sedentary activities (TV, computer, video games), and low physical activity levels have also been linked to poor diets in children (Patrick and Nicklas, 2005; Boumtje et al., 2005; Veugelers et al., 2005). Additionally, child-care centres have an impact on children's diet quality (Pollard, 2001). Regulations or policies that ensure proper nutrition and physical activity are not mandatory in many child-care centres. Child-care providers have a significant impact on children's health practices (Pollard, 2001), thus, the importance of educated instructors which ensure good diet quality and physical activity levels can impact children obesity rates.

Chronic disease has also been linked to poor diet quality in children. Feeding problems in children with chronic illness is a common issue in these children. Children with chronic illnesses tend to be fussy eaters and are prone to malnutrition. Child temperament affects diet quality since food refusal is common in some disease processes (Harris et al., 2000). Dietary restrictions or demands exist with certain chronic diseases such as asthma, diabetes, cystic fibrosis and chronic renal disease (Fielding and Alistair, 1999). Diseases affecting major organs are likely to cause children to have trouble with food acceptance, in addition, to certain minor diseases as well (Harris et al., 2000).

Several demographic and socioeconomic factors are related to diet quality (Patrick and Nicklas, 2005; Darmon and Drewnowski, 2008; Veugelers et al., 2005; Campbell et al., 2002). Specifically, a step-wise gradient between socioeconomic status and diet quality has been observed (Darmon and Drewnowski 2008; Veugelers et al., 2005). Individuals from higher socioeconomic status tend to consume more whole grains, lean meats, fish, low-fat dairy products, and fresh fruits and vegetables (Darmon and Drewnowski, 2008). Poor diets are also more prevalent among children from families of low socioeconomic status. These children tend to consume more refined grains, high-sugar and high-fat in their diets (Darmon and Drewnowski, 2008). A review conducted by Darmon and Drewnowski (2008), found that in the United States, the consumption of refined cereals (white bread), pasta, rice, added fats, and fatty meats were associated with lower socioeconomic status. In contrast, high socioeconomic families consumed more fresh vegetables and fruits, as well in a higher portion, to those from low socioeconomic families. This trend has also been observed in European countries (Irala-Estevez et al., 2000), Australia, (Giskes et al., 2002), the Netherlands (Giskes et al., 2004), and in Canada (Ricciuto and Tarasuk, 2007).

Veugelers et al. (2005) conducted a study in Nova Scotia, Canada, which examined the risk factors associated with poor diet among grade five children. This study found that parental place of origin (other than Canada), martial status of the parents (married or common law, separated or divorced, or single or widowed) and household annual income were not related to diet quality. However, household annual income has been positively associated with overweight among children in other studies conducted in the United States (Boumtje et al., 2005; Patrick and Nicklas, 2005). Children of parents with healthy eating practices, high socioeconomic backgrounds, and high parental education have been observed to have good quality diets (Veugelers et al., 2005; Boumtje et al., 2005; Patrick and Nicklas, 2005). Particularly, in the United States, children of parents with low education tend to consume less fruits and vegetables and have a limited selection of this food group to eat (Kirby et al., 1995). In some cases, children do not meet recommendations for fruits and vegetables by 40% (Neumark-Szatainer, 1998). Low intake of fruits and vegetables and high intake of sweetened beverages has also been observed in children from families of low socioeconomic status in European countries (Serra-Majem et al., 2002; Haapalahti et al., 2003; Laitinen et al., 1995; Vereecken et al., 2005). These children also have high intakes of sweetened beverages as well (Kirby et al., 1995).

Additionally, Patrick and Nicklas (2005) found that children from parents with higher education make healthy food choices and thus have "higher intakes of carbohydrates, protein, fiber, folate, vitamin A, and calcium; higher consumption of vegetables; and greater likelihood of consuming the recommended servings of dairy products" per day. Children from higher income families which have a higher intake of "polyunsaturated fats, protein, folate, calcium, and iron and were more likely to meet the recommended number of daily servings for dairy products" (Patrick and Nicklas, 2005). In the U.S, Crawford et al. 1995 demonstrated an inverse relationship between the percent of kilocalories consumed from fat in children and parental education and family income. A strong negative relationship exists between maternal education and children's consumption of sugar intake, as opposed to paternal education alone (Patrick and Nicklas, 2005; Campbell et al., 2002). Exclusive use of whole milk has been observed in families with parents that had less than a high school education as opposed to reduced fat milk, which was highest among parents who had graduated from college (Patrick and Nicklas, 2005). Mothers who were least educated and youngest also rely more heavily on convenience foods to feed their children (Lowry et al. 1996). Children from mothers with a higher education also tend to watch less television during evening meals (Campbell et al., 2002) and also are more likely to breastfeed their children (Martinez and Nalezienski, 1981). Breastfeeding has been observed to have a protective role against childhood obesity as well (Dubois and Girard, 2006).

Children of single parent homes or of two parents working outside the home tend to have poor diets as well (Patrick and Nicklas, 2005). Since these parents have longer work hours, they rely on convenience foods (i.e. fast foods) to feed their children as a result of time constraints. Mother's who are overweight also make poor food choices for their children, thus mother's behaviour significantly influences the child's diet quality (Khloe-Lehman et al., 2007). Lastly, rural dwelling creates difficultly in obtaining energy-dilute, nutrient-dense foods at reasonable prices. In addition to high costs, fruits and vegetables available in rural setting tend to be of poor quality and limited variety (Campbell et al., 2002). Thus, easy access to energy-dense foods becomes the norm in these locations and perpetuates poor diet in these communities (Darmon and Drewnowski 2008; Campbell et al, 2002).

Birth weight of children, an indicator of socioeconomic status, is indirectly related to diet quality. Low birth weight is associated with low socioeconomic status since an unequal number of low birth weights are found among low socioeconomic families in comparison to high socioeconomic families. Very low birth weight has been associated with increased morbidity in school-aged children, where the effect is amplified in those from low socioeconomic status families (McCormick, et al., 1992). Inequalities in low birth weight have also been observed in England, where a study found that 30% of low birth weights occur among socioeconomically disadvantaged families (Pattenden et al., 1999). Children from low-income families with parents who smoke have been observed to have poor diets as well (Johnson, 1996). Johnson et al., (1996) observed that "children whose parents smoked 11 or more cigarettes per day had lower vitamin A intakes and higher energy and sodium intakes than children whose parents smoked 10 or fewer cigarettes per day." Johnston et al., (1996), also found that "children whose parents smoked more than 20 cigarettes per day had a higher percentage of energy from saturated fat, and children whose parents smoked 11 to 20 cigarettes per day had the highest cholesterol intakes in comparison to the rest of the sample." It is also found that parental smoking is related to low fiber intakes in children (Johnson et al., 1996). Thus, parental smoking status has a significant relationship with children's diet quality, and increases the risk of chronic illness in children.

2.1.2 Relationship between covariates and obesity

Early determinants or risk factors for overweight/obesity have been defined by several studies. A Québec longitudinal study conducted in children 4.5 years of age found various social and behaviours factors to be associated with childhood overweight/obesity (Dubois and Girard, 2006). Maternal smoking (Dubois and Girard 2006; Toschke et al., 2008), weight gain between birth and 5 months (Dubois and Girard, 2006), household annual income (Dubois and Girard, 2006), single-parent households (Strauss and Knight, 1999; Gibson et al., 2007) and parental overweight/obesity (Dubois and Girard, 2006; Toschke et al., 2008; Reilly et al.,

2005) were all deemed early determinants of overweight at 4.5 years of age (Dubois and Girard, 2006). Birth weight as a predictor of childhood obesity, however, has mixed results. Studies suggest that birth weight can predict weight gain later in childhood since it programs the fat accumulation in the intra-abdominal area (Druet et al., 2008). Thus, children born small for gestational age are prone to weight gain later in life (Hokken-Koelega et al., 1995, Ong et al., 2000, Reilly et al., 2005). However, positive associations have also been found between higher birth weights and higher BMI in childhood (Whitaker and Dietz, 1998). Thus, birth weight is believed to be a causal factor that puts children at risk of subsequent childhood obesity (Hokken-Koelega et al, 1995, Karlberg et al., 1997, Ong et al., 2000, Baird et al., 2005, Ong, 2006).

Studies conducted in the United States (Whitaker, 2004) and Germany (Danielzik et al., 2004) found that parental overweight was the most potent risk factor for childhood obesity. A study conducted by Toschke et al. (2008) found that maternal overweight and high weight gain of the child in the first two years of life were significant risk factors for childhood obesity. They found that if all children in a population were exposed to these risk factors equally (and were susceptible to this risk factor), then a shift in BMI distribution would be observed. The mechanism in which maternal overweight is thought to contribute to childhood obesity is not conclusive; however, influences on a child's diet through obesogenic available foods, maternal food habits, maternal food beliefs, and amount of food served are thought to be the main culprits (Agras and Mascola, 2005).

Maternal smoking during pregnancy was deemed an early determinant for overweight/obesity in children as well (Dubois and Girard, 2006; Toschke et al., 2008). It was found that maternal smoking during pregnancy almost doubled the odds of being overweight at

4.5 years of age (Dubois and Girard, 2006). Additionally, children born to non-smoking mothers but with a high birth weight (more than 4000 g) were overweight at 4.5 years. The majority of children, who were more likely to be overweight at 4.5 years, were born to smoking mothers and were of normal birth weight (3000-4000g). These children gained the most weight during the first 5 months of life, compared to children of non-smoking mothers (Dubois and Girard, 2006).

Skipping breakfast has also been associated with overweight/obesity in children at 4.5 years of age (Dubois and Girard, 2006). Dubois and Girard (2006) demonstrated that almost 10% of children do not eat breakfast everyday. A greater proportion of these children have immigrant mothers, mothers with no high-school diploma, and come from families with a low household annual income. Skipping breakfast in the morning nearly doubled the odds of being overweight at 4.5 years of age (Dubois and Girard, 2006) and is associated with a lower diet quality. Dubois et al., (2008) found that children that skipped breakfast would overcompensate by consuming high-energy snacks, carbohydrates and proteins in the afternoon and evening as opposed to a more even distribution of energy intake throughout the day.

In developed countries, there tends to be a negative trend between high socioeconomic status and childhood obesity. This finding had been observed in the United States (Stunkard et al., 2004) Canada, and Germany (Danielzik et al., 2004). However, this trend has not been observed in Brazil (da Viega et al., 2004) or Russia (Wang et al., 2002). A study conducted in the United States found that from 2003 to 2007 the prevalence of obesity increased 10% from 16.4% for all U.S. children (Singh et al., 2009). The prevalence of obesity was about 23-33% for children from low-education, low-income, and unemployed households (Singh et al., 2009). Additionally, the prevalence of obesity grew between these years among single-mother households and various minority groups such as Hispanics, non-Hispanic White, and America Indian children (Singh et al., 2009). Further demonstrating the social inequalities in obesity children, the odds of being obese in children from low-income and low-education families were 3.4-4.3 times higher than those from high socioeconomic families (Singh et al., 2009). Low maternal education, in particular, has been deemed a risk factor for childhood obesity (Saxton et al., 2009). Low maternal education influences poor feeding choices, which impacts the child's diet quality and weight status (Saxton et al., 2009).

Physical inactivity is a well-known risk factor for childhood obesity. Physical inactivity in children has been shown to be inversely associated with BMI (Segal et. al, 2009). However, measuring the activity level of a child is difficult and therefore determining the level of physical activity necessary to combat childhood obesity is complex. Studies using an accelerometer have found that insufficient vigorous physical activity have been linked to childhood obesity (Patrick et al., 2004). The link between reduced physical activity, increased screen time and childhood obesity have been observed as well. Sedentary activities such as computer use, video games, and television viewing have been linked to childhood obesity. Overweight children that par-take the most in sedentary activities tend to be the least physically active (Jannsen et al., 2004).

High frequency of television viewing alone is also a risk factor for childhood obesity (Toschke et al., 2008; Dubois et al., 2008; Manios et al., 2009; Reilly et al., 2005). Dubois et al., 2008 found that roughly one quarter of children in Québec eat in front of the television at least twice daily. Children that watched television at this frequency in addition to consuming snacks during this time had higher BMIs than children who watched television at a lower frequency (Dubois et al., 2008). Children who ate snacks in front of the television also consumed "more carbohydrates (total), more fat and less protein, fewer fruits and vegetables, and drank soft drinks more than children who never ate snacks in front of the television" (Dubois et al., 2008). Additionally, television viewing for more than 2 hours per day has been associated with increased consumption of high-energy foods which are of high-fat and high-sugar content in preschool children in Greece (Manios et al, 2009). Thus, television-viewing behaviour has a significant impact on children food habits. It increases the risk of overweight and obesity among children since it reduces physical activity and increases energy intake.

Breastfeeding has been thought to have a protective role against childhood obesity (Toshcke et al., 2008, Agras and Mascola, 2005). A dose-dependent response was found between duration of breastfeeding and childhood obesity, however, this relationship was only present if the child was breastfed for 3 or more months (Grummer-Strawn and Mei, 2004). The negative association between breastfeeding and childhood obesity is thought to be a result of greater self-regulation of the child's diet later in life. It was found that the longer a mother breastfeeds, the less likely they are to restrict a child's diet at 1 year of age. This is linked to controlling a child's feeding style, which is associated with childhood obesity (Agras and Mascola, 2005).

In addition to behavioural and parental influences, neighbourhood characteristics also have an impact on childhood obesity. Living in rural areas can restrict access to stores with reasonably priced fruits and vegetables, parks, and recreational facilities. This in turn increases sedentary behaviour and reduces physical play. A study conducted in Nova Scotia, Canada, found that children from neighborhoods that have access to grocery stores had diets of higher quality and were less likely to be overweight or obese (Veugelers, 2008). It was also found that children with access to parks and recreational facilities were more physically fit (Veugelers, 2008). This trend was also observed in neighborhoods deemed safe by the parent (Veugelers, 2008).

Childhood obesity can also have short-term and long-term health effects on chronic illness. Obese children are more likely to develop orthopedic disorders (Barlow and Dietz, 1998), sleep disorders (Barlow and Dietz, 1998), gall bladder disease (Barlow and Dietz, 1998), insulin resistance (Barlow and Dietz, 1998; Reilly, 2005), and cardiovascular disease risk factors (Reilly, 2005) such as hypertension, dyslipidaemia, and left ventricular abnormalities. Short-term health consequences also include psychological ill-health (Reilly, 2005), such as behavioural problems and low self-esteem, which may result from bullying, and lack of popularity/friendship (Reilly, 2005). Asthma and chronic inflammation are additional short-term health consequences of childhood obesity (Reilly, 2005). Persistence of obesity into adulthood is commonly seen in addition to the health consequences that accompany the disease. The persistence of obesity in later life is significantly associated with parental obesity and the length and severity of obesity during childhood (Reilly, 2005).

2.1.3 Conclusion

In conclusion, diet quality and overweight/obesity in children share many covariates that are necessary to control for in statistical modeling. *Table 3* summaries the relationship between various covariates, diet quality and overweight/obesity.

Table 3. Relationship between various covariates and diet quality and overweight/obesity		
	Poor diet quality	**Overweight/obesity**
Child/Birth Characteristics		
Low birth weight (yes vs. no)	Positive	Positive or negative
Mother smoked during pregnancy (yes vs. no)	Positive	Positive
Breastfeeding (yes vs. no)	Negative	Negative
Chronic health illness (yes vs. no)	Positive	Positive
Level of physical activity (high vs. low)	Negative	Negative
Screen time (television watching, computer use) (high vs. low)	Positive	Positive
Child care/day care (yes vs. no)	Negative or positive	Negative or positive
Parent Characteristics		
Mother's level of education (high vs. low)	Negative	Negative
Mother's immigrant status (immigrant vs. non-immigrant)	Positive	Positive
Mother overweight/obese (obese vs. normal)	Positive	Positive
Demographic and Socioeconomic Characteristics		
Household annual income (high vs. low)	Negative	Negative
Family structure (single parent vs. intact)	Positive	Positive

Table 3. Relationship between various covariates and diet quality and overweight/obesity		
	Poor diet quality	**Overweight/obesity**
Urban dwelling (Rural vs. urban)	Positive	Positive

2.2 The Relationship Between Diet and Body Weight in Childhood: A Critical Appraisal of the Literature

This section details the critical appraisal of the literature that was conducted to determine what is currently known about the relationship between diet quality and overweight/obesity in children. The review was conducted prior to the initiation of the study described in the paper (November 2009) and updated upon completion of the study (June 2010).

2.2.1Literature Review Objective

The objective of this literature review was to use observational studies to assess the relationship between diet quality and childhood obesity in order to verify previous findings and propose methods to control childhood obesity.

2.2.2 Eligibility criteria

Studies were included if the relationship of diet quality (carbohydrate, protein, and dietary fats) was examined in association with overweight/obesity or BMI in children. The target population consisted of children between 1-15 years of age. This age group was chosen since it contained the age group examined in this study (4 and 6 years of age) and was presented as a limit using the main search engines. Studies conducted in under-developed or developing countries were excluded since the gap between the rich and the poor is greater in these countries and thus, socioeconomic inequalities are not comparable to Canada. Additionally, in contrast to developing countries, studies conducted in developed countries have found that the prevalence of overweight/obese children is greater in low socioeconomic groups.

The independent variable of interest (exposure) was diet quality. Studies were included if diet quality was measured by one or all macronutrients (carbohydrates, protein, fats) and studies that described individual intake of foods categories. Papers concerning only the temporal aspects of food intake (meal patterns, eating behaviours, etc.) were excluded since our study did not examine this type of relationship. Studies that focused solely on one or more micronutrients were excluded as well since our study focused on the relationship between macronutrients and childhood obesity.

The dependent variable of interest (outcome) was BMI or overweight/obesity. BMI or overweight must also be defined either by the IOTF, the CDC revised growth charts or another comparable growth chart. Studies that calculated BMI based on self-reported or measure height and weight measurements were included. Studies using skin fold thickness or waist circumferences alone were excluded. These studies were excluded to allow for meaningful comparison between populations.

Observational study designs were included in this review with the exception of randomized control trials. However, considering the unethical nature of randomized control trials, it is unlikely that these types of studies exist except in studies that focus on weight loss. Only studies published in English were included in this review.

2.2.3 Search Strategy

The electronic databases used to conduct this literature review include MEDLINE, EMBASE, CINHAL, Psych Info and In-process/non-indexed MEDLINE using the Ovid version 10.2.1 interface. The search strategy employed in MEDLINE is available in Appendix A. Search strategies for the other databases were adapted from the detailed search strategy used in MEDLINE. Only one reviewer was available to assess inclusion/exclusion criteria.

Search terms were based on the independent variable (diet quality, carbohydrates, proteins, fats), dependent variable (BMI or overweight/obesity), target population (children between 1-15 years of age), to the English language, and studies conducted in the last 10 years (2000-current) in developed countries. The exposure terms were grouped using the "OR" command and the outcome terms were grouped using the "OR" command as well. The findings of these commands were then grouped using the "AND" command.

The reference lists of all relevant articles were explored for additional studies relevant to this literature review. Additionally, manual searches were conducted between each exposure and each outcome using MEDLINE to ensure no relevant articles were left out.

All potential relevant studies were imported using a reference database (RefWorks). Duplicate and triplicate publications were removed from the initial search. After duplicate and triplicate publications were removed from the initial search, the titles and abstracts of 1333 potential studies were screened for inclusion. Full articles of the 153 remaining studies were obtained in order to thoroughly assess inclusion and exclusion criteria. This was based on the relevance of these articles to the objectives of this study and excluding articles, which investigate other diseases in conjugation with obesity (such as diabetes). After full articles were examined, 12 studies were consequently included in this review.

2.2.2 Results and Discussion

Study characteristics of the included studies are presented in Table 3.1. Five studies were conducted in the United States, 1 in Italy, 1 in Spain, 1 in New Zealand, 1 in France, 1 in Australia, 1 in Sweden and 1 in Germany.

Majority of studies were based on data collected from larger population studies while others were community-based studies. Measures of body mass index were comparable among the 12 included studies, where BMI was either based on the IOTF standards or CDC reference standards. Only the study from Italy used the French Rolland-Cachera curves to define overweight/obesity.

All of the 12 studies included both boys and girls, none focused on one sex alone. The age groups investigated in the included studies did vary significantly and the range in age from all the studies included was between 1-15 years of age. Cut-points for overweight/obesity were similar among all studies with the exception of the study conducted in Italy, which used the 90^{th} percentile as opposed to the 85^{th} percentile.

Table 3.1: Study Characteristics

Author(s), Year, & Country	Publication Type	Study Design & Objectives	Study Population & Age Range & Sex	Sample Size	Independent Variable of Interest Modeled (Exposure) & Measurement	Dependent Variable of Interest Modeled (Outcome) & Measurement
Field et al , 2003 United States	Journal article	Prospective cohort study "To assess whether intake of fruits and vegetables was associated with change in body mass index (BMI) among a large sample of children and adolescents in the United States "	Data were obtained from the 1996-1999 Growing Up Today Study (GVTS) Age 9-14 years of age Boys & Girls	8203 girls 6715 boys	Fruit, fruit juice (servings/day) and vegetable intake (servings/day) were evaluated using a validated food frequency questionnaire	Change in BMI z-scores over 3 years based on self-reported data BMI was based on age- and gender- (CDC reference standards) BMI between 85^{th} and 95^{th} percentile for age and gender were classified as obese
Grant et al , 2004 New Zealand	Journal article	Cross-sectional study in collaboration with the Pacific Island Advisory Council To determine whether dietary factors are associated with high levels of obesity in preschool children	Children were recruited by "Pacific community workers through personal networks and local churches " Age 2-5 years old Boys & Girls	60 children	Energy intake (kJ/d) Protein (g/d) Total energy from fat (%) Total energy from carbohydrates (%) Dietary intake was assessed using a 2-day weighed dietary record	Z-scores for BMI based on CDC reference data Trained examiners determined BMI for each child
Gunther et al , 2007 Germany	Journal article	Prospective cohort study To determine whether a high protein intake in early life predicts obesity in later life	Data were obtained from the Dortmund Nutritional and Longitudinally Designed Study Age 12 months – 7 years of age Boys & Girls	203 children – 102 males, 101 females	Energy (kcal/d) Total protein (g x kg-1 x d-1) Protein from animals (% of energy) Protein from vegetables (% of energy) Protein from dairy (% of energy) Meat protein (% of	Body mass index (BMI) based on IOTF criteria Trained nurses determined BMI for each child according to standard procedures

					energy) Cereal protein (% of energy) A 3-day weighted-diet record was used to obtain children's dietary intake Parents weighed all foods and beverages and recorded intake of foods to the nearest 1 g	
Lin and Morrison, 2002 United States	Journal article	Cross-sectional study To determine the relationship between fruit and/or vegetable consumption and body weight	Data were obtained from USDA's 1994-1996 Continuing Survey of Food Intakes by Individuals (CSFII) Age 5-12 years Boys & Girls	2181 children	Fruits (servings) Vegetables (servings) Food intake in grams was converted into servings Diet was assessed using two 24-hour recalls	BMI based on age- and gender- CDC reference standards BMI was calculated based on self-reported height and weight data Normal weight (BMI $<85^{th}$ percentile) Risk of overweight (BMI $\geq 85^{th}$ and $<95^{th}$ percentile) Overweight BMI $\geq 95^{th}$ percentile)
Magarey et al , 2001 Australia	Journal article	Prospective observational study To examine the relationship between food energy and macronutrient intake and body weight	Community-based study Age 2-15 years old Boys & Girls	143-243 children	Energy (MJ) Protein (g in) Energy from protein (%) Energy from fat (g) Carbohydrates (g) Energy from carbohydrates (%) Dietary intake was assessed using a 3-4 day diet diary	Body mass index (BMI) BMI was determined was weight and height measurements which were taken by the author (except at 2 years of age)

Maillard et al , 2000 France	Journal article	Cross-sectional study To determine the relationship between food intake and adiposity in non-obese children	Data were obtained from the Fleurbaix Ville Sante Study, with a focus on non-obese prepubertal children Age 5-11 years Boys & Girls	826 children	Energy intake (kcal) Percentage of energy intake from carbohydrates (%) Percentage of energy intake from complex carbohydrates (%) Percentage of energy intake from fats (%) Percentage of energy intake from proteins (%) Dietary intake was assessed using a single 24-hr diet record	Body mass index (BMI) Trained examiners determined BMI for each child
Nicklas, et al , 2003 United States	Journal article	Cross-sectional study To determine the association between eating patterns and overweight status in children	Data were obtained from the 1973-1994 Bogalusa Heart Study Age 10 years of age Boys & Girls	1562 children	Fats/oils (servings/day) Fruit, fruit juice, vegetable (servings/day) Breads/grains (servings/day) Meats (servings/day) Dietary intake was assessed using a 24-hour dietary recall	BMI based on age- and gender- CDC reference standards Trained examiners determined BMI for each child Normal weight (BMI $<85^{th}$ percentile) Risk of overweight (BMI $\geq 85^{th}$ and $<95^{th}$ percentile) Overweight BMI $\geq 95^{th}$ percentile)
Newby et al , 2003 United States	Journal article	Prospective cohort study To determine the association between nutrient and food group intake and annual weight change	Data were obtained from the North Dakota Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) Age 2-5 years of age Boys & Girls	1379 children	Total fat (% of energy, and intake g/day) Predefined food groups breads and grains, "fat foods", fruits and vegetables (servings/day) Dietary intake was assessed using a semi quantitative validated food frequency	Annual change in BMI based on CDC growth curves Trained examiners determined BMI for each child Change in annual weight (BMI)= weight at visit 2-weight at visit 1 x 12 months (to estimate an

					questionnaire	annual change in weight)
Ohlund et al , 2010 Sweden	Journal article	Cross-sectional study To determine whether current macronutrient intake is associated with BMI in children This study, however, did focus on the child's protein intake	Age 4 years Boys & Girls	127 children	Energy intake (MJ) Carbohydrate (grams and % of total energy) Protein (grams and % of total energy) Fat (grams and % of total energy) Monounsaturated fat (% of total energy) Polyunsaturated fat (% of total energy) n-6 fatty acids (grams and % of total energy) n-3 fatty acids (grams and % of total energy) Dietary intake was assessed using monthly 5-day food records	BMI was calculated based on weight and height measurements Height was measured (to the nearest mm) using a CMS stadiometer Weight was measured (to the nearest 0 1kg) using a Seca 835 digital adult scale Overweight/obesity in children was defined using Cole's criteria
Rocandio et al , 2001 Spain	Journal article	Cross-sectional study To compare the dietary intake of overweight and non-overweight children	School-children were selected at random Age 11 years old Boys & Girls	32 children – 16 males and 16 females	Carbohydrate intake (% of total energy) Protein intake (% of total energy) Fat intake (% of total energy) Saturated fat intake (% of total energy) Cholesterol intake (% of total energy) Monounsaturated and polyunsaturated fat intake (% of total energy) Dieticians trained parents on how to use a food	Body mass index (BMI) Trained examiners determined BMI for each child Children were considered overweight if their BMI was higher than the 90th percentile

					weighing method to determine their child's diet intake for 7 days Parents recorded dietary intake of children for 1 week using the food weighing method	
Scaglioni et al , 2000 Italy	Journal article	Prospective observational study To examine the relationship between micronutrient intake and the development of overweight	Children were recruited randomly from live births that occurred at the maternity ward of San Paolo Hospital Age 1-5 years of age Boys & Girls	147 children – 67 females and 80 males	Daily energy • Total (kJ) • Total (kcal) • Per kg body weight (kJ/kg) • Per kg body weight (kcal/kg) Nutrient (energy %) • Proteins • Carbohydrates • Fats - Saturated - Monounsaturated - Polyunsaturated Age-adjusted FFQ and 24hr recalls were used to obtain the children's dietary intake	Body mass index (BMI) Weight was measured using an electronic Sartorious scale and height was measured using a Harpenden stadiometer A child was defined as overweight if their BMI was over the 90th centile according to the Rolland-Cachera curves
Skinner et al , 2004 United States	Journal article	Prospective observational study To determine predictors of body mass index in children 2-8 years of age (longitudinal study)	Community-based study Age 2-8 years Boys & Girls	70 white children – 37 males and 33 females	Longitudinal dietary variables (between 2 to 8 years of age) • Energy (kJ) (kcal) • Fat (g) • Protein (g) • Carbohydrate (g) A 24-h recall and 2 days of food records were used to obtain the children's dietary intake	Body mass index (BMI) based on CDC growth curves Trained examiners determined BMI for each child

Results of Individual Studies

The studies included in this literature review are those deemed relevant by the reviewer's opinion and which meet the inclusion criteria stated above. Detailed study results from each individual study are presented in Table 3.2.

Of the 12 studies included in this review, 10 used multivariate regression models to examine the relationship between dietary intake and BMI, all of which modeled BMI or overweight as the main outcome of interest. Of the 12 included studies, 7 used linear regression models (BMI as the main outcome), 1 did not specify the type of regression used for their statistical analysis (Lin and Morrison, 2002), and 2 used logistic regression models (overweight as the main outcome). The remaining 2 studies used chi-square tests or student's t-test to determine the relationship between dietary intake and BMI. Dietary intake, whether defined as a particular macronutrient or pre-defined food group, was used as the independent variable in all the included studies.

Field et al., (2003) focused their regression analysis on children and adolescent between 9-14 years of age. No relationship was found for either boys or girls in regards to fruit, fruit juice and vegetable intake and a change in BMI over a 3-year period (β=0.003). A significant negative relationship was present among boys between vegetable intake and change in BMI. However, this relationship was no longer significant when the model was adjusted for caloric intake (β=0.003). Conversely, Lin and Morrison (2002) conducted a cross-sectional analysis in 2181 children between 5-12 years of age. They found that overweight/obese boys ate less fruits ($p \leq 0.01$) and vegetables ($p \leq 0.01$) than healthy-weight children. Furthermore, they found that overweight/obese and at risk of overweight girls ate less fruit than healthy weight children as well ($p \leq 0.05$).

Nicklas et al. (2003) found no significant relationship between fats/oils, fruits, fruit juice, vegetables and breads/grains consumption and overweight status in 10-year-old children. However, a positive relationship was found between consumption of meats (mixed meats, poultry, seafood, eggs, pork, and beef) and overweight status ($p<0.051$) (Nicklas et al., 2003). Newby et al., (2005) also found no significant relationship between total fat intake, fruits or vegetables and weight change among children 2-5 years of age. Weight change was determined by examining the difference in weight on two separate visits, which were scheduled 6 to 12 months apart. Newby et al., (2004) did find that for each additional serving of breads and grains, there was a 0.16-kg lower weight change per year (95% CI, -0.20 to -0.12kg, $p\leq0.01$). Additionally, for each additional serving of fats, there was a 0.05-kg greater weight change per year (95% CI, 0.1-0.09kg, $p<0.05$).

No significant difference between macronutrient intake (protein, fat, carbohydrates) and obesity in children was found cross-sectionally (Grant et al., 2004) or longitudinally (Magarey et al., 2001). In a longitudinal study conducted by Magarey et al., (2001), no relationship was observed between any energy-adjusted macronutrient intakes (protein, fat, carbohydrates) at previous ages and BMI at subsequent ages (across 2-15 years of age). In a cross-sectional study conducted by Grant et al., (2004), obese children did have a significant higher intake of energy ($p=0.01$), despite finding a null relationship between macronutrient intake and obesity in children. Nonetheless, this finding is not consistent with Rocandio et al., (2001) whom found that the percentage of energy intake was significantly lower in the overweight group compared to the non-overweight children ($p<0.01$). However, the study conducted by Rocandio et al., (2001) did have a different definition of obesity than the other studies included in this review.

Studies also found a relationship between carbohydrates and BMI (Maillard et al., 2000, Skinner et al., 2004) or overweight status (Rocandio et al., 2001; Scaglioni et al., 2000). Maillard et al., (2000) found a significant relationship between a high percentage of energy intake from carbohydrates and BMI in girls ($p < 0.02$). It was also found that children who were overweight at 5 years old had a lower percentage intake of energy from carbohydrates at 1 year old than non-overweight children ($p=0.031$) (Scaglioni et al., 2000). Mean carbohydrate intake (which was recorded between 2 and 8 years) were negatively associated with children's BMI at 8 years of age as well (Skinner et al., 2004). These results contradict the finding presented by Rocandio et al., (2001) where carbohydrate intake was significantly greater in the non-overweight group compared to overweight group ($p<0.01$). Again, the study conducted by Rocandio et al., (2001) did have a different definition of obesity than the other studies included in this review.

Mixed results were found for the association between fat and protein and overweight status. Rocandio et al., (2001) found that fat and protein intake was not significantly different between obese and non-obese children. However, Scaglioni et al., (2000) found that children who were overweight at 5 years old had a higher percentage intake of energy from protein at 1 year old than non-overweight children ($p=0.024$). Skinner et al., (2004) found that mean protein and fat intake (which was recorded between 2 and 8 years of age) were positively associated with children's BMI at 8 years of age. Similarly, Ohlund et al., (2010) conducted a cross-sectional analysis that demonstrated that protein intake at 4 years of age is also associated with BMI ($p=0.01$). Gunther et al., (2007) looked at particular types of proteins and their association with BMI. They observed that higher animal protein intake at 12 months was associated with a higher BMI at 7 years of age ($p=0.003$). Higher vegetable protein intake at 12 months or 5-6 years was not associated with a higher BMI at 7 years of age ($p=0.80$ and $p=0.20$ respectively). Lastly, they observed that higher dairy protein intake at 12 months was associated with a higher BMI at 7 years of age as well ($p=0.02$).

From the data provided in this review, it appears that obese children tend to consume more protein, carbohydrates and energy. The link between fruits, vegetables, fat intake and BMI is not consistent and, thus, subject to question.

Table 3.2: Individual Study Results

Study	Main statistical analyses conducted and presented	Reported measures of association & associated measure of statistical stability (where possible, only Odds Ratios (OR) are presented)	Methods used to control for confounding during data analysis
Field et al , 2003	Multivariate linear regression Multivariate linear regressions were re-run to control for caloric intake	No relation among girls between fruit, fruit juice and vegetable intake and change in BMI (either an increase or decrease in BMI) (β=0 003) A significant relationship was present among boys between vegetable intake and change in BMI However, this relationship was no longer significant when the model was adjusted for caloric intake (β=0 003)	Variables controlled for • Tanner stage of pubic health development • Age and gender specific z-score of BMI at the beginning of the 1 year interval • Age • Age squared • Height change • Activity/inactivity Adjusted for caloric intake
Grant et al , 2004	Pearson's chi-square test	Obese children had higher energy intakes than non-obese children (p=0 01) No difference was observed between obese and non-obese children in regards to macronutrient intakes (fat, protein, carbohydrates)	Age and/or gender
Gunther et al , 2007	Multivariate linear regression	Higher animal protein intake at 12 months is associated with a higher BMI at 7 years of age (p=0 03) Higher vegetable protein intake at 12 months or 5-6 years was not associated with a higher BMI at 7 years of age (p=0 80 and p=0 20 respectively) Higher dairy protein intake at 12 months is associated with a higher BMI at 7 years of age (p=0 02)	Variables controlled for • Maternal overweight (BMI ≥ 25, yes or no) • Maternal education status (12 years of schooling, yes or no) • Breastfeeding (full breastfeeding for ≥ 4 months, yes or no) • Firstborn status (yes or no) • Siblings in the dataset (yes or no)
Lin and Morrison, 2002	Regression analysis – does not specify the type	Overweight/obese boys ate less fruits (p≤0 01) and vegetables (p≤0 01) than healthy weight children Overweight/obese and at risk of overweight girls ate less fruit than healthy weight children (p≤0 05)	Variable controlled for • Age • Sex • Race/ethnicity

Magarey et al , 2001	Generalized linear estimating equations evaluated the longitudinal relationship between body fatness and macronutrient intake Regression analyses estimated the relationship between body fatness at specific age and macronutrient intake at previous ages	Across 2-15 years, no relationship was found between any macronutrient intake and BMI No relationship was observed between any energy-adjusted macronutrient intakes at a previous age and BMI at subsequent ages A single 24-hour dietary recall was used to collect the children's dietary intake	Variables controlled for • Sex • Maternal BMI • Paternal BMI • Gender • Total energy intake • Level of fatness at the beginning of the interval
Maillard et al , 2000	Multivariate linear regression Analyses were performed for all children and for boys and girls separately	A significant relationship exists between a high percentage of energy intake ascribed to carbohydrates and BMI in girls (p <0 02)	None reported
Nicklas, et al , 2003	Multivariate logistic regression	No significant relationship exists between fats/oils, fruits, fruit juice, vegetables and breads/grains and overweight status Fats/oils (OR 0 99, 95% CI 0 92-1 06) Fruit, fruit juice, vegetable (OR 0 96, 95% CI 0 81-1 13) Breads/grains (OR 1 05, 95% CI 0 87-1 25) Meats (OR 1 21, 95% CI 1 00-1 46) * *P<0 051, significant result A positive relationship exists between consumption of meats (mixed meats, poultry, seafood, eggs, pork, and beef) and overweight status (p<0 051)	Variables controlled for • Calorie intake • Age • Study year • Ethnicity • Gender • Ethnicity x gender
Newby et al , 2003	Multivariate linear regression	No significant relationship between total fat intake, fruits or vegetables and weight change For each additional serving of breads and grains, there was a 0 16-kg lower weight change per year (95% CI, -0 20 to -0 12kg, p<0 01) For each additional serving of fats, there was a 0 05-kg greater weight change per year (95% CI, 0 1-0 09 kg, p<0 05)	Variables controlled for • Baseline weight • Change in height during the time interval • Age • Sex • Total energy intake • Birth weight • Maternal education • Race/ethnicity • Residence • Poverty level
Ohlund et al , 2010	Univariate regression analyses Multivariate linear regression	*Univariate regression* Significant univariate associations between nutrient intake and BMI at 4 years	None reported

		• Energy at 4 years (p=0 014) • Protein at 4 years (g/day) (p=0 002) • Protein at 4 years (% energy) (p=0 023) • n-6 fatty acids at 4 years (g/day) (p=0 022) • Carbohydrates at 4 years (g/day) (p=0 009) *Multivariate stepwise linear regression* Energy (p=0 003) and protein intake (p=0 01) at 4 years of age is also associated with BMI	
Rocandio et al , 2001	Chi-square and student's t-test	Percentage energy intake was significantly lower in the overweight group compared to the non-overweight children (p<0 01) Carbohydrate intake was significantly greater in the non-overweight group compared to overweight group (p<0 01) Fat and protein intake was not significantly different between both groups of children There was no significant difference in fatty acid intake between both groups of children as well	None reported
Scaglioni et al , 2000	Multivariate logistic regression	Children who were overweight at 5 years old had a higher percentage intake of protein at 1 years old than non-overweight children (p=0 024) Children who were overweight at 5 years old had a lower percentage intake of carbohydrates at 1 years old than non-overweight children (p=0 031) Intake of protein at 1 year of age was associated with overweight at 5 years of age (p=0 05)	Variables controlled for • Infant's gender • Weight and length at birth and 1 year • Parental age
Skinner et al , 2004	Multivariate linear regression (forward stepwise regression)	Mean protein (p=0 0167) and fat intake (p=0 0039 for fat in grams and p=0 0095 for fat as % energy), which was recorded between 2 and 8 years, were positively associated with children's BMI at 8 years of age Mean carbohydrate intake (which was recorded between 2 and 8 years) were negatively associated with children's BMI at 8 years of	Variables controlled for • Gender • Birth weight • Breastfeeding duration • Age that cereal was introduced • BMI at age 2yr • Longitudinal dietary energy intake • Mother's perception of child as a

		age (p=0 0099)	picky eater at age 6 years • The number of foods liked at age 8 years • Average daily time spent watching television at 6 and 7 yrs old • Average dietary variety score at ages 3 5-7 years • BMI of both parents

2.2.3 Limitations of Review

Limitations of this review included the age range of the target population of the articles retrieved for this review. The age groups presented in the 12 included studies were not equivalent to the age used in this study, thus the comparability between studies is compromised. Several age groups are presented in the limitation section in MEDLINE. By choosing the groups relevant for this study in this search engine (Preschool child: 2-5 years and Child: 6-12 years), it significantly expanded the number of articles retrieved for this literature review. An age range between 1-15 years of age was then set to allow for relevant articles to be included based on search results. Thus, the articles explored may be less relevant to the narrow age group under investigation in this study (children 4 and 6 years of age).

Additional limitations include the use of 24-hour diet recalls or food frequency questionnaires in many studies, which can introduce recall and response bias. The use of published literature only could have also have produced publication bias. Additionally, one reviewer examined the articles that were included in this review and this reviewer was not blinded to the names of authors, journal, or institution. It would be more accurate to have two or more reviewers to assess the articles for inclusion in order to prevent bias in article selection and the possible loss of relevant articles.

CHAPTER 3: Study Objectives and Conceptualizing Variable Relationships

3.1 Goal

The overarching aim of this project is to evaluate associations between diet quality and overweight/obesity and BMI at 4 and 6 years, as well as changes in BMI from 4 to 6 years. Assessment of diet quality includes macronutrient intake and food group intake according to Canada's Food Guide to Healthy Eating.

3.2 Objectives and Hypotheses

1. To assess the association between diet quality and overweight/obesity at 4 and 6 years;
2. To assess the association between diet and body mass index at 4 and 6 years;
3. To assess the association between diet and the change in BMI from 4 to 6 years.

   - *Hypotheses: Children who have lower dietary fiber and fruits and vegetable intake are more likely to be overweight/obese at 4 and 6 years of age than normal weight children. The change in BMI from 4 to 6 years will be greatest for those who have low intake of these dietary elements as well.*
   - *Hypotheses: Children who have lower monounsaturated fat & polyunsaturated fat, linolenic acid, and linoleic acid intake are more likely to be overweight/ obese at 4 and 6 years of age than normal weight children. The change in BMI from 4 to 6 years will be greatest for those who have low intake of these types of fats.*

- *Children who have higher saturated fat and cholesterol intake are more likely to be overweight/ obese at 4 and 6 years of age. The change in BMI from 4 to 6 years will be greatest for those who have high intake of these types of fats.*
- *Hypothesis: Those who consume more carbohydrates, proteins and fats will have higher body mass indexes at both 4 and 6 years old, and greater changes in BMI from 4 to 6 years old.*

4. To examine and compare the diets of normal and overweight /obese children from different socioeconomic groups to the new DRI standard for total fiber intake, linoleic acid, linolenic acid, total protein intake, total carbohydrate intake, zinc, calcium, magnesium, phosphorous, iron, vitamin A, vitamin B_{12}, and vitamin C at 4 years (since this is the only time point in which nutrition information was gathered).

- *Few children will meet the DRI requirement for fiber*
- *Children who are overweight/obese will be more likely to meet the DRI requirement for various micronutrients due to nutrient- dilute diets (such as vitamin A, C, B_{12} etc.)*
- *More children who are overweight/obese will exceed the DRI for total carbohydrate and protein intake in comparison to normal weight children.*
- *Children from families with low socioeconomic status will be less likely to meet the DRI for all variables outlined in the objective.*

3.3 Conceptualizing Variable Relationships

Data from the Québec Longitudinal Study of Child Development (QLSCD) was reviewed following the literature search presented in the previous chapter. This investigation aimed to determine variables that would be added during model development to control for potential cofounders. These variables are listed in Table 4.

Table 4: Potential confounders identified in the QLSCD

Child/Birth Characteristics	Parent Characteristics	Family Demographic and Socioeconomic Characteristics
• Sex of child • Category of birth weight • Born premature • Breastfed (partial or exclusive for first 4 months) • Chronic illness (excluding allergies, but including asthma) at age 6 years • Level of physical activity in comparison to other children • Type of child care • Television viewing for 3 or more hours/day (weekdays and weekends) • Initial BMI at 2 years (mother's report) • Frequency of computer use at 6 years	• Mother's age when the child was born • Mother's level of education (highest diploma obtained when child was 4 years) • Mother smoked during pregnancy • Mother's employment status (when child was 4 years) • Mother's smoking status • Mother overweight or obese (BMI $\geq 25 kg/m^2$) when the child was 1.5 years	• Household annual income • Socioeconomic status • Family structure • Urban dwelling • Mother's immigrant status

A conceptual framework was developed to illustrate the relationship between diet quality and childhood obesity in accordance to the data from the QLSCD. See Figure 2 for this framework.

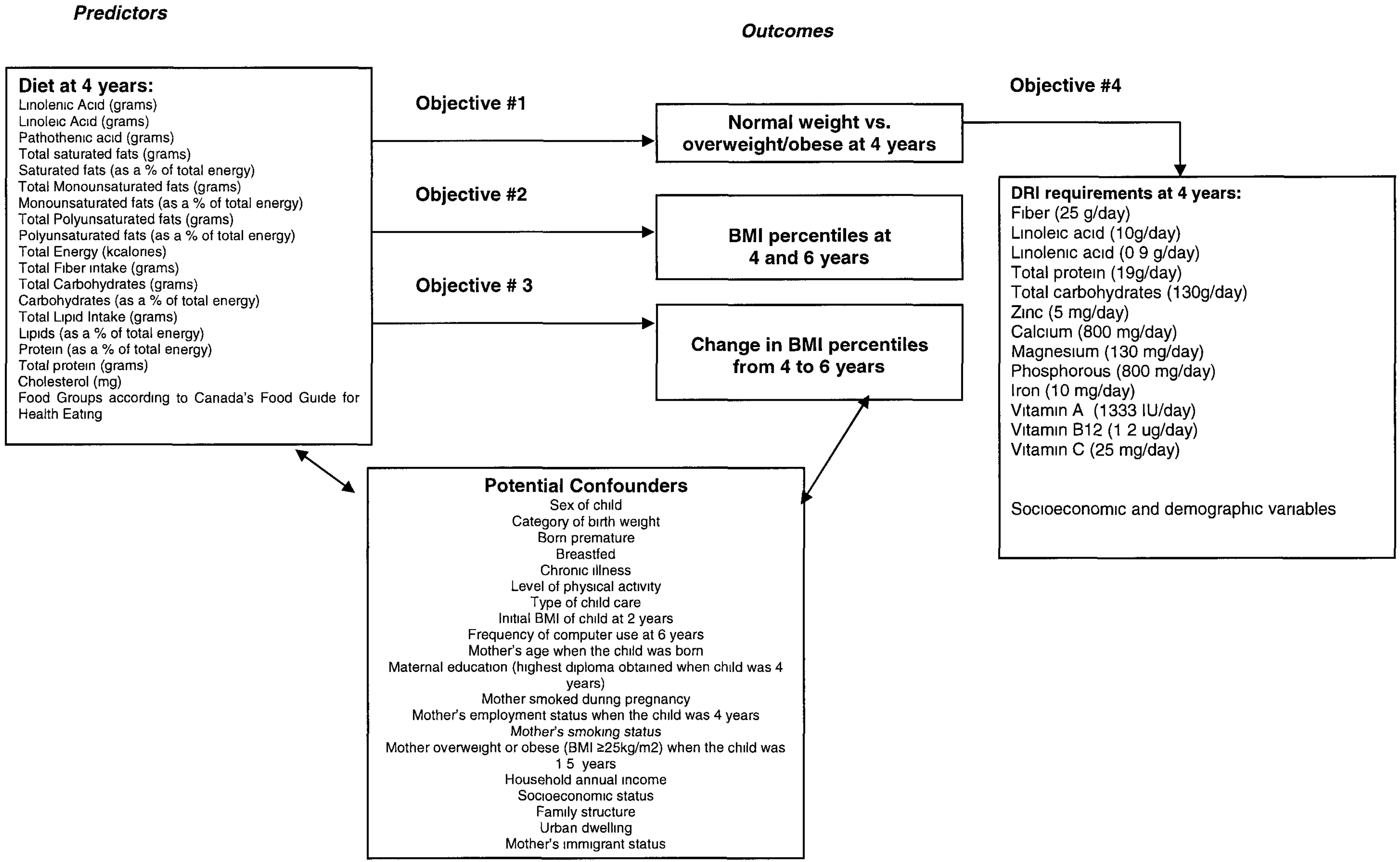


Figure 2. Conceptual framework outlining the potential relationships between the variables proposed in study

CHAPTER 4: Methods

4.1 Data source: The Québec Longitudinal Study of Child Development (QLSCD)

This study was conducted with data from the Québec Longitudinal Study of Child Development (QLSCD, 1998-2010). The QLSCD is a provincially representative, prospective longitudinal study conducted by Santé Québec (**Institut de la statistique du Québec).* It began in 1998 and was designed to advance our knowledge of child development. "It's main objective had been to identify factors that, coming into play during early childhood, affect the social adjustment and academic performance of young Québeckers" ([†]*Institut de la statistique du Québec website*). Ethical approval from the Ministry of Health Ethics Committee (Comité d'Ethique de Santé Québec) and consent from participants were obtained. [†]

4.2 Study Sample

A representative sample (n=2103) of children born in 1998 in the province of Québec was obtained (total population over 7 million, with approximately 70,000 newborns per year) by the QLSCD. Children were 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). A randomized 3-level stratified survey design was used to obtain a representative sample of children. Children born throughout the year in each geographic area of the province were included in order to minimize the effect of seasonality and to ensure geographic representation. Twins and children with major disease or disabilities at birth were excluded from the study.

[†] http://www.jesuisjeserai.stat.gouv.qc.ca/etude_an.htm

The children and their parents were first seen in 1998, when the children were approximately 5 months of age (adjusted for gestational age), and each year after that for data collection. At each data collection time point, information was collected about the child's weight, height, health and development, as well as demographic and socioeconomic characteristics that pertained to that child. The information pertaining to the child and parents were collected through the child's medical birth records, face-to-face paper and computer-based interviews, and computer-based and self-administered questionnaires. Questionnaires aimed at collecting information regarding demographic and socioeconomic characteristics include the *Interviewer Completed Paper Questionnaire (ICPQ), the Interviewer Completed Computerized Questionnaire (ICCQ) and the Self-Administered Questionnaire for the Mother (SAQM)*. Questionnaires pertaining to the child, including diet and eating behaviour, were addressed by the person deemed most knowledgeable (PMK) of the child, generally the mother. Further information regarding the construction and validation of these instruments can be found from the technical documentation available on the QLSCD's Website (Jette & DesGroselliers, 2000; Thibault et al., 2003; Thibault, Jette & Desrosiers, 2001).

The sample of 2103 children reduced to 1944 at 4-5 years of age in 2002 as a result of subjects that dropped out of the study, or families that could no longer be reached. During 2002, 1549 children volunteered to take part in a nutrition sub-study. This nutrition sub-study included a 24-hour dietary recall interview, a self-administered eating behaviour and television viewing questionnaire, and measurement of the children's height and weight. This recall was performed in order to collect nutrition data and to analyze the children's food consumption patterns.

4.2.1 Energy/macronutrient intake and food consumption analysis

The single 24-hour dietary recall was administered in the home of the children by a trained nutritionist in order to analyze the child's food consumption patterns. Mothers were asked to indicate the type, quantity, and recipes eaten by the child during the 24-hour period preceding the interview. The nutritionist then recorded this information during the interview. Volume food models were used to determine portion sizes and the verification of nutrition labels was used to ensure accuracy.

A second 24-hour recall was administered to 50% of the children seven days later in order to adjust recall data for random intra-child variability. Thus, all nutritional variables used in this study were based on the adjusted data. This double sampling method was used to validate that the first recall was not conducted on a day in which the child would consume foods different from their regular pattern of consumption (such as a birthday). If the child attended day-care, the nutritionist questioned the administrative staff regarding the child's food intake (e.g., time, meal, quantity) for the same 24-hour period.

The 24-hour recall was administered evenly across all days in the week. Energy, macronutrient and micronutrient intake, and food portion size were evaluated according to The Canadian Nutrient File (Cole at al., 2000). Dietary data collected were managed using a validated nutrient analysis software package from Micro Gesta (Québec, Canada; version 73). Final consumption and serving estimates were adjusted to minimize within-child variability (Dubois et al., 2007).

Anthropometric measurements of the child were measured at home at 4 and 6 years of age. A standardized protocol consisting of a measuring tape, a ruler, and a scale were used to take the anthropometric measurements of the child. Children were asked to wear light clothing and no shoes.

4.3 Measures

Data analyses were performed from data collected through the responses to the 24-hour dietary recall, anthropometric measurements and various questionnaires in regards to demographic and socioeconomic characteristics such as the *Self-Administered Questionnaire for the Mother (SAQM), and the Interviewer Completed Paper Questionnaire (ICPQ),* and the child's medical birth records.

4.3.1 Outcome

Three BMI outcome measures are examined in this study: 1) IOTF definition of overweight/obesity at 4 and 6 years of age, 2) BMI percentile at 4 and 6 years of age according to the CDC growth curves and 3) change in BMI from 4 to 6 years of age according to the CDC growth curves. Overweight/obesity and BMI at 4 years of age were used as outcomes since nutritional data was collected during this year. Overweight/obesity and BMI at 6 years of age were also used as outcomes since this was the most recent data available from the QLSCD, which contained important potential confounders required for this study (level of physical activity and television viewing for 3 or more hours/day).

4.3.1.1 IOTF definition of overweight/obesity

By using the IOTF definition of overweight/obesity, interprovincial and international comparisons are possible due to the structure of this variable. The relationship between this outcome and the nutritional predictors has been investigated in this study. According to the IOTF definition, girls and boys at 4 years of age are classified as 'overweight or obese' if their

BMI percentile is ≥17.2 kg/m^2 and ≥17.5 kg/m^2 respectively (Cole et al., 2000). At 6 years of age, girls and boys are classified as 'overweight or obese' if their BMI percentile is ≥17.3 kg/m^2 and ≥17.6 respectively (Cole et al., 2000). This dichotomous variable is categories into two subcategories, children of normal weight or children who are overweight or obese.

4.3.1.2 BMI percentile based on CDC growth curves

Investigating BMI percentile at 4 and 6 years of age aims to find an association between the nutrition predictors and food groups of interest and BMI. It is a continuous variable based on the CDC growth curves. Change in BMI from 4 to 6 years of age is a continuous variable as well, which was created by taking the raw difference in BMI from 4 to 6 years of age.

Change in BMI from 4 to 6 years of age was used to create models, which aimed to determine whether diet at 4 years of age would predict weight change at 6 years of age. It would be ideal to have information about dietary intake at more than one time point; however, this information was not present in the Québec Longitudinal Study of Child Development.

4.3.2 Main Predictors

There were four groups of main predictors, which were examined in this study. The four groups were:

1) Nutrition predictors in quintiles

2) Nutrition predictors dichotomized into high and low intake levels (quintiles 1-2 and quintile 3-5 were grouped in order to dichotomize the nutrition predictors)

3) Continuous nutrition predictors

4) Food groups (milk and alternatives, grains, meats and alternatives, fruits and vegetables) split in categories based on Canada's Food Guide to Healthy Eating for children 4-8 years of age.

The nutritional predictor variables and food groups, which were investigated in this study, are presented in *Figure 2* and *Table 5* respectively.

Table 5: Nutritional predictor food groups

Variable	**Category**
Grain products	0-2 servings/day 3 servings/day 4 servings/day ≥ servings/day
Grain products	< 4 servings/day ≥ 4 servings/day
Dairy products	0-1 serving/day ≥ 2 servings/day
Fruits and vegetables	0-2 servings/day 3 servings/day 4 servings/day ≥ 5 servings/day
Fruits and vegetables	0-1 serving/day ≥ 2 servings/day
Meats and alternatives	0-1 serving/day ≥ 2 servings/day

The nutritional predictor variables in quintiles were created from their corresponding continuous nutritional variables available in the QLSCD.

Nutrition predictor variables in quintiles were used when looking at overweight/obese since it provided further information in regards to the relationship between diet quality and overweight/obesity at 4 and 6 years of age in order to look for a gradient effect. The continuous nutrition variables were used for all outcomes since it suggested whether an association existed between these variables and BMI at 4 and 6 years, a change in BMI from 4 and 6 years, and overweight/obesity at 4 and 6 years. Nutrition variables in quintiles were not used for linear regression models since the models would be too complex to interpret. Instead, the quintiles were dichotomized into low and high subcategories and were run in the automated linear models.

Linear regression models were created when the outcome of interest was BMI at 4 and 6 years and change in BMI from 4 to 6 years (since these outcomes are continuous). Logistic regression models were created when the outcome of interest was overweight/obesity. Therefore, fifteen regression models are presented in total. See *Section 4.4.3 Multivariate Analyses* for details of the fifteen regression models in this study.

4.3.3 Covariates

A covariate, for the scope of this study, is defined as a predictor variable, which is a potential confounder in the association between diet quality and BMI. Therefore, the covariates included in the study were based on the literature and on the best available variables in the QLSCD. All covariates were categorical, as provided by the QLSCD database. Section 4.3.3.1 – 4.3.3.3 presents a description of each covariate that was used in this study.

4.3.3.1 Child Characteristics

These characteristics were obtained from different survey years since some years had a large number of missing data or since a particular characteristic of interest was only available at a particular year.

- Sex of the child
    - Categories: Male/Female
- Category of birth weight
    - <2.5kg (low birth weight)

- $\geq$2.5kg to $\leq$4kg (normal birth weight)
- >4 kg (high birth weight)

- Born premature
  - No/yes

- Maternal smoking during pregnancy
  - No/yes

  The variable maternal smoking during pregnancy was created based on the following question:
  "Did you smoke during your pregnancy with ... (name)?"
  YES (GO TO MED-Q4)
  NO
  DON'T KNOW
  REFUSAL

  MED-Q4 How many cigarettes per day did you smoke during your pregnancy with ... (name)? (QLSCD, 1998-2010)

- Breastfed (partial or exclusive) for first 4 months
  - Never breastfed, breastfed <4 months, breastfed 4 months or more

- Chronic illness (excluding allergies, but including asthma) at 6 years of age
  - No/yes

The definition for chronic illness was based on the following question:

Now I'd like to ask about any chronic health conditions you/... (name) may have. "Long-term conditions" refer to conditions that have lasted or are expected to last 6 months or more and have been diagnosed by a health professional.

Do you does he/she have any of the following long-term conditions? (Read list. Mark all that apply)
FOOD ALLERGIES
OTHER ALLERGIES
ASTHMA
ARTHRITIS OR RHEUMATISM
BACK PROBLEMS EXCLUDING ARTHRITIS
HIGH BLOOD PRESSURE
MIGRAINE HEADACHES

CHRONIC BRONCHITIS OR EMPHYSEMA
SINUSITIS
DIABETES
EPILEPSY
HEART DISEASE
CANCER
STOMACH OR INTESTINAL ULCERS
EFFECTS OF STROKE
ANY OTHER LONG TERM CONDITION (SPECIFY
NONE
DON'T KNOW
REFUSAL (QLSCD, 1998-2010)

- Level of physical activity in comparison to other children
  - No ('same as other children/lower or much lower)
  - Yes ('Higher/Much higher')
- Television viewing for 3 or more hours/day (weekdays and weekends)
  - No (<3hrs/day)
  - Yes (3 or more hrs/day)
- Type of child care
  - Not in day-care or being taken care of at home
  - Being taken care of at someone else's home
  - In a day-care centre
- Frequency of computer use at 6 years
  - Quintile 1, 2, 3, 4, 5 (1=lowest frequency, 5=highest frequency)
- Initial BMI of child at 2 years of age
  - Normal weight
  - Overweight
  - Obese

4.3.3.2 Parent Characteristics

Parent characteristics were only taken from the mother for this study in order to avoid multicollinearity and since more than 10% of the data for many of the covariates of interest from the father were missing. These characteristics were obtained from different survey years since some years had a large number of missing data or since a particular characteristic of interest was only available at a particular year.

- Mother's age when the child was born
    - 29 years or less, 30-34 years, 35-39 years, 40+years
- Mother's level of education (highest diploma obtained when the child was 4 years old)
    - No secondary school diploma
    - Secondary school diploma
    - College or professional school diploma
    - University diploma
- Mother's employment status (when the child was 4 years of age)
    - No (not employed)/Yes (employed)
- Mother's smoking status when the child was 4 years of age
    - Non-smoker/smoker

    The variable maternal smoking when the child was 4 years of age was created based on the following question:

    "At the present time do you / does he/she smoke cigarettes daily, occasionally or not at all?"

    DAILY (GO TO HLA-Q3)
    OCCASIONALLY
    NOT AT ALL
    DON'T KNOW
    REFUSAL

    "HLA-Q3 How many cigarettes do/does you/he/she smoke each day now?"

(QLSCD, 1998-2010)

- Mother's immigrant status
    - Not an immigrant/an immigrant

    The definition of an immigrant was based on the following question: "Are you/is ... (name) now, or have/has you/he/she ever been a landed immigrant? "

    YES
    NO
    DON'T KNOW
    REFUSAL (QLSCD, 1998-2010)

- Mother's overweight or obesity ($\geq$25kg/m^2) when the child was 1.5 years
    - No (not overweight or obese)/ Yes (overweight or obese)

4.3.3.3 Demographic and Socioeconomic Characteristics

Demographic and socioeconomic characteristics were obtained from different survey years since some years had a large number of missing data or since a particular characteristic of interest was only available at a particular year.

- Household annual income
    - Less than $30,000
    - $30,000-$49,999
    - $50,000-$79,999
    - $80,000-more
- Socioeconomic status
    - Quintile 1,2,3,4,5 (1=lowest, 5 highest)

The socioeconomic status indicator combines measures describing occupational prestige, educational level and financial situations of parents based on the method developed by Willms and Shields, (1996).

- Family structure
  - Intact
  - Recomposed
  - Single parent
- Urban dwelling
  - Rural
  - Urban

4.4. Statistical Analysis

4.4.1 Analysis of Baseline Characteristics

Statistical analyses were conducted using the SAS statistical software package version 9.1 (SAS Institute; Cary, NC). Simple descriptive statistics such as proportions, means and standard deviations were used to assess the distribution and fit of the data to statistical assumptions, and to find outliers or missing values.

Univariate analyses examined each variable individually. Categories present within a particular variable were collapsed if the sample in each category was too small. For example, the predictor, total fiber intake, is presented in three quintiles since quintiles 1 and 2 and quintiles 4 and 5 were collapsed. This was also repeated for the variable initial BMI recorded for the child at 2 years of age regrouping quintiles 1 and 2 and quintiles 4 and 5.

4.4.2 Bivariate Analyses

Single linear regressions were used to examine the crude associations between two outcomes (BMI at 4 and 6 years and change in BMI from 4 to 6 years) and predictor variables, covariates and predictors and covariates and outcome. The level of significance was set to $P \leq 0.05$.

Single logistic regressions were used to examine the crude association between IOTF definition of overweight/obesity at 4 and 6 years (normal vs. overweight/obesity) and predictor variables (in continuous form). Chi-square tests of association were used to examine associations between overweight/obesity and covariates, overweight/obesity and predictors (in quintiles) and covariates and predictors.

4.4.3 Modeling Strategy

Automated logistic regression analyses were performed with the IOTF definition for overweight/obesity at 4 and 6 years (normal vs. overweight/obesity) as supported by previous published literature, *see Objective #2&3*. Automated linear regression analyses were performed for models with continuous outcomes; BMI at 4 and 6 years old (objective 2), and for change in BMI from 4 to 6 years (objective 3).

Predictor variables and covariates for each model were selected in correspondence with literature (*see Main Predictors in Methods section*). These variables were included in the automated models when there was a significant association with the outcome based on the bivariate analyses mentioned in Section 4.4.2 and Section 4.4.3.

An automated model chose which predictor variables were included in the final models based on the statistical significance of these variables. In the forward procedure, one variable is added one at a time with the most significant variable added first. The backwards procedure starts with all the predictor variables in the model at once, and deletes those that are insignificant. The stepwise model uses a combination of both the forward and backward approach and was chosen as the method of choice for this study. Below are the detail steps for a stepwise selection procedure using SAS:

Step 1: If any significant variable can be added to the model (at the 0.05 significance level), add the most significant variable.

Step 2: If any variable in the model becomes insignificant based on the 0.05 significance level, drop the least significant one.

Step 3: Repeat step 2 until all variables are significant.

Step 4: Return to step 1 until unable to add another significant variable.

For the linear regression models, four covariates, which were categorical, were dichotomized. The covariates were: initial BMI when the child was two years of age, category of birth weight, family structure, and type of child care. Initial BMI of child at 2 years was dichotomized by merging underweight with normal weight and overweight with obese children. The final categories for initial BMI of child were normal weight (including underweight) and overweight/obese. Category of birth weight was dichotomized by merging the last two categories, ≥2.5kg to ≤4kg (normal birth weight) and >4 kg (high birth weight). The final variable categories for category of birth weight were <2.5kg (low birth weight) and ≥2.5kg >4kg (normal to high birth weight). Family structure was dichotomized by merging the last two categories, recomposed and single parent families. The final variable categories for family structure were intact family and recomposed/single parent families. Lastly, type of child care was dichotomized by merging the first two categories, not in day-care/being taken care of at home and being taken care of at someone else's home. The final categories for type of child care were not in day-care/being taken care of at home/being taken care of at someone else's home or in a day-care centre. The aim of dichotomizing these multilevel covariates for the linear regression models was to simplify the interpretability of the final results since there was a natural logic to condensing these particular variables.

Suspected interactions between predictors and predictors, or predictors and covariates, were included in the automated models. If an interaction was present in the model, then a manual backwards regression determined whether the interaction and its components were included in the final model based on a significance level of 5%. Odds ratios estimates, including confidence intervals, were determined through logistic regression analyses.

Energy intake (in kilocalories) was forced in all models in order to control for this variable. This is based on the rationale that a child with a high-energy intake will consume more of every food group and macronutrient.

Multicollinearity was investigated after all final models were produced. Evidence of multicollinearity using variance inflation factors (*VIF*s) was used. Multicollinearity was considered to be present if betas had *VIF*s of 10 or more.

All statistical tests included sample weights to adjust for any variations in the population.

4.4.3.1 Model Fit for Logistic and Linear Models

Model fit was assessed using the Hosmer and Lemeshow Goodness of Fit statistic for the logistic regression models. If the chi-square $P \geq 0.05$, then the model was judged to be a good fit. The linear regression models were assessed for fit by examining the residual and predictor plots of the final models. If the residuals were evenly dispersed without any trend present, then the model was deemed to have good fit.

4.4.3.2 Testing Linearity for Linear Models

The linearity of continuous variables was determined by examining the plots of continuous outcomes (BMI at 4 years of age, change in BMI from 4 to 6 years) against continuous predictors. If the bivariate relationship was non-linear, the covariate was categorized. Lastly, the normality of linear regression was examined using the Kernel density method. The final density plot was observed to determine the normality of the final models.

4.4.3.3 Influence and Outlier Detection for Logistic Regression Models

For the logistic regression, standardized Pearson residuals plots and DFBETA plots of each predictor variable were used to identify outliers.

Residuals are based on comparing observed values of the outcome variables with predicted values from a fitted model. Since logistic outcomes are binary, the values of the residuals cluster into the two outcome groups. Graphical displays are difficult to interpret compared to linear model residuals. However, it is possible to look at the residuals considering this cluster effect and identify outliers. Thus, standardized Pearson residual plot were used for each logistic model against the ordered observation number. Absolute standardized Pearson residuals cut-offs were determined based on analyses of this plot.

DFBETA measures how much the estimated coefficient for a fitted model would change if the observation were deleted. DBETA plot for each variable were plotted against the estimated outcome probabilities. All predictor variables were assessed using DFBETA plots. Outliers were identified by examination of these plots.

4.4.3.4 Influence and Outlier Detection for Linear Regression Models

A detailed influence analysis was carried out on the final weighed models. Studentized residuals (*rstudents*) from each of the models and one summary measure of influence, Cook's D, were examined in detail. The *rstudent* is sensitive to both an observation's distance from the fitted line and to its degree of leverage, therefore, the larger the *rstudent* value, the greater the leverage of the observation. Internal scaling was used to specify *rstudent* cut-offs based on influence statistic graphical analysis.

The absolute cut-off value for Cook's D (D_i) is based on statistical theory and was set to $D_i > 1$ (Dupont, 2002).

Lastly, scatter bubble plots of *rstudents* by predicted value were used to detect influential observations for linear regression analyses. The bubbles in the plot represent the D_i of each observation, where the larger the bubble, the larger the D_i value.

4.4.3.5 Missing Data Analysis

The impact of missing data in the covariates was taken in consideration for all models. If less than 5% of the data were missing, then it was considered as having no impact and the missing data was removed from the analyses. Otherwise, with- or 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.

4.4.3.6 Final Models

The logistic regression models that were examined in this analysis are:

Model # 1: Nutrition predictor variables (in quintiles) in association with overweight/obesity at 4 years

Model # 2: Nutrition predictor variables (in quintiles) in association with overweight/obesity at 6 years

Model # 3: Nutrition predictor variables (continuous) in association with overweight/obesity at 4 years

Model # 4: Nutrition predictor variables (continuous) in association with overweight/obesity at 6 years

Model # 5: Food groups (according to Canada's Food in association with overweight/obesity at 4 years

Model # 6: Food groups (according to Canada's Food in association with overweight/obesity at 6 years

The linear regression models that were examined in this analysis are:

Model # 7: Nutrition predictor variables (quintiles were dichotomized) in association with BMI at 4 years

Model # 8: Nutrition predictor variables (quintiles were dichotomized) in association with BMI at 6 years

Model # 9: Nutrition predictor variables (continuous) in association with BMI at 4 years

Model # 10: Nutrition predictor variables (continuous) in association with BMI at 6 years

Model # 11: Food groups (according to Canada's Food Guide for Healthy Eating) in association with BMI at 4 years

Model # 12: Food groups (according to Canada's Food Guide for Healthy Eating) in association with BMI at 6 years

Model # 13: Nutrition predictor variables (quintiles were dichotomized) in association with change in BMI from 4 to 6 years in association

Model # 14: Nutrition predictor variables (continuous) in association with change in BMI from 4 to 6 years in association

Model # 15: Food groups (according to Canada's Food Guide for Healthy Eating) in association with change in BMI from 4 to 6 years in association

4.4.4 Statistical analysis for DRI comparison (Objective #4)

The diets of normal weight and overweight/obese children at 4 years of age was compared to the new DRI standard for total fiber (grams), linoleic acid(grams), linolenic acid (grams), total protein (grams), total carbohydrate intake (grams), zinc (mg), calcium (mg), magnesium (mg), phosphorous (mg), iron (mg), vitamin A (IU), vitamin B_{12} (ug), and vitamin C (mg). *Table 6* presents the DRI summary of each nutritional variable under investigation for Objective #4.

Table 6. Summary of DRI's Presented in Study	
Fiber	25 g/day
Linoleic acid	10g/day
Linolenic acid	0.9 g/day
Total protein	19g/day
Total carbohydrates	130g/day
Zinc	5 mg/day
Calcium	800 mg/day
Magnesium	130 mg/day
Phosphorous	800 mg/day
Iron	10 mg/day
Vitamin A	1333 IU/day
Vitamin B_{12}	1.2 ug/day
Vitamin C	25 mg/day

These variables were chosen for examination since they are available from the QLSCD and have a DRI outlined by Health Canada. These DRI's are specific for children between 4-8 years of age and were retrieved from the 2007 Canada's Food Guide for Healthy Eating. This analysis refers to the children at 4 years of age when the QLSCD conducted a 24-hour dietary recall. Each of the variables was dichotomized into two groups: "meets the DRI" or "does not meet the DRI". This division was based on the most current DRI's outlined by Health Canada. The IOTF definition of overweight/obesity was the outcome of interest used to assess the diet of children at 4 years of age for this objective. Chi-square tests of association were used to determine whether overweigh/obese children were different from normal weight children in terms of their likelihood of meeting the DRI.

Bivariate analyses were conducted using the chi-square test of association in order to determine whether a significant relationship exists between various demographic and socioeconomic variables and the DRI standards for the nutrients listed above (*Table 6*). The demographic and socioeconomic factors that were examined included household annual income, socioeconomic status, urban dwelling, family structure, and mother's level of education.

Bivariate analyses were also conducted using the chi-square test of association in order to determine whether each nutrient was associated with overweight/obesity at 4 years. A multivariate model was not conducted for this objective since it would be redundant in this study. For example, some of these nutrients are part of the nutrition predictors and food groups examined in previous objectives, thus, chi-square tests of association were used instead to determine whether a significant relationship exists between different nutrients and overweight/obesity at 4 years of age.

Chapter 5: Results

5.1 Characteristics of the study sample

From the initial 2103 children sampled in cycle 1, 1549 children were included in the nutrition sub-study when the children were 4 years of age. There was no missing data regarding the nutritional predictor variables of these 1549 children at 4 years. Missing data does exist in regards to height and weight measures of each child, thus, BMI at 4 and 6 years of age do have missing values. *Table 7* presents the descriptive characteristics of the children included (n=1134) and excluded in the analyses at age 4 and 6 years (n=415).

5.1.1 Descriptive analysis for included sample at 4 years of age

There are more males than females included in the sample at 4 years of age. The majority of mothers did not smoke during pregnancy and breastfed their child (partial or exclusive) 4 months or more. The majority of the children did not have a chronic illness (excluding allergies, but including asthma) at 4 years of age and their level of physical activity was the same, lower or much lower than other children. The majority of the children included at 4 years of age also watched television for less than 3 hours per day and attended child care outside of the home.

In terms of parent characteristics, mothers of the children included in the analysis were generally between 30-34 years of age when the child was born, had a college or professional school diploma, were employed when the child was 4 years of age, do not smoke, were not an immigrant, and were not overweight or obese.

Children included in the study at 4 years of age tended to come from families with a household annual income between $50,000-$79,999, had an intact family structure and lived in urban dwellings.

5.1.2 Descriptive analysis for excluded sample at 4 years

There are more males than females excluded in the study at 4 years of age. The majority of mothers did not smoke during pregnancy and breastfed their child (partial or exclusive) 4 months or more. The majority of the children did not have a chronic illness (excluding allergies, but including asthma) at 4 years of age and their level of physical activity was the same, lower or much lower than other children. The majority of the children excluded at 4 years of age also watched television for less than 3 per day and attended child care at a day care centre.

In term of parent characteristics, mothers of these children were generally between 35-39 years of age when the child was born, had a college or professional school diploma, were employed when the child was 4 years of age, do not smoke, were not an immigrant, and were not overweight or obese.

The majority of children excluded in the study at 4 years of age came from families with a household annual income less than $30,000, had an intact family structure and lived in urban dwellings.

A significant difference ($P \leq 0.05$) exists between children included and excluded in the study at 4 years of age for mother's level of education (lower for excluded) and household annual income (lower for excluded).

5.1.3 Descriptive analysis for included sample at 6 years

There are more females than males included in the study at 6 years of age. The majority of mothers did not smoke during pregnancy and breastfed their child (partial or exclusive) 4 months or more. The majority of the children did not have a chronic illness (excluding allergies, but including asthma) at 6 years of age and their level of physical activity was the same, lower or much lower than other children. The majority of children included at 4 years of age watch television for less than 3 hours per day and attended child care outside of the home.

In term of parent characteristics, mothers of these children were generally between 35-39 years of age when the child was born, had a college or professional school diploma, were employed when the child was 6 years of age, do not smoke, were not an immigrant, and were not overweight or obese.

The majority of children included in the study at 6 years of age came from families with a household annual income of $50,000-$79,999, had an intact family structure and lived in urban dwellings.

5.1.4 Descriptive analysis for excluded sample at 6 years

There are more males than females excluded in the study at 6 years of age. The majority of mothers did not smoke during pregnancy and breastfed their child (partial or exclusive) 4 months or more. The majority of the children did not have a chronic illness (excluding allergies, but including asthma) at 6 years of age and their level of physical activity was the same, lower or much lower than other children. The majority of the children excluded at 6 years of age also watched television for less than 3 hours per day and attended child care at a day care centre.

In term of parent characteristics, mothers of these children were generally between 35-39 years of age when the child was born, have a college or professional school diploma, were employed at the survey time-point (when the child was 4 years of age), do not smoke, were not an immigrant, and were not overweight or obese.

The majority of children excluded in the study at 6 years of age came from families with a household annual income less than $30,000, had an intact family structure and lived in urban dwellings.

A significant difference (P≤0.05) exists between children included and excluded in the study at 6 years of age for the following variables: sex of the child (lower for males and higher for females in the included), chronic illness (higher for excluded), frequency of computer use (lower for excluded), mother's level of education (lower for excluded) and mother's immigrant status (higher for excluded).

Table 7: Descriptive characteristics† of the sample included and excluded from analyses

Characteristics of the children	Children included in analyses at 4 years	Children excluded from analyses (Missing data on BMI at 4 years)	Children included in analyses at 6 years	Children excluded from analyses (Missing data on BMI at 6 years)
Variable	(%)	(%)	(%)	(%)
Child/Birth Characteristics				
Sex of child				
Male	50.59	52 50	47 27	55 28**
Female	49.41	47 50	52 73	44.72
Category of birth weight				
<2.5 kg	3 22	3.71‡	3.62	3.12
≥2.5 kg to ≤4kg	84.69	84.74	85.36	84 02
>4kg	10.84	9.13	10.49	10 10
Missing	1 25	2.43	0 53	2.75
Born premature (<37 weeks)				
No	96.12	95.15‡	95.59	96.05
Yes	3.42	3.99	3.97	3 21
Missing	0.46	0 86	0.44	0.73
Mother smoked during pregnancy				
No	75.69	72.04	75.49	73 55

Table 7: Descriptive characteristics† of the sample included and excluded from analyses				
Characteristics of the children	Children included in analyses at 4 years	Children excluded from analyses (Missing data on BMI at 4 years)	Children included in analyses at 6 years	Children excluded from analyses (Missing data on BMI at 6 years)
Yes (smoked during pregnancy)	23 98	27.10	23.99	25 99
Missing	0.33	0.86	0 53	0.46
Breastfed (partial or exclusive) for first 4 months				
Never breastfed	25.36	34.81	25.75	31.04
Breastfed <4 months	32.06	29.81	30.42	32.32
Breastfed 4 or months or more	42.58	35.38	43.83	36.64
Chronic illness (excluding allergies, but including asthma) at 6 years of age				
No	91.13	96.43‡	89 24	96 51**
Yes (child has a chronic illness)	8.87	3.57	10 76	3.49
Level of physical activity in comparison to other children ('Higher' or 'Much higher')				
No ('Same as other children/lower/or much lower')	79.17	31.10‡	95.59	31.13
Yes ('Higher/Much higher')	3.29	2.43	4.32	1.65
Missing	17 54	66.48	0 09	67.22
Television viewing for 3 or more hours per day (weekdays and weekends)				
No (<3hrs/day)	78.25	31 24‡	95 24	30.3
Yes (3 or more hours/day)	4.20	2 43	4.67	2.57
Missing	17.54	66 33	0.09	67.13
Type of child care				
No in daycare/at home	28.58	19.12	27.95	23.14
Outside of home	37.52	20.40	36.68	27.36
Day care centre	33.71	20 68	34.66	24.33
Missing	0.20	39.80	0.71	25.16
Frequency of computer use at 6 years				
Quintile 1	14 13	6.56‡	16.23	7.07*
Quintile 2	31.01	10.70	37.30	11.39

Table 7: Descriptive characteristics† of the sample included and excluded from analyses				
Characteristics of the children	Children included in analyses at 4 years	Children excluded from analyses (Missing data on BMI at 4 years)	Children included in analyses at 6 years	Children excluded from analyses (Missing data on BMI at 6 years)
Quintile 3	16.29	99	21.08	5.97
Quintile 4	8.48	3 57	10.93	2 75
Quintile 5	12.61	4.85	14.46	5.69
Missing	17.48	66 33	0	67.13
Parent Characteristics				
Mother's age (when the child was born)				
29 years or less	21.55	23.68	20.99	23.51
30-34 years	32.39	29.81	32 28	30.85
35-39 years	32.26	33.95	32 36	33.24
40+ years	13.80	12.41	14.37	12.30
Missing	0	0.41	0	0.09
Mother's level of education (highest diploma obtained when the child was 4 years old)				
No secondary school diploma	13.27	11.27‡ *	13 32	11.94**
Secondary school diploma	20.83	13.69	20.37	16.71
College or professional school diploma	35.55	19.26	32.72	28.01
University diploma	29.63	15.55	32.28	17.81
Missing	0.72	40.23	1.32	25.53
Mother's employment status (when the child was 4 years old)				
No (not employed)	33.64	18.97	32.63	25.25
Yes (employed)	65.57	40 80	65.96	49.22
Missing	0.79	40 23	1.41	25.53
Mother's smoking status				
No (non-smoker)	77.27	73.61	77.25	74.93
Yes (Smoker)	22.73	26.11	22.66	24.98
Missing	0	0 29	0 09	0.09
Mother's immigrant status (is the mother an immigrant?)				
No (not immigrant)	91.39	81.31‡	93 21	83.01**

Table 7: Descriptive characteristics† of the sample included and excluded from analyses				
Characteristics of the children	Children included in analyses at 4 years	Children excluded from analyses (Missing data on BMI at 4 years)	Children included in analyses at 6 years	Children excluded from analyses (Missing data on BMI at 6 years)
Yes (immigrant)	8.61	18.40	6.70	16.90
Missing	0	0.29	0.09	0.09
Mother overweight or obese (BMI≥25 kg/m^2) when the child was 1 5 years				
No (not overweight/obese)	69.71	51.78	69.31	58 59
Yes (overweight/obese)	28.45	21.54	28.92	23 51
Missing	1 84	26.68	1.76	17.91
Family Demographic and Socioeconomic Characteristics				
Household annual income				
Less than $30,000	26.74	33.10‡*	25.40	32 23
$30,000-$49,999	29.37	25.39	28.92	27.27
$50,000-$79,999	28.25	25.82	29.37	25.53
$80,000-more	14.59	12.13	15.52	12.03
Missing	1 05	3.57	0.79	2.94
Family structure				
Intact	81.93	80.31‡	82.89	79.89
Recomposed	11.50	10.13	11.29	10.84
Single parent	6.44	9.13	5.64	9.00
Missing	0.13	0.43	0.18	0.28
Urban dwelling				
Rural	34.69	33.74	35.36	32 05
Urban	63.07	63.92	61.99	65.93
Missing	2.23	2.34	2.65	2 02

*Significant difference between those excluded and included (Chi-square, two-sided p≤0 05),
** Significant difference between those excluded and included (Chi-square, two-sided p≤0 01)
† Weighed data
‡ 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 Québec Institute of Statistics, QLSCD 1998-2010

5.1.5 Descriptive Statistics for IOTF definition of overweight/obesity

Using the IOTF BMI definition for overweight/obesity in boys and girls at age 4 and 6 years, approximately 13% (11% of boys; 14% of girls) of the sample was classified as overweight/obese at age 4 years, and 16% (13% of boys; 15% of girls) at 6 years of age. *Table 8* presents the distribution of BMI by overweight/obesity status (IOTF definition) in boys and girls at 4 and 6 years. No significant difference in overweight/obesity exists between boys and girls at 4 or 6 years of age.

Table 8: Mean† BMI (kg/m^2) by overweight/obesity status in boys and girls at age 4 and 6 years

	BMI (Body Mass Index kg/m^2) at 4 years of age		
	Total	**Boys**	**Girls**
Overweight/Obese at age 4 years (IOTF definition)	*Mean (SD) and Range (lowest-highest value)*	*Mean (SD) and Range (lowest-highest value)*	*Mean (SD) and Range (lowest-highest value)*
Non-overweight/Obese at age 4 years	15 22 (1 32) (3 70-17 62)	15 26 (1 41) (3 69-17 62)	15 17 (1 22) (6 52-17 40)
Overweight/Obese at age 4 years	19 03 (1 86) (17 25-27 08)	19 36 (2 06) (17 56-26 15)	18 74 (1 64) (17 25-27 08)
	BMI (Body Mass Index kg/m^2) at 6 years of age		
	Total	**Boys**	**Girls**
Overweight/Obese at age 6 years (IOTF definition)	*Mean (SD) and Range (lowest-highest value*	*Mean (SD) and Range (lowest-highest value*	*Mean (SD) and Range (lowest-highest value*
Non-overweight/Obese at age 6 years	15 18 (1 13) (11 10-17 53)	15 28 (1 13) (11 10-17 53)	15 10 (1 11) (11 96-17 32)
Overweight/Obese at age 6 years	19 41 (2 08) (17 22-28 45)	19 56 (2 15) (17 58-27 14)	19 21 (2 00) (17 22-28 45)

†Weighted data
Source Data courtesy of the Quebec Institute of Statistics, QLSCD 1998 2010

5.1.6 Descriptive Statistics of the Included Sample by Sex and Prevalence of Overweight/Obesity at 4 and 6 years

The descriptive characteristics of the sample by sex and prevalence of overweight/obesity at 4 and 6 years are presented in *Table 9*. At 4 years of age, boys who were classified as overweight or obese using the IOTF criteria were more likely to have a mother that was overweight/obese (Chi-square, $p \leq 0.05$), as opposed to mother of normal weight.

Boys that were overweight or obese at 6 years of age were more likely to have a mother which was not an immigrant and were more likely to come from a family with a lower household annual income (Chi-square, $p \leq 0.05$).

Girls who were considered overweight or obese at 4 years of age were more likely to come from mothers with higher education in comparison to girls of normal weight (Chi-square, $p \leq 0.05$), however, again, due to a large number of cells having an expected count less than 5, a chi-square test may not valid to determine whether this difference is statistically significant (see *Table 9*).

Girls who were considered overweight or obese at 6 years of age were more likely to have a chronic illness (excluding allergies but including asthma), where more likely to have the same/lower/or much lower physical activity levels, watch television for 3 or more hours/day (weekdays and weekends), and use the computer more frequently in comparison to girls of normal weight (Chi-square, $p \leq 0.05$). More girls who were overweight or obese were more likely to have a mother who was an immigrant and a mother with higher education in comparison to girls of normal weight (Chi-square, $p \leq 0.05$).

Table 9: Descriptive characteristics† of the sample by sex and prevalence of overweight/obesity (IOTF cut-offs) at age 4 and 6 years								
Variables	**Sample included in analyses to age 4 years**				**Sample included in analyses to age 6 years**			
	Boys		**Girls**		**Boys**		**Girls**	
	% for all	**Proportion (%) of overweight /obese**	**% for all**	**Proportion (%) of overweight /obese**	**% for all**	**Proportion (%) of overweight /obese**	**% for all**	**Proportion (%) of overweight /obese**
Child/Birth Characteristics								
Category of birth weight								
<2 5kg	4 57	3 50 ‡	4 05	2 92‡	5 13	3 92‡	4 05	5 13‡
≥2 5kg to ≤4kg	81 20	82 10	86 79	87 38	81 56	82 09	86 79	81 56
>4kg	13 20	13 36	7 87	8 23	12 56	13 25	7 87	12 56
Missing	0 95	1 04	1 29	1 46	0 75	0 75	1 29	0 75
Born premature (<37 weeks or with low birth weight (<2 5kg)								
No	95 04	96 11‡	95 31	96 15‡	95 04	95 71‡	95 31	95 48‡
Yes (born premature or with low birth weight)	4 70	3 63	3 98	3 19	4 70	4 10	3 98	3 85
Missing	0 25	0 26	0 71	0 66	0 25	0 19	0 71	0 67
Mother smoked during pregnancy								
No	75 47	75 88‡	73 55	75 43‡	76 99	77 61	73 55	73 58‡
Yes (smoked during pregnancy)	24 40	23 99	25 89	24 04	23 01	22 20	25 89	25 59
Missing	0 13	0 13	0 56	0 53	0	0 19	0 56	0 84
Breastfed (partial or exclusive) for first 4 months								
Never breastfed	24 69	24 77	26 66‡	25 90	24 18	25 56	26 66	25 92
Breastfed <4 months	30 27	31 13	33 39	33 20	27 70	27 80	33 39	32 78
Breastfed 4 or more months	45 04	44 10	39 96	40 90	48 11	46 64	39 96	41 30
Chronic illness (excluding allergies but including asthma) at age 6 years								
No	89 85	90 01	91 90	92 30‡	86 96	88 25	91 90	90 13**
Yes	10 15	9 99	8 10	7 70	13 04	11 75	8 10	9 87
Level of physical activity in comparison to other children ('higher' or 'much higher')								
No ('Same as other children/lower/ or much lower')	75 09	77 17‡	80 22	81 14‡	95 05	95 52‡	80 22	95 65**
Yes	3 62	3 37	2 89	3 32	4 95‡	4 48	2 98	4 18
Missing	21 29	19 46	16 89	15 54	0	0	16 89	0 17
Television viewing for 3 or more hours/day (weekdays and weekends)								
No (<3hrs/day)	74 37	76 65‡	78 27	79 95‡	94 35	95 34‡	78 27	95 15**
Yes (3 or more hrs/day)	4 26	3 76	5 02	4 65	5 52	4 48	5 02	4 85
Missing	21 37	19 58	16 71	15 41	0 12	0 19	16 71	0
Type of child care								

Table 9: Descriptive characteristics† of the sample by sex and prevalence of overweight/obesity (IOTF cut-offs) at age 4 and 6 years								
Variables	**Sample included in analyses to age 4 years**				**Sample included in analyses to age 6 years**			
	Boys		**Girls**		**Boys**		**Girls**	
	% for all	**Proportion (%) of overweight /obese**	**% for all**	**Proportion (%) of overweight /obese**	**% for all**	**Proportion (%) of overweight /obese**	**% for all**	**Proportion (%) of overweight /obese**
No in daycare/at home	29 94	27 76	31 59	29 48‡	27 56	27 43*‡	31 59	28 43‡
Outside of home	34 31	36 96	35 59	37 98	34 36	36 75	35 59	26 62
Daycare centre	35 50	35 02	32 68	32 40	37 67	35 07	32 68	34 28
Missing	0 25	0 26‡	0 14	0 13	0 41	0 75	0 14	0 67
Frequency of computer use at 6 years								
Quintile 1	16 08	16 47	11 54	11 69‡	18 16	20 15	11 54	12 71**
Quintile 2	29 05	30 61	29 96	31 34	38 27	37 50	29 96	37 13
Quintile 3	15 31	15 43	16 86	17 13	20 28	20 34	16 86	21 74
Quintile 4	6 29	6 10	10 15	10 89	9 00	8 02	10 15	13 55
Quintile 5	11 98	11 93	14 78	13 55	14 29	13 99	14 78	14 88
Missing	21 29	19 46	16 71	15 41	0	0	16 71	0
Parent Characteristics								
Mother's age (when the child was born)								
29 years or less	22 53	21 53	23 28‡	21 65	23 28‡	22 57	23 28	19 57
30-34 years	31 41	32 30	30 19	32 40	30 19	31 16	30 19	33 28
35-39 years	30 94	32 17	32 54	32 40	32 54	30 97	32 54	33 61
40+ years	15 12	14 01	13 99	13 55	13 99	15 30	13 99	13 55
Missing	0	0	0	0	0	0	0	0
Mother's level of education (highest diploma obtained when the child was 4 years old)								
No secondary school diploma	14 75	12 32	16 56	14 21*‡	11 70	11 01	16 56	15 38*
Secondary school diploma	22 00	20 75	21 83	20 98	23 31	21 64	21 83	19 23
College or professional school diploma	35 60	36 71	33 79	34 40	34 33	34 51	33 79	31 10
University diploma	26 62	29 18	27 10	30 61	29 43	31 34	27 10	33 11
Missing	1 03	1 04	0 72	0 40	1 24	1 49	0 72	1 17
Mother's employment status (when the child was 4 years old)								
No (not employed)	36 72	33 59‡	36 27	33 73‡	36 71	33 21	36 27	32 11‡
Yes (employed)	62 25	65 37	62 93	65 74	62 05	65 30	62 93	66 56
Missing	1 03	1 04	0 80	0 53	1 24	1 49	0 80	1 34
Mother's smoking status when child is 4 years old								
No (non-smoker)	76 52	77 43	75 32	77 16‡	78 70	79 85	75 32	74 92
Yes (smoker)	23 48	22 57	24 68	22 84	21 30	20 15	24 68	24 92
Missing	0	0	0	0	0	0	0	0 17
Mother's immigrant status								
No (not an immigrant)	85 13	90 66	87 78	92 03‡	88 68	93 10**	87 78	93 31**
Yes (an	14 87	9 34	12 22	7 97	11 32	6 90	12 22	6 52

Table 9: Descriptive characteristics† of the sample by sex and prevalence of overweight/obesity (IOTF cut-offs) at age 4 and 6 years								
Variables	**Sample included in analyses to age 4 years**				**Sample included in analyses to age 6 years**			
	Boys		**Girls**		**Boys**		**Girls**	
	% for all	**Proportion (%) of overweight /obese**	**% for all**	**Proportion (%) of overweight /obese**	**% for all**	**Proportion (%) of overweight /obese**	**% for all**	**Proportion (%) of overweight /obese**
immigrant)								
Missing	0	0	0	0	0	0	0	0 17
Mother overweight or obese (BMI $\geq$ 25 kg/m^2) when the child was 1 5 years								
No (not overweight/obese)	70 90	70 82**	69 49	68 53‡	72 48	70 52**‡	69 49	68 23
Yes (overweight/obese)	27 52	28 02	27 69	28 82	26 68	28 17	27 69	29 60
Missing	1 58	1 17	2 82	2 66	0 84	1 31	2 82	2 17
Family Demographic and Socioeconomic Characteristics								
Household annual income								
Less than $30,000	33 47	26 89	30 20	26 69‡	29 29	24 07*	30 20	26 59
$30,000-$49,999	26 26	28 53	29 58	30 15	28 29	29 85	29 58	28 09
$50,000-$79,999	27 64	30 22	24 60	36 26	29 20	30 60	24 60	28 26
$80,000-more	11 49	13 10	14 62	16 07	12 42	14 55	14 62	16 39
Missing	1 15	1 17	1 01	0 93	0 83	0 93	1 01	0 67
Family Structure								
Intact	80 38	82 23‡	79 86	81 54‡	82 47	84 51	79 86	81 44‡
Recomposed	10 82	11 02	11 95	11 95	10 46	10 45	11 95	12 04
Single parent	8 66	6 61	8 01	6 37	7 07	5 04	8 01	6 19
Missing	0 13	0 13	0 18	0 13	0	0	0 18	0 13
Urban dwelling								
Rural	35 50	35 67	33 62	33 73‡	37 67	36 94‡	33 62	33 95
Urban	62 93	62 39	64 23	63 75	60 75	61 01	64 23	62 88
Missing	1 57	1 95	2 15	2 52	1 57	2 05	2 15	3 18

*Significant difference between all children and proportion of overweight/obese children (Chi square, two sided p≤0 05)
**Significant difference between all children and proportion of overweight/obese children (Chi-square, two-sided p≤0 01)
† Weighted data
‡ 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 IOTF definition of overweight/obesity as the Primary Outcome

The purpose of this section aims to assess the association between diet quality and overweight/obesity at 4 and 6 years (Objective #1).

5.2.1 Bivariate associations between nutrition predictors and overweight/obesity

At the bivariate level, chi-square tests of independence showed that the following nutrition predictor (in quintiles) are positively associated with overweight or obesity at 4 years of age: linolenic acid ($p<0.0001$), linoleic acid ($p<0.0001$), pathothenic acid ($p=0.0137$), total saturated fats ($p=0.0069$), total monounsaturated fats ($p=0.0005$), total polyunsaturated fats ($p<0.0001$), energy ($p<0.0001$), total fiber ($p=0.04378$), total carbohydrates ($p<0.0001$), total lipid ($p=0.0004$), and total protein ($p=0.044$). The following nutrition predictor (in quintiles) are positively associated with overweight/obesity at 6 years of age (with the exception of saturated fats where a negative association was observed): linolenic acid ($p<0.0001$), linoleic acid ($p=0.0176$), total saturated fats ($p=0.0293$), total polyunsaturated fats ($p=0.0234$), energy ($p=0.0014$), and total carbohydrates ($p=0.0097$). See *Table 10* for details of the bivariate analysis of the total sample for nutritional predictor variables (in quintiles) by overweight/obesity at 4 and 6 years of age.

Table 10: Bivariate analysis † for nutritional predictor variables (in quintiles) by overweight/obese status at 4 and 6 years

Nutritional variable	Quintiles	4 years of age			6 years of age		
		% normal weight (87%)	% overweight/obesity (13%)	P-value (Chisq.)	% normal weight (87%)	% overweight/obesity (13%)	P-value (Chisq.)
Linolenic Acid (grams)	Quintile 1	95.96 [2 3 4 5]	4 04 [2 3 4 5]		91.77 [4 5]	8.23 [4 5]	
	Quintile 2	86.81 [1 5]	13.19 [1 5]	<0.0001*	86.24	13.76	<0.0001*
	Quintile 3	90.41 [1]	9.59 [1]		89 57 [4]	10 43 [4]	
	Quintile 4	84.77 [1]	15.23 [1]		81.66 [1 3]	18.34 [1 3]	
	Quintile 5	76 28 [1 2 3]	23 72 [1 2 3]		72.50 [1]	27.50 [1]	
Linoleic Acid (grams)	Quintile 1	91.22 [4 5]	8.78 [4,5]		85.62	14.38	
	Quintile 2	88 01 [5]	11.99 [5]	<0.0001*	87.39	12.61	0.0176*
	Quintile 3	91.79 [4 5]	8 21 [4 5]		90 67	9 33	
	Quintile 4	84.72 [1 3]	15.28 [1,3]		81.17	18.83	
	Quintile 5	78 58 [1 2 3]	21 42 [1 2 3]		71.68	22 32	
Pathothenic acid (grams)	Quintile 1	91.20 [4,5]	8.80 [4 5]		86.55	13.45	
	Quintile 2	87.39	12.61	0.0137*	84.77	15.23	0.3784
	Quintile 3	89.93 [4 5]	10.07 [4 5]		87.94	12.06	
	Quintile 4	83.31 [1 3]	16.69 [1 3]		82.57	17.43	
	Quintile 5	82.38 [1 3]	17.62 [1 3]		80 16	22 25	
Total saturated fats (grams)	Quintile 1	90.64 [2 5]	9.36 [2 5]		85.44	14.56	
	Quintile 2	84.54 [1]	15.46 [1]		81.07 [3]	18.93 [3]	0.0128*
	Quintile 3	89.50 [5]	10.50 [5]	0.0069*	90.35 [2 5]	9.65 [2 5]	
	Quintile 4	88.76	11.24		88.32	11 68	
	Quintile 5	80.63 [1 3]	19.37 [1 3]		77.60 [3]	22.40 [3]	
Saturated fats (as a % of total energy)	Quintile 1	85 11 [5]	14 89 [5]		76.65	23.25	
	Quintile 2	84.58 [5]	15.42 [5]	0.2166	88.99	11 01	0.0293*
	Quintile 3	87 16	12.84		84.56	15.44	
	Quintile 4	86.06	13.94		84.34	15.66	
	Quintile 5	91 23 [1 2]	8 77 [1 2]		87 89	12.11	
Total Monounsaturated fats (grams)	Quintile 1	91.50 [5]	8.50 [5]		85.67	14.33	
	Quintile 2	84 49 [5]	10.51 [5]	0.0005*	86.97	13.03	0.0507
	Quintile 3	87.75	12 25		87.57	12 43	
	Quintile 4	86.86	13.14		85 39	14 61	
	Quintile 5	78.61 [1 2 3]	21.39 [1 2,3]		76.40	23 60	
Monounsaturated	Quintile 1	88.68	11.32		83.09	16.91	

Table 10: Bivariate analysis † for nutritional predictor variables (in quintiles) by overweight/obese status at 4 and 6 years							
Nutritional variable	**Quintiles**	**4 years of age**			**6 years of age**		
		% normal weight (87%)	**% overweight/obesity (13%)**	**P-value (Chisq.)**	**% normal weight (87%)**	**% overweight/obesity (13%)**	**P-value (Chisq.)**
fats (as a % of total energy)	Quintile 2	87.04	12.96	0.4571	82.82	17.18	0.7559
	Quintile 3	83.39	16.61		83 13	16.87	
	Quintile 4	86.68	13.32		86.34	13.66	
	Quintile 5	88.41	11.59		87.01	12.99	
Total Polyunsaturated fats (grams)	Quintile 1	90 88 [4,5]	9.12 [4 5]		87.12[5]	12.88[5]	
	Quintile 2	91.00 [4 5]	9.00 [4 5]		89.15	10.85	0.0234*
	Quintile 3	90 38 [5]	9 62 [5]	<0.0001*	84.54	15.46	
	Quintile 4	84 63 [1,2]	15.37 [1 2]		85.22	14 78	
	Quintile 5	77 20 [1 2 3]	22 80 [1 2 3]		75 93[1]	24.07[1]	
Polyunsaturated fats (as a % of total energy)	Quintile 1	89 47	10 53		83.86	16 14	
	Quintile 2	86.46	13.54	0.5247	84.17	15.83	0.3014
	Quintile 3	86.22	13.78		86.03	13 97	
	Quintile 4	87.86	12.14		88.62	11 38	
	Quintile 5	84.14	15.86		79 72	20 28	
Total Energy (kcalories)	Quintile 1	93.44 [3 4 5]	6.56 [3 4 5]		87 78[5]	12 22[5]	
	Quintile 2	90.34 [5]	9.66 [5]	<0 0001*	89.63[5]	10.37[5]	0.0014*
	Quintile 3	85.82 [1 5]	14.18 [1 5]		84.99[5]	15.01[5]	
	Quintile 4	88 84 [1]	11.16 [1]		85 50	14.50	
	Quintile 5	75.61 [1 2 3]	24.39 [1 2,3]		73 55[1 2 3]	26 45[1 2 3]	
Total Fiber intake (grams)	Quintile 1	89.63[3]	10.37[3]		83 72	16.28	0.5802
	Quintile 2	86.75	13.25	0.04378*	82 76	17.24	
	Quintile 3	84.10[1]	15.90[1]		86 10	13.90	
Total Carbohydrates (grams)	Quintile 1	95.17 [2 3 4 5]	4.83 [2 3,4 5]		89.89[4 5]	10.11[4 5]	0.0097*
	Quintile 2	89 26 [1 5]	10.74 [1 5]	<0.0001*	88.62[5]	11.38[5]	
	Quintile 3	87.14 [1]	12.86 [1]		84 80	15 20	
	Quintile 4	85.39 [1]	14.61 [1]		81 90[1]	18 10[1]	
	Quintile 5	77.08 [1 2 3]	22.92 [1 2 3]		76 61[1 2]	4 47[1 2]	
Carbohydrates (as a % of total energy)	Quintile 1	88 79	11.21		85 95	14.05	0.4542
	Quintile 2	88.70	12.30	0.8213	87 12	12.88	
	Quintile 3	88.94	14.06		86.06	13.94	
	Quintile 4	85.62	14 38		83.29	16 71	
	Quintile 5	86.08	13 92		80.09	19.91	

Table 10: Bivariate analysis † for nutritional predictor variables (in quintiles) by overweight/obese status at 4 and 6 years

Nutritional variable	Quintiles	4 years of age			6 years of age		
		% normal weight (87%)	% overweight/obesity (13%)	P-value (Chisq.)	% normal weight (87%)	% overweight/obesity (13%)	P-value (Chisq.)
Total Lipid Intake (grams)	Quintile 1	90.64 [5]	9.36 [5]		85.66	14.34	0.0787
	Quintile 2	89.17 [5]	10.83 [5]	0.0004*	85.96	14.04	
	Quintile 3	88.18 [5]	11.82 [5]		88.46	11.54	
	Quintile 4	88.20	11.80		85.06	14.94	
	Quintile 5	78.03 [1,2,3]	21.97 [1,2,3]		76.91	23.09	
Lipids (as a % of total energy)	Quintile 1	84.51	15.49		79.74	20.26	0.4334
	Quintile 2	87.16	12.84	0.5556	84.90	15.10	
	Quintile 3	86.06	13.94		84.57	15.43	
	Quintile 4	86.65	13.35		86.11	13.89	
	Quintile 5	89.75	10.25		87 17	12.83	
Protein (as a % of total energy)	Quintile 1	88.42	11.58		83.68	16.32	0.1908
	Quintile 2	84.07	15.93	0.2134	82.52	17.48	
	Quintile 3	83.81	16.19		79.95	20.05	
	Quintile 4	89.29	10.71		88.83	11.17	
	Quintile 5	88.57	11.43		87.34	12.66	
Total protein (grams)	Quintile 1	92.37 [2,4,5]	7.63 [2,4,5]		86.56	13.44	0.4218
	Quintile 2	85.71 [1]	14.29 [1]	0.044*	85.88	14.12	
	Quintile 3	89.51 [5]	10.49 [5]		86.24	13.76	
	Quintile 4	85.58 [1]	14.42 [1]		83.74	16.26	
	Quintile 5	81.03 [1,3]	18.97 [1,3]		79.38	20.62	
Cholesterol (mg)	Quintile 1	87.19	12.81		82.63	17.37	0.1828
	Quintile 2	84.80	15.20	0.6389	86.67	13.33	
	Quintile 3	87.8	12.20		87.00	13.00	
	Quintile 4	89.02	10.98		87.00	13.00	
	Quintile 5	85.30	14.70		78.49	21.51	

*Significant difference present between nutrition predictors and overweigh/obesity (Chi-square, two-sided p≤0 05)

[1 2 3 4 5] There is a significant difference (CHISQ p≤0 05) present in the nutritional predictor variables (in quintiles) according to weight status as marked by variable subgroups with the same superscript letter

† Weighted data

Source Data courtesy of the Québec Institute of Statistics, QLSCD 1998-2010

At the bivariate level, single logistic regressions showed that the following nutrition predictor variables (continuous) are positively associated with overweight or obesity at 4 years of age: linolenic acid (p<0.0001), linoleic acid (p<0.0001), pathothenic acid (p=0.0001), total saturated fats (p=0.0024), total monounsaturated fats (p<0.0001), total polyunsaturated fats (p<0.0001), total energy (p<0.0001), total fiber (p=0.0135), total carbohydrates (p<0.0001), total lipid (p<0.001), and total protein (p<0.001). The following nutrition predictor variables (continuous) are positively associated with overweight/obesity at 6 years of age: linolenic acid (p<0.0001), linoleic acid (p=0.0003), pathothenic acid (p=0.0374), total saturated fats (p=0.0421), total polyunsaturated fats (p<0.0001), total energy (p<0.0001), total carbohydrates (p<0.0001), total lipid intake (p=0.0037), and total protein (p=0.0080). See *Table 11* for details of the bivariate analysis of the total sample for nutritional predictor variables (continuous) by overweight/obesity at 4 and 6 years of age.

Table 11: Bivariate analysis† for nutritional predictor variables (continuous) by overweight/obese status at 4 and 6 years

Nutritional variable	Overweight/obesity at 4 years			Overweight/obesity at 6 years		
	Beta Estimate	Standard error (SE)	P-value (simple logistic regression)	Beta Estimate	Standard error (SE)	P-value (simple logistic regression)
Linolenic Acid (grams)	2.05	0.29	<0.0001*	1.88·	0.34	<0.0001*
Linoleic Acid (grams)	0.22	0.04	<0.0001*	0.18	0.049	0.0003*
Pathothenic acid (grams)	0.31	0.08	0.0001*	0.21	0.099	0.0374*
Total saturated fats (grams)	0.05	0.02	0.0024*	0.036	0.017	0.0421*
Saturated fats (as a % of total energy)	-0.08	0.04	0.0561	-0.096	0.049	0.0513
Monounsaturated fats (as a % of total energy)	-0.009	0.07	0.8941	-0.123	0.077	0.1097
Total monounsaturated fats (grams)	0.09	0.02	<0.0001*	0.060	0.021	0.0051
Polyunsaturated fats (as a % of total energy)	0.18	0.11	0.1038	0.20	0.13	0.110
Total polyunsaturated fats (grams)	0.21	0.04	<0.0001*	0.17	0.041	<0.0001*
Total Energy (kilocalories)	0.0018	0.00029	<0.0001*	0.0014	0.00033	<0.0001*
Total Fiber intake	0.07	0.03	0.0135*	-0.0033	0.033	0.9214

Table 11: Bivariate analysis† for nutritional predictor variables (continuous) by overweight/obese status at 4 and 6 years						
Nutritional variable	**Overweight/obesity at 4 years**			**Overweight/obesity at 6 years**		
	Beta Estimate	**Standard error (SE)**	**P-value (simple logistic regression)**	**Beta Estimate**	**Standard error (SE)**	**P-value (simple logistic regression)**
(grams)						
Carbohydrates (as a % of total energy)	0.02	0.02	0.2909	0.048	0.025	0.0491
Total carbohydrates (grams)	0.02	0.0020	<0.0001*	0.010	0.0022	<0.0001*
Lipid Intake (as a % of total energy)	-0.03	0.03	0.2782	-0.059	0.035	0.0938
Total Lipids (grams)	0.03	0.0069	<0.001*	0.023	0.0080	0.0037*
Total protein (grams)	0.03	0.0058	<0.001*	0.018	0.0069	0.0080*
Protein (as a % of total energy)	-0.02	0.04	0.6225	-0.055	0.046	0.2364
Cholesterol (mg)	0.00088	0.0017	0.6136	0.0030	0.0021	0.1496

*Significant difference present between nutrition predictors and overweigh/obesity (simple logistic regression, $p \leq 0.05$)
† Weighted data
Source Data courtesy of the Québec Institute of Statistics, QLSCD 1998-201

5.2.2 Bivariate association between food groups and overweight/obesity (as outlined by Canada's Food Guide)

At the bivariate level, chi-square tests of independence showed that grain products (both 4 subcategories and 2 subcategories) are positively associated with being overweight or obese at 4 years of age (Chisq., $P \leq 0.05$). The food groups with two subcategories were produced in accordance to Canada's Food Guide (*see Table 33*). Thus, children meet the recommended servings of food groups set by Canada's Food Guide if they consumed:

- $\geq$ 4 servings of grains/day
- $\geq$ 2 servings of dairy products/day
- $\geq$ 5 servings of fruits and vegetables
- $\geq$ 2 servings of meats and alternatives/day

Two extra variables were created for grain products and for fruits and vegetables. These variables contained four subcategories instead of two subcategories since children at 4 and 6 years of age may not meet the high recommendations of grains and fruits and vegetables set by Health Canada. The high recommendations for grains and fruits and vegetables are represented by the variables for grains and fruits and vegetables which both have two subcategories (*Table 12*). Grain products (both 2 and 4 subcategories) met the criteria for inclusion in the multivariate analysis for *Model # 5: Food groups (according to Canada's Food Guide) in association with overweight/obesity at 4 years* and *Model # 6: Food groups (according to Canada's Food Guide) in association with overweight/obesity at 6 years.* However, only grain products with 2 subcategories was used in *Model # 5 and Model # 6* in order to avoid multicollinearity and since it is the exact recommendation made by Health Canada for children between 4-8 years of age. This variable was included in these models based on its significant association with overweight/obesity at 4 years ($p<0.0001$) and 6 years ($p=0.0003$). See *Table 12* for details of the bivariate analysis of the total sample in analyses for food groups by overweight/obese at 4 and 6 years of age.

Table 12: Bivariate analysis† for food groups by overweight/obese status at 4 and 6 years

		4 years of age			6 years of age		
Variable	**Category**	**% normal weight (87%)**	**% overweight/ obese (13%)**	**P-value (Chisq.)**	**% (normal weight)**	**% (overweight/ obese)**	**P-value (Chisq.)**
Grain products	0-2 servings	10.68[3,4]	4.61[3,4]	<0.0001*	10.76 [3,4]	5.71[3,4]	<0.0001*
	3 servings	42.95[3,4]	25.86[3,4]		44.99 [3,4]	25.59[3,4]	
	4 servings	32.16[1,2,4]	34.96[1,2,4]		31.86 [1,2]	43.46[1,2]	
	≥ 5 servings	14.21[1,2,3]	34.58[1,2,3]		12.39 [1,2]	25.25[1,2]	
Grain products	< 4 servings	85.79	65.42	<0.0001*	87.61	74.75	0.0003*
	≥ 4 servings	14.21	34.58		12.39	25.25	
Dairy products	0-1 servings	52.91	48.38	0.2935	52.67	46.64	0.2284
	≥ 2 servings	47.09	51.62		47.33	53.36	
Fruits and vegetables	0-2 servings	35.93	35.89		34.48	34.20	0.7531
	3 servings	29.32	27.75	0.9658	29.97	30.01	
	4 servings	18.37	18.60		18.86	22.25	
	≥ 5 servings	16.38	17.76		16.69	13.54	
Fruits and vegetables	0-1 servings	83.62	82.24	0.6688	83.31	86.46	0.3943
	≥ 2 servings	16.38	17.76		16.69	13.54	
Meats and alternatives	0-1 servings	62.02	53.77	0.0504	64.60	60.01	0.3404
	≥ 2 servings	37.98	46.23		35.40	39.99	

*Significant difference present between food group and overweight/obesity (Chi-square, two-sided p≤0.05)

[1 2 3 4 5] There is a significant difference (CHISQ p≤0.05) present in the food group quintiles according to weight status as marked by variable subgroups with the same superscript letter

† Weighted data

Source Data courtesy of the Québec Institute of Statistics, QLSCD 1998-2010

5.2.3 Bivariate association between overweight/obesity and covariates in sample

At the bivariate level, chi-square tests of independence showed that the following covariates are positively associated with being overweight or obese at 4 years of age: sex of the child (female) ($p=0.02527$), high birth weight ($p=0.0161$), a child who is overweight/obese at 2 years ($p<0.0001$), a mother who is an immigrant ($p=0.0464$), a mother who is overweight/obesity ($p<0.0001$), and low household annual income ($p=0.0251$). The following covariates are significantly associated with being overweight or obesity at 6 years of age: a child who is overweight/obese at 2 years ($p<0.0001$), mother's age when the child was born (younger mothers) ($p=0.0002$), a mother with a higher level of education ($p=0.0456$), a mother who is an immigrant ($p=0.0002$),), a mother who is overweight/obesity ($p=0.0456$), low household annual income ($p=0.0002$), and a child who is from recomposed or single parent family ($p=0.0456$). See *Table 13* for details of the bivariate analysis of the total sample for covariates by overweight/obese 4 and 6 years.

Table 13: Bivariate analysis † for covariates (in quintiles) by overweight/obese status at 4 and 6 years

		4 years of age			6 years of age		
Covariate	**Categories of covariate**	**% normal weight (87%)**	**% overweight /obese (13%)**	**P-value (Chisq.)**	**% normal weight (87%)**	**% overweight /obese (13%)**	**P-value (Chisq.)**
Child/Birth Characteristics							
Sex of child	Male	85 68	14 32	0 02527*	84 91	15 09	0 7556
	Female	87 94	12 06		84 10	15 90	
Category of birth weight	<2 5kg	83 75	16 25		80 74	19 26	0 8377
	≥2 5kg to ≤4kg	88 02 [3]	11 98 [3]	0 0161*	84 61	15 39	
	>4kg	79 06 [2]	20 94 [2]		84 28	15 72	
Born premature (<37 weeks)	No	87 04	12 96		84 77	15 23	0 6053
	Yes (born premature)	83 88	16 21	0 5118	81 49	18 51	
Initial BMI of child at 2 years	Underweight	95 33 [3 4]	4 67 [3 4]		89 16	10 84	<0 0001*
	Normal weight	90 80 [3 4]	9 20 [3 4]	<0 0001*	76 01	23 99	
	Overweight	77 97 [1 2]	22 03 [1 2]		69 87	30 13	
	Obese	70 49 [1 2]	29 51 [1 2]				
Mother smoked during pregnancy	No	87 48	12 52		85 96	14 04	0 0745
	Yes (smoked during pregnancy)	84 79	15 21	0 2444	80 52	19 48	
Breastfed (partial or exclusive for first 4 months)	Never breastfed	86 87	13 13		83 23	16 77	0 2987
	Breastfed <4 months	85 63	14 37	0 6718	82 28	17 72	
	Breastfed 4 or more months	87 70	12 30		86 75	13 25	

Table 13: Bivariate analysis † for covariates (in quintiles) by overweight/obese status at 4 and 6 years							
		4 years of age			**6 years of age**		
Covariate	**Categories of covariate**	**% normal weight (87%)**	**% overweight /obese (13%)**	**P-value (Chisq.)**	**% normal weight (87%)**	**% overweight /obese (13%)**	**P-value (Chisq.)**
Chronic illness (excluding allergies, but including asthma) at age 6 years	No Yes (child has a chronic illness)	86.94 85.79	13.06 14.21	0.7387	84.77 82.40	15.23 17.60	0.5610
Level of physical activity in comparison to other children ('higher' or 'much higher')	No (same/lower/much lower Yes (higher/much higher)	87.24 82.98	12.76 17.02	0.4405‡	84.90 74.35	15.10 25.65	0.1133‡
Television viewing for 3 or more hours/day (weekdays or weekends)	No (<3hrs/day) Yes (3 or more hrs/day)	87.54 79.55	12.46 20.45	0.0874	84.48 84.57	15.52 15.43	0.9867
Type of child care	Not in daycare/ at home Outside of home Day care centre	89.15 86.33 85.17	10.85 13.67 14.83	0.2543	88.04 84.34 81.50	11.96 15.66 18.50	0.1376
Frequency of computer use at 6 years	Quintile 1 Quintile 2 Quintile 3 Quintile 4 Quintile 5	85.37 86.82 86.60 87.65 89.69	14.63 13.18 13.40 12.35 10.31	0.8332	85.28 84.30 85.95 90.46 78.10	14.75 15.70 14.05 9.54 21.90	0.1768
Parent Characteristics							
Mother's age	29 year or less	86.87	13.13		72.71	27.29[3,4]	0.0002*

Table 13: Bivariate analysis † for covariates (in quintiles) by overweight/obese status at 4 and 6 years

		4 years of age			6 years of age		
Covariate	**Categories of covariate**	**% normal weight (87%)**	**% overweight /obese (13%)**	**P-value (Chisq.)**	**% normal weight (87%)**	**% overweight /obese (13%)**	**P-value (Chisq.)**
(when the child was born)	30-34 years 35-39 years 40+ years	87.59 86.96 84.91	12.41 13.04 15.09	0.8629	77.88 85.61 89.46	22.12[4] 14.39[1] 10.54[1,2]	
Mother's level of education (highest diploma obtained when the child was 4 years old)	No secondary school Secondary school College or professional University	85.94 83.59 [3] 89.55 [2] 86.08	14.06 16.41 [3] 10.45 [2] 13.92	0.1566	86.01 79.16 75.80	13.99[3] 20.84 24.20[1]	0.0456*
Mother's employment status (when the child was 4 years)	No (not employed) Yes (employed)	85.37 87.50	14.63 12.50	0.3011	85.87 83.44	14.13 16.56	0.3789
Mother's immigrant status	No Yes (an immigrant)	87.61 81.87	12.39 18.13	0.0464*	72.71 77.88 85.61 89.46	27.29[3,4] 22.12[4] 14.39[1] 10.54[1,2]	0.0002*
Mother overweight or obese (BMI ≥ 25kg/m²)	No Yes (overweight/obese)	89.76 79.58	10.24 20.42	<0.0001*	86.01 79.16 75.80	13.99[3] 20.84 24.20[1]	0.0456*
Family Demographic and Socioeconomic Characteristics							
Household annual income	Less than $30,000 $30,000-$49,999 $50,000-$79,999 $80,000-more	78.80 [3,4] 85.13 88.76 [1] 88.30 [1]	21.20 [3,4] 14.87 11.24 [1] 11.70 [1]	0.0251*	72.71 77.88 85.61 89.46	27.29[3,4] 22.12[4] 14.39[1] 10.54[1,2]	0.0002*

Table 13: Bivariate analysis † for covariates (in quintiles) by overweight/obese status at 4 and 6 years							
		4 years of age			6 years of age		
Covariate	**Categories of covariate**	**% normal weight (87%)**	**% overweight /obese (13%)**	**P-value (Chisq.)**	**% normal weight (87%)**	**% overweight /obese (13%)**	**P-value (Chisq.)**
Family structure	Intact Recomposed Single parent	86.95 86.72 85.59	13.05 13.28 14.41	0.9304	86.01 79.16 75.80	13.99[3] 20.84 24.20[1]	0.0456*
Urban dwelling	Rural Urban	88.09 86.13	11.91 13.87	0.3473‡	85.87 83.44	14.13 16.56	0.3789

*Significant difference present between covariate and overweight/obesity (Chi-square, two-sided p≤0 05)

[1 2 3 4 5] There is a significant difference (CHISQ p≤0 05) present in the nutritional predictor variables (in quintiles) according to weight status as marked by variable subgroups with the same superscript letter

† Weighted data, *Source Data courtesy of the Québec Institute of Statistics, QLSCD 1998-2010*

5.2.4 Final multivariate models

A set of multivariate logistic regression models was used to examine the association between nutrition predictor (both in quintiles and continuous) and overweight/obesity in children at 4 and 6 years of age. These multivariate models were examined with adjustments for covariates deemed to act as important risk-factors for overweight/obesity or important confounders to the main association.

The nutritional predictors and covariates that were significantly related to the outcome were put into an automatic stepwise selection process to attain the final models. Separate models were performed for nutritional predictors in quintiles and those which are continuous. The same covariates identified in Section 5.2.3 were used in both of these models. A third separate model was also created which investigated the association between food groups and overweight/obesity. The covariates identified in Section 5.2.3 were used in this model as well. For simplicity, there was no indication of an interaction, multicollinearity, nonlinearity, or lack of fit if these results were not mentioned for each model below.

5.2.4.1 Model # 1: Nutrition predictor variables (in quintiles) in association with overweight/obesity at 4 years

Table 14 presents the final model to examine the strength of association between the nutrition predictor variables (in quintiles) and overweight/obesity in children at 4 years of age, with adjustments for covariates listed in Section 5.2.3. Adjusted odds ratios and 95% confidence intervals for *Model # 1: Nutrition predictor variables (in quintiles) in association with overweight/obese status* are presented in *Table 14*.

When looking at *Model #1*, the odds of being overweight/obese at 4 years of age were:

1) Significantly higher for children who fell into the 3rd (OR: 3.70, 95% CI: 1.72-7.95), 4th (OR: 2.99, 95%CI: 1.31-6.84), and 5th (OR: 6.68, 95% CI: 2.77-16.12) quintile of energy consumption (in kilocalories) in comparison to those who fell into the 1st quintile respectively.

2) Significantly lower for children who fell into the 3rd (OR: 0.41, 95% CI: 0.20-0.86), 4th (OR: 0.42, 95%CI: 0.20-0.89), and 5th (OR: 0.43, 95% CI: 0.19-0.97) quintile of linoleic acid (in grams) in comparison to those who fell into the 1st quintile respectively.

3) Significantly higher for children who fell into the 2nd (OR: 3.49, 95% CI: 1.62-7.51), 3rd (OR: 3.37 (95%CI: 1.46-7.78), 4th (OR: 5.29 (95% CI: 2.24-12.46), and 5th (OR: 9.74 (95% CI: 3.95-24.04) quintile of linolenic acid (in grams) in comparison to those who fell into the 1st quintile respectively.

4) Significantly lower for children who fell into the 3rd (OR: 0.40, 95% CI: 0.19-0.80), 4th (OR: 0.32, 95%CI: 0.16-0.66), and 5th (OR: 0.43, 95% CI: 0.21-0.91) quintile of total saturated fat consumption (in grams) in comparison to those who fell into the 1st quintile respectively.

5) Significantly higher for females as opposed to males (OR: 1.58, 95% CI: 10.19-0.80).

6) Significantly lower for children born in the normal category of birth weight in comparison to those born in the low category of birth weight (OR: 0.40, 95% CI: 0.19-0.87).

7) Significantly higher for children who were overweight (OR: 2.98, 95% CI: 1.87-4.74) or obese (OR: 4.87, 95%CI: 3.19-7.42) at 2 years of age in comparison to children of normal weight.

8) Significantly higher (OR: 2.13, 95% CI: 1.47-3.07) for children from overweight/obese mothers (BMI $\geq$ 25 kg/m^2) as opposed to those from normal weight mothers.

Table 14: Adjusted† odds ratios£ and 95% confidence intervals for nutrition predictor variables (in quintiles) according to overweight/obese status 4 years		
Model 1: Nutritional predictor variables and covariates (adjusted for potential confounders)		
Variable	**Adjusted ORξ**	**95% CIξ**
Energy (in kilocalories)¶		
Quintile 1 ‡	1.00	--
Quintile 2	2.00	0.97-4.12
Quintile 3	3.70	1.72-7.95*
Quintile 4	2.99	1.31-6.84*
Quintile 5	6.68	2.77-16.12*
Linoleic acid (grams)		
Quintile 1 ‡	1.00	--
Quintile 2	0.92	0.48-1.77
Quintile 3	0.41	0.20-0.86*
Quintile 4	0.42	0.20-0.89*
Quintile 5	0.43	0.19-0.97*
Linolenic acid (grams)		
Quintile 1 ‡	1.00	--
Quintile 2	3.49	1.62-7.51*
Quintile 3	3.37	1.46-7.78*
Quintile 4	5.29	2.24-12.46*
Quintile 5	9.74	3.95-24.04*
Total saturated fats (grams)		
Quintile 1 ‡	1.00	--
Quintile 2	1.00	0.55-1.82
Quintile 3	0.40	0.19-0.80*
Quintile 4	0.32	0.16-0.66*
Quintile 5	0.43	0.21-0.91*

Sex of child		
Male ‡	1.00	--
Female	1.58	1.11-2.24*
Category of birth weight		
<2.5kg ‡	1.00	--
≥2.5kg to ≤4kg	0.40	0.19-0.87*
>4kg	0.55	0.23-1.33
Initial BMI of child at 2 years		
Normal weight ‡	1.00	--
Overweight	2.98	1.87-4.74*
Obese	4.87	3.19-7.42*
Mother overweight or obese (BMI ≥ 25kg/m²)		
No ‡	1.00	--
Yes	2.13	1.47-3.07*

*Significantly different from the reference category ($p \leq 0.05$)
† Adjusted for all variables in the model as well as covariates
‡ Reference category
¶ Variable forced into the model to control for its confounding effect
ξ OR, odds ratio, CI, confidence interval
£ Weighted data

5.2.4.2 Model # 2: Nutrition predictor variables (in quintiles) in association with overweight/obesity at 6 years

Table 15 presents the final model to examine the strength of association between the nutrition predictor variables (in quintiles) and overweight/obesity in children at 6 years of age, with adjustments for covariates listed in Section 5.2.3. Adjusted odds ratios and 95% confidence intervals for *Model # 2 Nutrition predictor variables (in quintiles) in association with overweight/obesity* at 6 years of age are presented in *Table 15* as well.

When looking at *Model #2*, the odds for overweight/obesity at 6 years of age were:

1) Significantly higher for children who fell into the 4th (OR: 2.94 (95% CI: 1.36-6.36), and 5th (OR: 3.17, 95% CI: 1.46-6.87) quintile of linolenic acid (in grams) in comparison to those who fell into the 1st quintile respectively.

2) Significantly lower for children who fell into the 2nd (OR: 0.39, 95% CI: 0.21-0.75) quintile of saturated fat consumption (% of total energy intake) in comparison to those who fell into the 1st quintile respectively.

3) Significantly higher for children who were initial overweight (OR: 3.09, 95% CI: 1.78-5.36), or obese (OR: 3.65, 95% CI: 2.20-6.08) at 2 years of age in comparison to children of normal weight.

4) Significantly higher for children who had a mother who is an immigrant (OR: 2.32, 95% CI: 1.25-4.31) than children whose mother was not an immigrant.

5) Significantly higher (OR: 2.22, 95% CI: 1.54-3.20) for children who from overweight or obese mothers (BMI $\geq$ 25 kg/m^2) as opposed to those from normal weight mothers.

6) Significantly lower for children from the 2nd (OR: 0.41, 95% CI: 0.21-0.81), 3rd (OR: 0.38, 95% CI: 0.19-0.75), and 4th (OR: 0.26, 95% CI: 0.14-0.50) quintile of household annual income in comparison to those who come from the 1st quintile of household annual income.

Table 15: Adjusted† odds ratios£ and 95% confidence intervals for nutrition predictor variables (in quintiles) according to overweight/obese status at 6 years		
Model 2: Nutritional predictor variables and covariates (adjusted for potential confounders)		
Variable	**Adjusted ORξ**	**95% CIξ**
Energy (in kilocalories)¶		
Quintile 1 ‡	1.00	--
Quintile 2	0.61	0.30-1.25
Quintile 3	0.93	0.45-1.84
Quintile 4	0.65	0.31-1.33
Quintile 5	1.18	0.58-2.39
Linoleic acid (grams)		
Quintile 1 ‡	1.00	--
Quintile 2	2.07	1.00-4.28
Quintile 3	1.66	0.74-3.70
Quintile 4	2.94	1.36-6.36*
Quintile 5	3.17	1.46-6.89*
Saturated fat (as a % of total energy)		
Quintile 1 ‡	1.00	--
Quintile 2	0.39	0.21-0.75*
Quintile 3	0.60	0.33-1.09
Quintile 4	0.71	0.40-1.28
Quintile 5	0.36	0.19-0.68*
Initial BMI of child at 2 years		
Normal weight ‡	1.00	--
Overweight	3.09	1.78-5.36*
Obese	3.65	2.20-6.08*
Mother's immigrant status		
No	1.00	--
Yes	2.32	1.25-4.31*

Mother overweight or obese (BMI ≥ 25kg/m²)		
No ‡	1.00	--
Yes	1.64	1.08-2.50*
Household annual income		
Less than $30,000 ‡	1.00	--
$30,000-$49,999	0.41	0.21-0.81*
$50,000-$79,999	0.38	0.19-0.75*
$80,000-more	0.26	0.14-0.50*

*Significantly different from the reference category (p≤ 0 05)
† Adjusted for all variables in the model as well as covariates
‡ Reference category
¶ Variable forced into the model to control for its confounding effect
ξ OR, odds ratio, CI, confidence interval
£ Weighted data

5.2.4.3 *Model # 3: Nutrition predictor variables (continuous) in association with overweight/obesity at 4 years*

*Table 16 p*resents the final model to examine the strength of association between the nutrition predictor variables (continuous) and overweight/obesity in children at 4 years of age, with adjustments for covariates listed in Section 5.2.3 Adjusted odds ratios and 95% confidence intervals for *Model # 3: Nutrition predictor variables (continuous) in association with overweight/obese status at 4 years of age* are presented in *Table 16* as well.

When looking at *Model # 3*, the results indicate the following:

1) A one-kilocalorie increase in energy is associated with increased odds of being overweight/obese at 4 years of age (OR: 1.003, 95% CI: 1.001-1.004).

2) A one-gram increase in linolenic acid is associated with increased odds of being overweight or obese at 4 years of age (OR: 10.52, 95% CI: 4.63-23.89).

3) A one-gram increase in total lipid consumption is associated with decreased odds of being overweight or obese at 4 years of age (OR: 0.949, 95% CI: 1.418-2.91).

4) The adjusted odd of being overweight or obese at 4 years of age is significantly higher (OR: 2.03, 95% CI: 1.42-2.91) for females as opposed to males.

5) The adjusted odds of being overweight or obese at 4 years is significantly lower (OR, 0.34, 95% CI: 0.16-0.72) for children born in the normal category of birth weight in comparison to those in the low birth weight category.

6) The adjusted odds of being overweight or obese at 4 years of age is significantly higher for children who were initially overweight (OR: 3.08, 95% CI: 1.96-4.85) and obese (OR: 4.82, 95%CI: 3.19-7.28) in comparison to those who were normal weight at 2 years of age.

7) The adjusted odds of being overweight or obese at 4 years of age is significantly higher (OR: 2.03, 95% CI: 1.43-2.90) for children who have mother's that are overweight or obese (BMI ≥ 25 kg/m^2) as opposed to those who have mother's of normal weight.

Table 16: Adjusted† odds ratios£ and 95% confidence intervals for overweight/obese status at 4 years, according to nutritional predictor variables (continuous) for Model #3		
Model 3: Nutritional predictor variables (continuous) and covariates (adjusted for potential confounders)		
Variable	**Adjusted ORξ**	**95% CIξ**
Energy (in kilocalories)¶	1.003	1.001-1.004*
Linolenic acid (grams)	10.52	4.63-23.89*
Total lipid intake (grams)	0.95	0.92-0.98*
Sex of child		
Male ‡	1.00	--
Female	2.03	1.42-2.91*
Category of birth weight		
<2 5kg ‡	1.00	--
≥2 5kg to≤4kg	0.34	0.16-0.72*
>4kg	0.52	0.22-1.21
Initial BMI of child at 2 years		
Normal weight ‡	1.00	--
Overweight	3.08	1.96-4.85*
Obese	4.82	3.19-7.28*
Mother overweight or obese (BMI ≥ 25kg/m²)		
No ‡	1.00	--
Yes	2.03	1.43-2.90*

*Significantly different from the reference category ($p \leq 0.05$)
† Adjusted for all variables in the model as well as covariates
‡ Reference category
¶ Variable forced into the model to control for its confounding effect
ξ OR, odds ratio, CI, confidence interval
£ Weighted data

5.2.4.4 *Model # 4: Nutrition predictor variables (continuous) in association with overweight/obesity at 6 years.*

Table 17 presents the final model to examine the strength of association between the nutrition predictor variables (continuous) and overweight/obesity in children at 6 years, with adjustments for covariates listed in Section 5.2.3. Adjusted odds ratios and 95% confidence intervals for *Model #4: Nutrition predictor variables (continuous) in association with overweight/obese status at 6 years* are presented in *Table 17* as well.

When looking at *Model # 4*, the results indicate the following:

1) A one-gram increase in linolenic acid is associated with increased odds of being overweight or obese at 6 years of age (OR: 6.47, 95% CI: 2.53-16.53).

2) A one-gram increase in total lipid consumption is associated with decreased odds of being overweight or obese at 6 years of age (OR: 0.96, 95% CI: 0.93-0.99).

3) The adjusted odds of being overweight or obese at 6 years of age is significantly higher for children who were initially overweight (OR: 2.68, 95% CI: 1.56-4.59) and obese (OR: 3.52, 95% CI: 2.15-5.77) at 2 years of age in comparison to children of normal weight.

4) The adjusted odds of being overweight or obese at 6 years of age is significantly higher for children who have a mother who is an immigrant (OR: 1.97, 95% CI: 1.08-3.63) than children whose mother are not an immigrant.

5) The adjusted odds of being overweight or obese at 6 years of age is significantly higher (OR: 1.75, 95% CI: 1.16-2.63) for children who have mother's that are overweight or obese (BMI ≥ 25 kg/m^2) as opposed to those who have mothers of normal weight.

6) The adjusted odds of being overweight or obese at 6 years is significantly lower for children from the 2nd (OR: 0.39, 95% CI: 0.20-0.76), 3rd (OR: 0.36, 95% CI: 0.19-0.70), and 4th (OR:

0.24, 95% CI: 0.13-0.46) quintile of household annual income in comparison to those who come from the 1st quintile of household annual income.

Table 17: Adjusted† odds ratios£ and 95% confidence intervals for overweight/obese status at 6 years, according to nutritional predictor variables (continuous) for Model #4		
Model 4: Nutritional predictor variables and covariates (adjusted for potential confounders)		
Variable	**Adjusted ORξ**	**95% CIξ**
Energy (in kilocalories)¶	1.00	1.000-1.003
Linolenic acid (grams)	6.47	2.53-16.53*
Total lipid intake (grams)	0.96	0.93-0.99*
Initial BMI of child at 2 years		
Normal weight ‡	1.00	--
Overweight	2.68	1.56-4.59*
Obese	3.52	2.15-5.77*
Mother's immigrant status		
No ‡	1.00	--
Yes	1.97	1.08-3.63*
Mother overweight or obese (BMI ≥ 25kg/m²)		
No ‡	1.00	--
Yes	1.75	1.16-2.63*
Household annual income		
Less than $30,000 ‡	1.00	--
$30,000-$49,999	0.39	0.20-0.76*
$50,000-$79,999	0.36	0.19-0.70*
$80,000-more	0.24	0.13-0.46*

*Significantly different from the reference category (p≤ 0 05)
† Adjusted for all variables in the model as well as covariates
‡ Reference category
¶ Variable forced into the model to control for its confounding effect
ξ OR, odds ratio, CI, confidence interval
£ Weighted data

5.2.4.5 Model #5: Food groups (in categories according to Canada's Food Guide) in overweight/obesity at 4 years

Table 18 presents the final model to examine the strength of association between food groups and overweight/obesity in children at 4 years, with adjustments for covariates listed in Section 5.2.3. Adjusted odds ratios and 95% confidence intervals for *Model #5: Food groups (in categories according in Canada's Food Guide) in overweight/obese status at 4 years* are presented in *Table 18.*

When looking at *Model #5*, the odds for overweight/obesity at 4 years were:

1) Significantly higher for children who fell into the 3rd (OR: 1.80, 95%CI: 0.95-3.38), 4th (OR: 1.29, 95% CI: 0.67-2.49), and 5th (OR: 2.77, 95% CI: 1.49-5.15) quintile of energy consumption (in kilocalories) in comparison to those in the 1st quintile of energy (lowest).

2) Significantly higher (OR: 2.53, 95% CI: 1.68-3.83) for children who consumed >4 servings of grains per day in comparison to those who consumed 4 or less servings.

3) Significantly higher (OR: 2.00, 95% CI: 1.39-2.91) for females as opposed to males.

4) Significantly lower (OR: 0.38, 95% CI: 0.18-0.81) for children born in the normal category of birth weight in comparison to those in the low birth category.

5) Significantly lower (OR: 0.64, 95% CI: 0.28-1.50) for those born in the overweight category of birth weight in comparison to those born in the low birth weight category.

6) Significantly higher for children who were overweight at 2 years (OR: 3.17, 95% CI: 2.02-4.99) and for children who were obese (OR: 4.68 (95%CI: 3.11-7.03) in comparison to children of normal weight.

7) Significantly higher (OR: 1.93, 95% CI: 1.35-2.75) for children from overweight/obese mothers (BMI $\geq$ 25kg/m^2) as opposed to children from normal weight mothers.

Table 18: Adjusted† odds ratios£ and 95% confidence intervals for overweight/obese status at 4 years, according to food groups for Model #5		
Model 5: Food groups and covariates (adjusted for potential confounders)		
Variable	**Adjusted OR ξ**	**95% CI ξ**
Energy (in kilocalories)¶		
Quintile 1 ‡	1.00	--
Quintile 2	1.45	0.74-2.81
Quintile 3	1.80	0.95-3.38
Quintile 4	1.29	0.67-2.49
Quintile 5	2.77	1.49-5.15*
Grain Products		
< 4 servings/day ‡	1.00	--
≥ 4 servings/day	2.53	1.68-3.83*
Sex of child		
Male ‡	1.00	--
Female	2.00	1.39-2.91*
Category of birth weight		
<2 5kg ‡	1.00	--
≥2 5kg to ≤4kg	0.381	0.181-0.806*
>4kg	0.643	0.28-1.50
Initial BMI of child at 2 years		
Normal weight ‡	1.00	--
Overweight	3.17	2.02-4.99*
Obese	4.68	3.11-7.03*
Mother overweight or obese (BMI ≥ 25kg/m^2)		
No ‡	1.00	--
Yes	1.93	1.35-2.75*

*Significantly different from the reference category (two-sided p≤ 0 05)
† Adjusted for all variables in the model as well as covariates
‡ Reference category
¶ Variable forced into the model to control for its confounding effect
ξ OR, odds ratio, CI, confidence interval
£ Weighted data

5.2.4.6 Model #6: Food groups (in categories according to Canada's Food Guide) in overweight/obesity at 6 years

Table 19 presents the final model to examine the strength of association between food groups and overweight/obesity in children at 6 years, with adjustments for covariates listed in Section 5.2.3. Adjusted odds ratios and 95% confidence intervals for *Model #6: Food groups (in categories according in Canada's Food Guide) in association with overweight/obese status at 6 years* are presented in *Table 19.*

When looking at *Model #6*, the odds for being overweight/obesity at 6 years were:

1) Significantly higher (OR: 2.85, 95% CI: 1.82-4.47) for children who consumed >4 servings of grains per day in comparison to those who consumed 4 or less servings.

2) Significantly higher for children who were overweight (OR: 2.85, 95% CI: 1.65-4.91) and obese (OR: 3.48, 95%CI: 2.12-5.70) at 2 years of age in comparison to children of normal weight.

3) Significantly higher (OR: 1.73, 95% CI: 1.14-2.61) for children from overweight or obese mothers (BMI $\geq$ 25 kg/m^2) as opposed to children from normal weight mothers.

4) Significantly lower for children from the 2nd (OR: 0.46, 95% CI: 0.23-0.90), 3rd (OR: 0.38, 95% CI: 0.20-0.74), and 4th (OR: 0.26, 95% CI: 0.14-0.49) quintile of household annual income in comparison to those who come from the 1st quintile of household annual income.

Table 19: Adjusted† odds ratios£ and 95% confidence intervals for overweight/obese status at 6 years, according to food groups for Model #6

Model 6: Food groups and covariates (adjusted for potential confounders)		
Variable	**Adjusted ORξ**	**95% CIξ**
Energy (in kilocalories) ¶		
Quintile 1 ‡	1.00	--
Quintile 2	0.63	0.32-1.26
Quintile 3	0.97	0.51-1.86
Quintile 4	0.58	0.29-1.16
Quintile 5	1.12	0.59-2.11
Grain Products		
< 4 servings/day ‡	1.00	--
≥ 4 servings/day	2.85	1.82-4.47*
Initial BMI of child at 2 years		
Normal weight ‡	1.00	--
Overweight	2.85	1.65-4.91*
Obese	3.48	2.12-5.70*
Mother overweight or obese (BMI ≥ 25kg/m^2)		
No ‡	1.00	--
Yes	1.73	1.14-2.61*
Household annual income		
Less than $30,000 ‡	1.00	--
$30,000-$49,999	0.46	0.23-0.90*
$50,000-$79,999	0.38	0.20-0.74*
$80,000-more	0.26	0.14-0.49*

*Significantly different from the reference category ($p \leq 0.05$)
† Adjusted for all variables in the model as well as covariates
‡ Reference category
¶ Variable forced into the model to control for its confounding effect
ξ OR, odds ratio, CI, confidence interval
£ Weighted data

5.3 BMI percentiles (continuous) as the Primary Outcome

The purpose of this section is to assess the association between diet and body mass index at 4 and 6 years (objective #2).

5.3.1 Bivariate associations between BMI and nutrition predictors in sample

At the bivariate level, simple linear regressions showed that high consumption levels of the following nutrition predictor variables (quintiles were dichotomized) are significantly associated with BMI at 4 years ($P \leq 0.05$): linolenic acid (grams), linoleic acid (grams), pathothenic acid (grams), total saturated fats (grams), total monounsaturated fats (grams), total polyunsaturated fats (grams), total energy (kilocalories), total fiber intake (grams), total carbohydrates (grams), total lipid intake (grams), and total protein (grams).

At the bivariate level, simple linear regressions showed that high consumption levels of the following nutrition predictor variables (quintiles were dichotomized) are significantly associated with BMI at 6 years ($P \leq 0.05$): linolenic acid (grams), linoleic acid (grams), total saturated fats (grams), total monounsaturated fats (grams), total polyunsaturated fats (grams), total energy (kilocalories), total carbohydrates (grams), total lipid intake (grams), and total protein (grams).

See *Table 20* for details of the bivariate analysis of the total sample in analyses for nutritional predictor variables (quintiles were dichotomized) by BMI at 4 and 6 years.

Table 20: Bivariate analysis † of the total sample in analyses for nutritional predictor variables (in quintiles) by BMI (continuous) at 4 and 6 years

Nutritional variable	Quintiles	BMI at 4 years			BMI at 6 years		
		Beta Estimate	Standard Error	P-value (simple linear regression)	Beta Estimate	Standard error	P-value (simple linear regression)
Linolenic Acid (grams)	Quintile 1 -3 ‡ Quintile 4- 5	0.43	0.10	<0.0001*	0.43	0.13	0.0008*
Linoleic Acid (grams)	Quintile 1 -3 ‡ Quintile 4- 5	0 24	0.10	0 0178*	0.27	0.13	0.0330*
Pathothenic acid (grams)	Quintile 1 -3 ‡ Quintile 4- 5	0.40	0 10	<0.0001*	0.24	0.13	0.0600
Total saturated fats (grams)	Quintile 1 -3 ‡ Quintile 4- 5	0.24	0.10	0.0163*	0.013	0.13	0.032*
Saturated fats (as a % of total energy)	Quintile 1 -3 ‡ Quintile 4- 5	-0.047	0.10	0.6396	-0.29	0.13	0.0598
Total Monounsaturated fats (grams)	Quintile 1 -3 ‡ Quintile 4- 5	0.40	0.10	<0.0001*	0 37	0 13	0 0038*
Monounsaturated fats (as a % of total energy)	Quintile 1 -3 ‡ Quintile 4- 5	0.12	0.10	0 2485	-0.090	0 13	0.4862
Polyunsaturated fats (as a % of total energy)	Quintile 1 -3 ‡ Quintile 4- 5	0.0098	0.10	0 9215	0 0022	0.13	0.9864
Total polyunsaturated	Quintile 1 -3 ‡ Quintile 4- 5	0 43	0.10	<0.0001*	0.39	0 13	0 0025*

Table 20: Bivariate analysis † of the total sample in analyses for nutritional predictor variables (in quintiles) by BMI (continuous) at 4 and 6 years							
		BMI at 4 years			**BMI at 6 years**		
Nutritional variable	**Quintiles**	**Beta Estimate**	**Standard Error**	**P-value (simple linear regression)**	**Beta Estimate**	**Standard error**	**P-value (simple linear regression)**
fats (grams)							
Total Energy (kilocalories)	Quintile 1 -3 ‡ Quintile 4- 5	0.61	0.099	<0.0001*	0.63	0.13	<0.0001*
Total Fiber intake (grams)	Quintile 1 -3 ‡ Quintile 4- 5	0.21	0.10	0.0392*	0.13	0.13	0.3306
Carbohydrates (as a % of total energy)	Quintile 1 -3 ‡ Quintile 4- 5	0.066	0.10	0.5093	0.38	0.13	0.0534
Total Carbohydrates (grams)	Quintile 1 -3 ‡ Quintile 4- 5	0.57	0 099	<0.0001*	0.73	0.13	<0.0001*
Lipid Intake (as a % of total energy)	Quintile 1 -3 ‡ Quintile 4- 5	-0.0050	0.10	0 9602	-0.12	0 13	0 3583
Total lipids (grams)	Quintile 1 -3 ‡ Quintile 4- 5	0 40	0.099	<0.0001*	0.36	0.13	0.0050*
Protein (as a % of total energy)	Quintile 1 -3 ‡ Quintile 4- 5	0 059	0.10	0.5565	-0 17	0 13	0.1943
Total protein (grams)	Quintile 1 -3 ‡ Quintile 4- 5	0.33	0.099	0 0010*	0.25	0 13	0 0498*
Cholesterol (mg)	Quintile 1 -3 ‡ Quintile 4- 5	0.016	0.10	0 8745	-0.0015	0.13	0.9906

*Significant difference present between nutrition predictor and BMI (Simple linear regression, p≤0 05)

[1,2,3,4,5] There is a significant difference (CHISQ $p \leq 0$ 05) present in the nutritional predictor variables (in quintiles) according to weight status as marked by variable subgroups with the same superscript letter
† Weighted data
‡Reference category
Source Data courtesy of the Québec Institute of Statistics, QLSCD 1998-2010

At the bivariate level, simple linear regressions showed that the following nutrition predictor variables (continuous) are significantly associated with BMI at 4 years: linolenic acid ($p<0.0001$), linoleic acid ($p=0.0178$), pathothenic acid ($p<0.0001$), total saturated fats ($p=0.0163$), total monounsaturated fats ($p<0.0001$), total polyunsaturated fats ($p<0.0001$), total energy ($p<0.0001$), total fiber intake ($p=0.0392$), total carbohydrates ($p<0.0001$), total lipid intake ($p<0.0001$), and total protein ($p=0.0010$). A positive association was observed between all the nutrition predictors mentioned and BMI at 4 years. The following nutrition predictor variables (continuous) are significantly associated with BMI at 6 years: linolenic acid ($p=0.0008$), linoleic acid ($p=0.0330$), total saturated fats ($p=0.0032$), total monounsaturated fats ($p=0.0038$), total polyunsaturated fats ($p=0.0025$), total energy ($p<0.0001$), total carbohydrates ($p<0.0001$), carbohydrates ($p=0.0258$), lipid intake ($p=0.0050$), and total protein ($p=0.0498$). A positive association was observed between all the nutrition predictors mentioned and BMI at 6 years, with the exception of saturated fat.

See *Table 21* for details of the bivariate analysis of the total sample in analyses for nutritional predictor variables (continuous) by BMI at age 4 and 6 years.

Table 21: Bivariate analysis † of nutritional predictor variables (continuous) by BMI (continuous) at 4 and 6 years						
	BMI at 4 years			BMI at 6 years		
Nutritional variable	**Beta Estimate**	**Standard error (SE)**	**P-value (simple linear regression)**	**Beta Estimate**	**Standard error (SE)**	**P-value (simple linear regression)**
Linolenic Acid (grams)	1.52	0.20	<0.0001**	1.52	0.26	<0.0001*
Linoleic Acid (grams)	0.15	0.0029	<0.0001**	0.17	0.037	<0.0001*
Pathothenic acid (grams)	0.30	0.054	<0.0001**	0.26	0.072	0.0003*
Total saturated fats (grams)	0.051	0.0099	<0.0001**	0.043	0.013	0.0008*
Saturated fats (as a % of total energy)	-0.013	0.027	0.6318	-0.087	0.034	0.0130*
Monounsaturated fats (as a % of total energy)	0.019	0.043	0.6589	0.078	0.015	<0.0001*
Total monounsaturated fats (grams)	0.077	0.012	<0.0001**	-0.044	0.056	0.4297
Polyunsaturated fats (as a % of total energy)	0.059	0.073	0.4167	0.16	0.031	<0.0001*
Total polyunsaturated fats (grams)	0.15	0.024	<0.0001**	0.10	0.093	0.2669
Total Energy (kilocalories)	0.0014	0.00018	<0.0001**	0.0016	0.00023	<0.0001*

Table 21: Bivariate analysis † of nutritional predictor variables (continuous) by BMI (continuous) at 4 and 6 years

Nutritional variable	BMI at 4 years			BMI at 6 years		
	Beta Estimate	**Standard error (SE)**	**P-value (simple linear regression)**	**Beta Estimate**	**Standard error (SE)**	**P-value (simple linear regression)**
Total Fiber intake (grams)	0.050	0.018	0.0056**	0.047	0.024	0.0525
Carbohydrates (as a % of total energy)	0.0036	0.014	0.7937	0.012	0.0016	<0.0001*
Total carbohydrates (grams)	0.010	0.0013	<0.0001**	0.040	0.018	0.0258*
Lipid Intake (as a % of total energy)	-0.0046	0.020	0.8186	0.027	0.0057	<0.0001*
Total lipids (grams)	0.028	0.0044	<0.0001**	-0.044	0.026	0.0860
Total protein (grams)	0.024	0.0039	<0.0001**	-0.043	0.033	0.1948
Protein (as a % of total energy)	0.0062	0.026	0.8101	0.021	0.005	<0.0001*
Cholesterol (mg)	0.0026	0.0011	0.0230*	0.0030	0.0015	0.0470*

*Significant difference present between nutrition predictor and BMI (Simple linear regression, p≤0 05)
† Weighted data
Source Data courtesy of the Québec Institute of Statistics, QLSCD 1998-2010

5.3.2 Bivariate association between BMI and Food Groups According to Canada's Food Guide

At the bivariate level, simple linear regressions showed that grain products (both 4 subcategories and 2 subcategories), dairy products, and meats and alternatives are significantly associated with BMI at 4 years ($P \leq 0.05$). However, only grain products with 2 subcategories was used in *Model # 11 and 12* in order to avoid multicollinearity.

At the bivariate level, a chi-square test of independence showed that grain products (both 4 subcategories and 2 subcategories) are significantly associated with BMI at 6 years (Chisq., $P \leq 0.05$). However, only grain products with 2 subcategories were used in Model # 11 and 12 in order to avoid multicollinearity as well. *A positive association was observed between grain products and BMI at 4 and 6 years.* See *Table 22* for details of the bivariate analysis of the total sample in analyses for food groups by BMI at 4 and 6 years.

Table 22: Bivariate analysis† of the total sample in analyses for food groups by BMI (continuous) at 4 and 6 years							
	BMI at 4 years				BMI at 6 years		
Food Groups	**Category**	**Beta estimate**	**Standard error (SE)**	**P-value (simple linear regression)**	**Beta estimate**	**Standard error (SE)**	**P-value (Simple linear regression)**
Grain products	0-2 portions [2,3,4]	Reference category	Reference category	Reference category	Reference category	Reference category	Reference category
	3 portions [1,3,4]	0.22	0.17	0.1860	0.24	0.22	0.2642
	4 portions [1,2]	0.62	0.17	0.0003*	0.89	0.22	<0.0001*
	≥ 5 portions [1,2]	1.34	0.19	<0.0001*	1.51	0.25	<0.0001*
Grain products	< 4 portions	Reference category	Reference category	Reference category	Reference category	Reference category	Reference category
	≥ 4 portions	0.98	0.13	<0.0001*	1.05	0.18	<0.0001*
Dairy products	0-2 portion	Reference category	Reference category	Reference category	Reference category	Reference category	Reference category
	≥ 2 portions	0.30	0.098	0.0022*	0.20	0.13	0.1126
Fruits and vegetables	0-2 portions	Reference category	Reference category	Reference category	Reference category	Reference category	Reference category
	3 portions	-0.0472	0.12	0.6981	0.083	0.16	0.5974
	4 portions	0.0627	0.14	0.6539	0.277	0.18	0.1235
	≥ 5 portions	0.1989	0.15	0.1703	0.020	0.19	0.9166
Fruits and vegetables	0-2 portion	Reference category	Reference category	Reference category	Reference category	Reference category	Reference category
	≥ 2 portions	0.20	0.13	0.1249	-0.074	0.17	0.6667
Meats and alternatives	0-1 portion	Reference category	Reference category	Reference category	Reference category	Reference category	Reference category
	≥ 2 portions	0.28	0.10	0.0055*	0.17	0.13	0.1977

*Significant difference present between food group and BMI (simple linear regression, p≤0 05)

[1 2 3 4 5] There is a significant difference (CHISQ p≤0 05) present in the food group quintiles according to BMI as marked by variable subgroups with the same superscript letter

† Weighted data

Source Data courtesy of the Québec Institute of Statistics, QLSCD 1998-2010

5.3.3 Bivariate association between BMI and covariates in sample

At the bivariate level, simple linear regressions showed that the following covariates are significantly associated with BMI at 4 years ($P \leq 0.05$): a child who is overweight/obese at 2 years, having a chronic illness (excluding allergies, but including asthma) at 6 years, being in a child-care centre, high household annual income, and a mother who is overweight/obese. The following covariates are significantly associated with BMI at 6 years ($P \leq 0.05$): a child who is overweight/obese at 2 years, higher or much higher levels of physical activity in comparison to other children ('higher' or 'much higher'), being in a child care centre , a mother who is an immigrant, a mother who is overweight/obese, high household annual income and a child from recomposed or single parent family. See *Table 23* for details of the bivariate analysis of the total sample in analyses for covariates by BMI at 4 and 6 years.

Table 23: Bivariate analysis † of covariates (in quintiles) by BMI (continuous) at 4 and 6 years

Child/Birth Characteristics

Covariate	Categories of covariate	BMI at 4 years			BMI at 6 years		
		Beta Estimate	Standard Error	P-value (simple linear regression)	Beta Estimate	Standard Error	P-value (simple linear regression)
Sex of child	Female Male	Reference category 0.077	Reference category 0.098	Reference category 0.4323	Reference category 0.21	Reference category 0.13	Reference category 0.0965
Category of birth weight	<2.5kg ≥2.5kg to >4kg	Reference category -0.27	Reference category 0.24	Reference category 0.2594	Reference category -0.041	Reference category 0.32	Reference category 0.8962
Born premature (<37 weeks)	No Yes (born premature)	Reference category 0.35	Reference category 0.24	Reference category 0.1416	Reference category -0.065	Reference category 0.31	Reference category 0.8325
Initial BMI of child at 2 years	Normal weight Overweight/Obese	Reference category 1.21	Reference category 0.11	Reference category <0.0001*	Reference category 1.23	Reference category 0.14	Reference category <0.0001*
Mother smoking during pregnancy	No Yes (smoked during pregnancy)	Reference category 0.038	Reference category 0.11	Reference category 0.7329	Reference category 0.20	Reference category 0.15	Reference category 0.1717
Breastfed (partial or exclusive for first 4 months)	Never breastfed Breastfed <4 months Breastfed 4 or more months	Reference category -0.092 -0.025	Reference category 0.13 0.13	Reference category 0.4525 0.8474	Reference category 0.11 0.0057	Reference category 0.17 0.16	Reference category 0.5228 0.9711

Table 23: Bivariate analysis † of covariates (in quintiles) by BMI (continuous) at 4 and 6 years							
Child/Birth Characteristics							
Covariate	**Categories of covariate**	**BMI at 4 years**			**BMI at 6 years**		
		Beta Estimate	**Standard Error**	**P-value (simple linear regression)**	**Beta Estimate**	**Standard Error**	**P-value (simple linear regression)**
Chronic illness (excluding allergies, but including asthma) at age 6 years	No Yes (child has a chronic illness)	Reference category 0.37	Reference category 0.17	Reference category 0.0279*	Reference category 0.32	Reference category 0.20	Reference category 0.1115
Level of physical activity in comparison to other children ('higher' or 'much higher')	No (same/lower/much lower Yes (higher/much higher)	Reference category 0.23	Reference category 0.27	Reference category 0.3918	Reference category 1.13	Reference category 0.32	Reference category 0.0004*
Television viewing for 3 or more hours/day (weekdays or weekends)	No (<3hrs/day) Yes (3 or more hrs/day)	Reference category -0.074	Reference category 0.23	Reference category 0.7436	Reference category -0.17	Reference category 0.29	Reference category 0.5466
Type of child care	Not in daycare/ at home Outside of home/ Day care centre	Reference category 0.21	Reference category 0.10	Reference category 0.0426*	Reference category 0.46	Reference category 0.13	Reference category 0.0005*
Frequency of computer use at 6 years	Quintile 1 Quintile 2 Quintile 3	Reference category -0.27 -0.13	Reference category 0.18	Reference category 0.1425	Reference category [2] 0.05 [1,3]	Reference category 0.19	Reference category 0.7931 0.3481

Table 23: Bivariate analysis † of covariates (in quintiles) by BMI (continuous) at 4 and 6 years							
Child/Birth Characteristics							
Covariate	**Categories of covariate**	**BMI at 4 years**			**BMI at 6 years**		
		Beta Estimate	**Standard Error**	**P-value (simple linear regression)**	**Beta Estimate**	**Standard Error**	**P-value (simple linear regression)**
	Quintile 4 Quintile 5	-0.0074 -0.067	0.21 0.17 0.15	0.5251 0.9657 0.6628	0.20 [2] -0.28 0.28	0.21 0.25 0.23	0.2651 0.2174
Parent Characteristics							
Mother's age (when the child was born)	29 year or less 30-34 years 35-39 years 40+ years	Reference category 0.033 0.14 0.13	Reference category 0.16 0.13 0.13	Reference category 0.8414 0.2978 0.3383	Reference category 0.22 0.19 -0.11	Reference category 0.17 0.17 0.21	Reference category 0.2084 0.2827 0.5887
Mother's level of education (highest diploma obtained when the child was 4 years old)	No secondary school Secondary school College or professional University	Reference category 0.23 -0.086 0.23	Reference category 0.15 0.15 0.16	Reference category 0.1426 0.5622 0.1563	Reference category -0.18 [4] -0.48 -0.25 [2]	Reference category 0.21 0.20 0.20	Reference category 0.3918 0.0140 0.2173
Mother's employment status (when the child was 4 years)	No (not employed) Yes (employed)	Reference category -0.06	Reference category 0.10	Reference category 0.5494	Reference category 0.12	Reference category 0.13	Reference category 0.3654
Mother's immigrant status	No Yes (an immigrant)	Reference category 0.14	Reference category 0.14	Reference category 0.3151	Reference category 0.96	Reference category 0.21	Reference category <0.0001*
Mother overweight or obese (BMI ≥	No Yes (overweight/obese)	Reference category 0.56	Reference category 0.11	Reference category <0.0001*	Reference category 0.85	Reference category 0.14	Reference category <0.0001*

Table 23: Bivariate analysis † of covariates (in quintiles) by BMI (continuous) at 4 and 6 years							
Child/Birth Characteristics							
Covariate	**Categories of covariate**	**BMI at 4 years**			**BMI at 6 years**		
		Beta Estimate	**Standard Error**	**P-value (simple linear regression)**	**Beta Estimate**	**Standard Error**	**P-value (simple linear regression)**
25kg/m²)							
Family Demographic and Socioeconomic Characteristics							
Household annual income	Less than $30,000 $30,000-$49,999 $50,000-$79,999 $80,000-more	Reference category [4] -0.34 -0.32 -0.088 [1]	Reference category 0.17 0.18 0.19	Reference category 0.0475* 0.0783* 0.6377	Reference category [3 4] 0.06 [3] -0.41 [1,2] -0.50 [1]	Reference category 0.25 0.24 0.22	Reference category 0.7930 0.0839 0.0258*
Family structure	Intact Recomposed/single parent	Reference category 0.13	Reference category 0.18	Reference category 0.4699	Reference category 0.27	Reference category 0.24	Reference category 0.0266*
Urban dwelling	Rural Urban	Reference category 0.040	Reference category 0.10	Reference category 0.7009	Reference category 0.030	Reference category 0.133	Reference category 0.8206

*Significant difference present between covariate and BMI (Simple linear regression, p≤0 05)

[1 2 3 4 5] There is a significant difference (p≤0 05) present in the nutritional predictor variables (in quintiles) according to weight status as marked by variable subgroups with the same superscript letter

† Weighted data

Source Data courtesy of the Québec Institute of Statistics, QLSCD 1998-2010

5.3.4 Final multivariate models

Three multivariate linear regression models were used to examine the association between nutrition predictor (both in quintiles and continuous) and food groups and BMI in children at 4 and 6 years. These multivariate models were examined with adjustments for covariates deemed to act as important risk-factors for overweight/obesity or important confounders to the main association.

The nutritional predictors and covariates that were significantly related to the outcome were put into an automatic stepwise selection process to attain the final models. Separate models were performed for nutritional predictors in quintiles and those which are continuous. The same covariates identified in Section 5.3.3 were used in both of these models. A third separate model was also created which investigated the association between food groups and overweight/obesity. The covariates identified in Section 5.2.3 were used in this model as well. For simplicity, there was no indication of an interaction, multicollinearity, nonlinearity, or lack of fit if these results were not mentioned for each model.

5.3.4.1 Model # 7: Nutrition predictor variables (quintiles were dichotomized) in association with BMI at 4 years

Table 24 present the final model to examine the strength of association between the nutrition predictor variables (in quintiles) and BMI in children at 4 years, with adjustments for covariates listed in *Section 5.3.3*. Parameter estimates, standard error, and p-values are present in *Table 24*.

The nutritional predictors in the final model were energy, and linolenic acid, and total saturated fat. The covariates in the final model were initial BMI of child at 2 years, mother overweight or obese, type of child care, and chronic illness at 6 years. All significant predictors, both nutritional and covariates, had a positive association with BMI. There was no statistically significant interaction present in this model.

The corresponding adjusted R^2s for this model was 0.1285, thus, this model predicts 13% of the variation in BMI at 4 years.

Table 24: Multivariate linear regression† displaying association between nutrition predictor variables (quintiles were dichotomized) and BMI in children at 4 years (with relevant covariates)†

Nutritional variable	**Category of variable**	**Beta Estimate**	**Standard error (SE)**	**P-value (Multivariate linear regression)**
Energy (in kilocalories)	Quintile 1-3 (high intake) ‡ Quintile 4-5 (low intake)	0.61	0.12	<0.0001*
Initial BMI of child at 2 years	Normal weight‡ Overweight/obese	1.11	0.11	<0.0001*
Mother overweight or obese (BMI ≥ 25kg/m²)	Normal weight‡ Overweight/obese	0.44	0.10	<0.0001*
Child care	Not in day-care‡ Outside of home/daycare centre	0.27	0.010	0.0058*
Chronic illness (excluding allergies, but including asthma) at age 6 years)	No‡ Yes	0.44	0.17	0.0081*
Total saturated fat (grams)	Quintile 1-3 (high intake) ‡ Quintile 4-5 (low intake)	0.30	0.12	0.0097*
Linolenic acid (grams)	Quintile 1-3 (high intake) ‡ Quintile 4-5 (low	0.25	0.11	0.0171*

	intake)			

*Significant difference present between nutrition predictor and BMI ($p \leq 0.05$)
† Weighted data
‡ Reference category of variable
Source Data courtesy of the Québec Institute of Statistics, QLSCD 1998-2010

5.3.4.2 Model # 8: Nutrition predictor variables (quintiles were dichotomized) in association with BMI at 6 years

Table 25 present the final model to examine the strength of association between the nutrition predictor variables (quintiles were dichotomized) and BMI in children at 6 years, with adjustments for covariates listed in *Section 5.3.3*. Parameter estimates, standard error, and p-values are present in *Table 25*.

The nutritional predictors in the final model were energy, linolenic acid and total saturated fats. The covariates in the final model were initial BMI of child at 2 years, level of physical activity, child care, mother's immigrant status, and family structure. All significant predictors, both nutritional and covariates, had a positive association with BMI at 6 years. There was no statistically significant interaction present in this model.

The corresponding adjusted R^2s for this model was 0.1663, thus, this model predicts 17% of the variation in BMI at 6 years.

Table 25: Multivariate linear regression† displaying association between nutrition predictor variables (quintiles were dichotomized) and BMI in children at 6 years (with relevant covariates)†

Nutritional variable	Category of variable	Beta Estimate	Standard error (SE)	P-value (Multivariate linear regression)
Energy (in kilocalories)	Quintile 1-3 (high intake) ‡ Quintile 4-5 (low intake)	0.52	0.16	0.0008*
Initial BMI of child	Normal weight‡	1.20	0.14	<0.0001*

at 2 years	Overweight/obese			
Level of physical activity at 6 years	Same/lower/much lower than other children‡ Higher/much than other children	0.18	0.086	0.0347*
Child care	Not in day-care‡ Outside of home/daycare centre	0.41	0.13	0.0020*
Mother's immigrant status	No‡ Yes	0.95	0.22	<0.0001*
Family structure	Intact‡ Recomposed/single parent	0.58	0.25	0.0219*
Total saturated fat (grams)	Quintile 1-3 (high intake) ‡ Quintile 4-5 (low intake)	0.47	0.15	0.0019*
Linolenic acid (grams)	Quintile 1-3 (high intake) ‡ Quintile 4-5 (low intake)	0.28	0.14	0.041*

*Significant difference present between nutrition predictor and BMI ($p \leq 0.05$)
† Weighted data
‡ Reference category of variable
Source Data courtesy of the Quebec Institute of Statistics, QLSCD 1998-2010

5.3.4.3 Model # 9: Nutrition predictor variables (continuous) in association with BMI at 4 years

Table 26 presents the final model to examine the strength of association between the nutrition predictor variables (continuous) and BMI in children at 4 years, with adjustments for covariates listed in *Section 5.3.3.* Parameter estimates, standard error, and p-values are present in *Table 26.*

The nutritional predictors in the final model were energy (in kilocalories), total carbohydrates (in grams), total saturated fats (in grams), total protein (in grams), and linolenic acid (in grams). The covariates in the final model were initial BMI of child at 2 years and mother overweight or obese. All predictors, both nutritional and covariates, had a positive association with BMI. The statistically significant interaction present in the model was total carbohydrates (in grams) x mother overweight or obese.

The corresponding adjusted R^2s for this model was 0.1497, thus, this model predicts 15% of the variation in BMI at 4 years.

Table 26: Multivariate linear regression† displaying association between nutrition predictor variables (continuous) and BMI in children at 4 years (with relevant covariates)†

Nutritional variable	Category of variable	Beta Estimate	Standard error (SE)	P-value (Multivariate linear regression)
Energy (in kilocalories)	Continuous	0.0046	0.0014	0.0010*
Initial BMI of child at 2 years	Normal weight‡ Overweight/obese	1.06	0.11	<0.0001*
Mother overweight or obese (BMI ≥ 25kg/m²)	Normal weight‡ Overweight/obese	0.26	0.16	0.0441*
Total protein intake (grams)	Continuous	0.034	0.0080	<0.0001*
Total saturated fat (grams)	Continuous	0.030	0.016	0.0289*
Total carbohydrate intake (grams)	Continuous	0.023	0.0057	<0.0001*
Linolenic acid (grams)	Continuous	1.21	0.25	<0.0001*
Total carbohydrate intake (grams) x Mother overweight or obese	Interaction	0.029	0.20	0.034*

*Significant difference present between nutrition predictor and BMI (p≤0 05)
† Weighted data

‡ Reference category of variable
Source Data courtesy of the Québec Institute of Statistics, QLSCD 1998-2010

5.3.4.4 Model # 10: Nutrition predictor variables (continuous) in association with BMI at 6 years

Table 27 presents the final model to examine the strength of association between the nutrition predictor variables (continuous) and BMI in children at 6 years, with adjustments for covariates listed in *Section 5.3.3*. Parameter estimates, standard error, and p-values are present in *Table 27.*

The nutritional predictors in the final model were energy (in kilocalories), linolenic acid (grams), total carbohydrate intake (grams). The covariates in the final model were initial BMI of child at 2 years, mother overweight/obese, mother's immigrant status, level of physical activity at 6 years, child care, and family structure. All significant predictors, both nutritional and covariates, had a positive association with BMI. The statistically significant interaction present in the model was total carbohydrate intake (grams) x Initial BMI of child at 2 years.

The corresponding adjusted R^2s for this model was 0.1873, thus, this model predicts 19% of the variation in BMI at 6 years.

Table 27: Multivariate linear regression† displaying association between nutrition predictor variables (continuous) and BMI in children at 6 years (with relevant covariates)†

Nutritional variable	Category of variable	Beta Estimate	Standard error (SE)	P-value (Multivariate linear regression)
Energy (in kilocalories)	Continuous	0.0028	0.0011	0.0146*
Initial BMI of child at 2 years	Normal weight‡ Overweight/obese	0.46	0.79	0.5616

Mother overweight or obese (BMI ≥ 25kg/m²)	Normal weight‡ Overweight/obese	0.66	0.13	<0.0001*
Mother's immigrant status	No ‡ Yes (an immigrant)	0.81	0.22	0.0002*
Level of physical activity at 6 years	Same/lower/much lower than other children‡ Higher/much than other children	0.19	0.085	0.0266*
Child care	Not in day-care‡ Outside of home/daycare centre	0.46	0.13	0.0004*
Family structure	Intact‡ Recomposed/single parent	0.50	0.26	0.0423*
Total carbohydrate intake (grams)	Continuous	0.13	0.044	0.0587
Linolenic acid (grams)	Continuous	0.94	0.31	0.0021*
Total carbohydrate intake (grams) x Initial BMI of child at 2 years	Interaction	0.0072	0.0035	0.043*

*Significant difference present between nutrition predictor and BMI ($p \leq 0.05$)
† Weighted data
‡ Reference category of variable
Source Data courtesy of the Québec Institute of Statistics, QLSCD 1998-2010

5.3.4.5 Model # 11: Food groups (in categories according in Canada's Food Guide) in association with BMI at 4 years

Table 28 presents the final model to examine the strength of association between food groups according to Canada's Food Guide and BMI in children at 4 years, with adjustments for covariates listed in *Section 5.3.3.* Parameter estimates, standard error, and p-values are present in *Table 28.*

The nutritional variables, which were predictors in the final model, were energy (in kilocalories), and grain products. The covariates present in the final model were initial BMI of child at 2 years and mother overweight/obese. All significant predictors, both nutritional and covariates, had a positive association with BMI. The statistically significant interaction present in the model was mother overweight/obese (BMI ≥ 25kg/m^2) x meats and alternatives.

The corresponding adjusted R^2s for this model was 0.1441, this model predicts 14% of the variation in BMI at 4 years.

Table 28: Multivariate linear regression† displaying association between food groups and BMI in children at 4 years (with relevant covariates)†

Nutritional variable	Category of variable	Beta Estimate	Standard error (SE)	P-value (Multivariate linear regression)
Energy (in kilocalories)	Quintile 1-3 (high intake) ‡ Quintile 4-5 (low intake)	0.00082	0.00021	<0.0001*
Initial BMI of child at 2 years	Normal weight‡ Overweight/obese	1.09	0.10	<0.0001*
Mother overweight or obese (BMI ≥ 25kg/m^2)	Normal weight‡ Overweight/obese	0.22	0.13	0.0870
Meats and alternatives	0-1 serving ‡ ≥ 2 servings	0.33	0.10	0.1056
Grain products	<4 servings/day‡ ≥ 4 servings/day	0.18	0.12	0.0012*
Meats and alternatives x Mother overweight or obese	Interaction	0.67	0.20	0.0010*

*Significant difference present between nutrition predictor and BMI (p≤0 05)
† Weighted data
‡ Reference category of variable
Source Data courtesy of the Québec Institute of Statistics, QLSCD 1998-2010

5.3.4.6 Model # 12: Food groups (in categories according in Canada's Food Guide) in association with BMI at 6 years

Table 29 presents the final model to examine the strength of association between food groups according to Canada's Food Guide and BMI in children at 6 years, with adjustments for covariates listed in *Section 5.3.3*. Parameter estimates, standard error, and p-values are present in *Table 29.*

The nutritional variables, which were predictors in the final model, were energy (in kilocalories), and grain products. The covariates present in the final model were level of physical activity at 6 years, child care, mother's immigrant status, mother overweight/obese, and family structure. All predictors, both nutritional and covariates had a positive association with BMI. There was no statistically significant interaction present in this model.

The corresponding adjusted R^2s for this model was 0.1805, this model predicts 18% of the variation in BMI at 6 years.

Table 29: Multivariate linear regression† displaying association between food groups and BMI in children at 6 years (with relevant covariates)†

Nutritional variable	**Category of variable**	**Beta Estimate**	**Standard error (SE)**	**P-value (Multivariate linear regression)**
Energy (in kilocalories)	Quintile 1-3 (high intake) ‡ Quintile 4-5 (low intake)	0.00082	0.00021	<0.0001*
Level of physical activity at 6 years	Same/lower/much lower than other children‡ Higher/much than other children	0.20	0.086	0.0213*
Child care	Not in day-care‡	0.43	0.13	0.0008*

	Outside of home/daycare centre			
Mother's immigrant status	No ‡ Yes (an immigrant)	0.86	0.22	0.0001*
Mother overweight or obese (BMI ≥ 25kg/m²)	Normal weight‡ Overweight/obese	0.69	0.13	<0.0001*
Family structure	Intact‡ Recomposed/single parent	0.49	0.25	0.0440*
Grain products	<4 servings/day‡ ≥ 4 servings/day	0.55	0.14	<0.0001*

*Significant difference present between nutrition predictor and BMI ($p \leq 0.05$)
† Weighted data
‡ Reference category of variable
Source Data courtesy of the Québec Institute of Statistics, QLSCD 1998-2010

5.4 Change in BMI from 4 to 6 years as the Primary Outcome

The purpose of this section is to assess the association between diet and the change in BMI from 4 to 6 years (objective #3).

The absolute change in BMI from 4 to 6 years was created to determine which nutritional variables at 4 years would predict weight change at 6 years. This variable was created by taking the raw difference in BMI from 4 to 6 years.

5.4.1 Bivariate association between nutrition predictors and change in BMI from 4 to 6 years

At the bivariate level, simple linear regressions showed that there was no nutrition variables (quintiles were dichotomized) significantly associated with change in BMI from 4 to 6 years. See *Table 30* for details of the bivariate analysis of the total sample in analyses for nutritional predictor variables (quintiles were dichotomized) by a change in BMI from 4 to 6 years.

Table 30:Bivariate analysis† of the total sample in analyses for nutritional predictor variables (in quintiles) by change in BMI (continuous) from 4 to 6 years

Nutritional variable	Quintiles	Beta estimate	Standard error	P-value (simple linear regression)
Linoleic Acid (grams)	Quintile 1 -3 ‡ Quintile 4- 5	-0.0509	0.046	0.2014
Linolenic Acid (grams)	Quintile 1 -3 ‡ Quintile 4- 5	-0.052	0.046	0.2582
Pathothenic acid (grams)	Quintile 1 -3 ‡ Quintile 4- 5	-0.016	0.046	0.7310
Total saturated fats (grams)	Quintile 1 -3 ‡ Quintile 4- 5	-0.056	0.046	0.2257
Saturated fats (as a % of total energy)	Quintile 1 -3 ‡ Quintile 4- 5	-0.040	0.047	0.3954
Monounsaturated fats (as a % of total energy)	Quintile 1 -3 ‡ Quintile 4- 5	-0.047	0.047	0.3102
Total Monounsaturated fats	Quintile 1 -3 ‡ Quintile 4- 5	-0.029	0.046	0.5340

Table 30: Bivariate analysis† of the total sample in analyses for nutritional predictor variables (in quintiles) by change in BMI (continuous) from 4 to 6 years				
Nutritional variable	**Quintiles**	**Beta estimate**	**Standard error**	**P-value (simple linear regression)**
(grams)				
Polyunsaturated fats (as a % of total energy)	Quintile 1 -3 ‡ Quintile 4- 5	-0.044	0.046	0.3419
Total polyunsaturated fats (grams)	Quintile 1 -3 ‡ Quintile 4- 5	-0.049	0.046	0.2945
Total Energy (kilocalories)	Quintile 1 -3 ‡ Quintile 4- 5	-0.058	0.046	0.2063
Total Fiber intake (grams)	Quintile 1 -3 ‡ Quintile 4- 5	-0.042	0.047	0.3693
Carbohydrates (as a % of total energy)	Quintile 1 -3 ‡ Quintile 4- 5	0.039	0.047	0.4015
Total carbohydrates (grams)	Quintile 1 -3 ‡ Quintile 4- 5	0.026	0.046	0.5762
Lipids (as a % of total energy)	Quintile 1 -3 ‡ Quintile 4- 5	-0.056	0.047	0.2292
Total Lipid Intake (grams)	Quintile 1 -3 ‡ Quintile 4- 5	-0.039	0.046	0.3949
Protein (as a % of total energy)	Quintile 1 -3 ‡ Quintile 4- 5	-0.033	0.046	0.4772
Total protein (grams)	Quintile 1 -3 ‡ Quintile 4- 5	0.016	0.046	0.7324
Cholesterol (mg)	Quintile 1 -3 ‡ Quintile 4- 5	0.041	0.046	0.3763

*Significant difference present between nutrition predictors and change in BMI from 4 to 6 years (simple linear regression, $p \leq 0.05$)
† Weighted data
‡ Reference category
Source Data courtesy of the Québec Institute of Statistics, QLSCD 1998-2010

At the bivariate level, a simple linear regression showed that the only nutritional predictor variable (continuous) that was negatively associated with a change in BMI from 4 to 6 years was saturated fat (p=0.0282). Since this variable is significantly associated with a change in BMI from 4 to 6 years, it met the criteria for inclusion in *Model # 14: Nutrition predictor variables (continuous) in association with change in BMI from 4 to 6 years.* See

Table 31 for details of the bivariate analysis of the total sample in analyses for covariates by overweight/obese at age 4 years.

Table 31: Bivariate analysis † of the total sample in analyses for nutritional predictor variables (continuous) by change in BMI (continuous) from 4 to 6 years

Nutritional variable	Beta Estimate	Standard error (SE)	P-value (simple linear regression)
Linolenic Acid (grams)	0.048	0.029	0.0999
Linoleic Acid (grams)	0.183	0.204	0.3715
Pathothenic acid (grams)	-0.0066	0.056	0.9074
Total saturated fats (grams)	-0.0034	0.010	0.7320
Saturated fats (as a % of total energy)	-0.0601	0.027	0.0282*
Monounsaturated fats (as a % of total energy)	-0.012	0.0437	0.7813
Total Monounsaturated fats (grams)	0.0123	0.0122	0.3131
Polyunsaturated fats (as a % of total energy)	0.122	0.074	0.0976
Total Polyunsaturated fats (grams)	0.045	0.025	0.0657
Total Energy (kilocalories)	0.00024	0.00019	0.1889
Total Fiber intake (grams)	0.0054	0.019	0.7772
Carbohydrates (as a % of total energy)	0.014	0.014	0.3139
Total Carbohydrates (grams)	0.0016	0.0013	0.2182
Lipids (as a % of total energy)	-0.028	0.02	0.1591
Total Lipid Intake (grams)	0.0023	0.0045	0.6146
Protein (as a % of total energy)	-0.0186	0.0257	0.4700
Protein (grams)	0.00137	0.0040	0.7310
Cholesterol (mg)	0.0050	0.0012	0.9307

*Significant difference present between nutrition predictors and change in BMI (simple linear regression, $p \leq 0.05$)

† Weighted data
Source Data courtesy of the Québec Institute of Statistics, QLSCD 1998-2010

5.4.2 Bivariate association between food groups according to Canada's Food Guide and change in BMI from 4 to 6 years

At the bivariate level, simple linear regressions showed that none of the food groups were associated with a change in BMI from 4 to 6 years (P ≤0.05). Since there are no bivariate association between any food groups and change in BMI from 4 to 6 years, *Model # 15: Food groups in accordance to Canada's Food Guide in association with change in BMI from 4 to 6 years* could not be produced. See *Table 32* for details of the bivariate analysis of the total sample in analyses for food groups by change in BMI from 4 to 6 years.

Table 32: Bivariate analysis† of the total sample in analyses for food groups by change in BMI (continuous) from 4 to 6 years

Variable	Category	Beta estimate	Standard error (SE)	P-value (Simple linear regression)
Grain products	0-2 portions[2]	Reference category	Reference category	Reference category
	3 portions[1,3]	0.060	0.17	0.7314
	4 portions[2]	0.302	0.18	0.0915
	≥ 5 portions	-0.0311	0.20	0.8792
Grain products	< 4 portions	Reference category	Reference category	Reference category
	≥ 4 portions	-0.18	0.14	0.2098
Dairy products	0-3 portion	Reference category	Reference category	Reference category
	≥ 2 portions	-0.13	0.10	0.1950
Fruits and vegetables	0-2 portions	Reference category	Reference category	Reference category
	3 portions	0.053	0.12	0.6675
	4 portions	0.1194	0.14	0.3972
	≥ 5 portions	-0.0926	0.15	0.5346
Fruits and vegetables	0-3 portion	Reference category	Reference category	Reference category
	≥ 2 portions	-0.14	0.13	0.3011
Meats and alternatives	0-1 portion	Reference category	Reference category	Reference category
	≥ 2 portions	0.12	0.10	0.2390

*Significant difference present between food groups and change in BMI from 4 to 6 years (Simple linear regression, p≤0 05)
† Weighted data
Source Data courtesy of the Québec Institute of Statistics, QLSCD 1998-2010

5.4.3 Bivariate association between covariates and change in BMI from 4 to 6 years

At the bivariate level, simple linear regressions showed that the following covariates are significantly associated with a change in BMI from 4 to 6 years (P ≤0.05): born premature (<37 weeks), a child who was overweight/obese at 2 years, high or much higher levels of physical activity in comparison to other children ('higher' or 'much higher'), a mother with a higher level of education, a mother who is overweight/obese, and a child from a recomposed or single parent family. These covariates met the criteria for inclusion in multivariate analyses for *Model # 13: Nutrition predictor variables (continuous) in association with change in BMI from 4 to 6 years,* and *Model # 14: Nutrition predictor variables (continuous) in association with change in BMI from 4 to 6.* The inclusion of these variables is based on their significant associations with a change in BMI from 4 to 6 years (P≤0.05). See *Table 33* for details of the bivariate analysis of the total sample in analyses for covariates by change in BMI from 4 to 6 years.

Table 33: Bivariate analysis† of the total sample in analyses for covariates (in quintiles) by change in BMI (continuous) from 4 to 6 years

Covariate	Categories of covariate	Beta estimate	Standard error	P-value (simple linear regression)
Child/Birth Characteristics				
Sex of child	Female Male	Reference category 0.109	Reference category 0.099	Reference category 0.2698
Category of birth weight	<2.5kg ≥2.5kg to >4kg	Reference category -0.12	Reference category 0.11	Reference category 0.2638
Born premature (<37 weeks)	No Yes (born premature)	Reference category -0.5311	Reference category 0.240	Reference category 0.0270*
Initial BMI of child at 2 years	Underweight Normal weight Overweight Obese	Reference category -0.12	Reference category 0.054	Reference category 0.0217*

Table 33: Bivariate analysis† of the total sample in analyses for covariates (in quintiles) by change in BMI (continuous) from 4 to 6 years

Covariate	Categories of covariate	Beta estimate	Standard error	P-value (simple linear regression)
Mother smoked during pregnancy	No Yes (smoked during pregnancy)	Reference category 0 148	Reference category 0 12	Reference category 0 2016
Breastfed (partial or exclusive for first 4 months)	Never breastfed Breastfed <4 months Breastfed 4 or more months	Reference category 0 13 0 09	Reference category 0 13 0 12	Reference category 0 3270 0 4532
Chronic illness (excluding allergies, but including asthma) at age 6 years	No Yes (child has a chronic illness)	Reference category 0 012	Reference category 0 16	Reference category 0 9381
Level of physical activity in comparison to other children ('higher' or 'much higher')	No (same/lower/much lower Yes (higher/much higher)	Reference category 0 55	Reference category 0 26	Reference category 0 0336*
Television viewing for 3 or more hours/day (weekdays or weekends)	No (<3hrs/day) Yes (3 or more hrs/day)	Reference category 0 0036	Reference category 0 23	Reference category 0 9874
Type of child care	Not in daycare/ at home Outside of home Day care centre	Reference category -0 0050	Reference category 0 048	Reference category 0 9176
Frequency of computer use at 6 years	Quintile 1 Quintile 2 Quintile 3 Quintile 4 Quintile 5	Reference category[2] 0 05[1 3] 0 184[2] -0 283 0 244	Reference category 0 15 0 17 0 20 0 18	Reference category 0 7494 0 2799 0 1551 0 1769
Parental Characteristics				
Mother's age (when the child was born)	29 year or less 30-34 years 35-39 years 40+ years	Reference category 0 12 0 13 -0 0902	Reference category 0 14 0 14 0 16	Reference category 0 3945 0 3522 0 5845
Mother's level of education (highest diploma obtained when the child was 4 years old)	No secondary school Secondary school College or professional University	Reference category[4] -0 3661[4] -0 4211[4] -0 3705[1 2 3]	Reference category 0 16 0 15 0 16	Reference category 0 0281* 0 0060* 0 0175*
Mother's employment status (when the child was 4 years)	No (not employed) Yes (employed)	Reference category 0 060	Reference category 0 10	Reference category 0 5612
Mother's immigrant	No	Reference category	Reference category	Reference category

Table 33: Bivariate analysis† of the total sample in analyses for covariates (in quintiles) by change in BMI (continuous) from 4 to 6 years				
Covariate	**Categories of covariate**	**Beta estimate**	**Standard error**	**P-value (simple linear regression)**
status	Yes (an immigrant)	0.290	0.17	0.0828
Mother overweight or obese (BMI ≥ 25kg/m²)	No Yes (overweight/obese)	Reference category 0 380	Reference category 0.11	Reference category 0.0005*
Family Demographic and Socioeconomic Characteristics				
Household annual income	Less than $30,000 $30,000-$49,999 $50,000-$79,999 $80,000-more	Reference category 0.17 0.017 -0.034	Reference category 0.19 0.19 0.18	Reference category 0.3911 0.9297 0.8466
Family structure	Intact Recomposed Single parent	Reference category 0.10	Reference category 0.088	Reference category 0.0237*
Urban dwelling	Rural Urban	Reference category 0.024	Reference category 0.104	Reference category 0.8182

*Significant difference present between covariates and change in BMI from 4 to 6 years (Simple linear regression, p≤0 05)
[1 2 3 4 5] There is a significant difference present in the nutritional predictor variables (in quintiles) according to change in BMI as marked by variable subgroups with the same superscript letter
† Weighted data
Source Data courtesy of the Québec Institute of Statistics, QLSCD 1998-2010

5.4.4 Final multivariate models

Two multivariate linear regression models was used to examine the association between nutrition predictor (both in quintiles and continuous) and change in BMI from 4 to 6 years. These multivariate models were examined with adjustments for covariates deemed to act as important risk-factors for change in BMI or important confounders to the main association.

The nutritional predictors and covariates that were significantly related to the outcome were put into an automatic stepwise selection process to attain the final models. Separate models were performed for nutritional predictors in quintiles and those which are continuous. The same covariates identified in section 5.4.3 were used in both of these models. For simplicity, there was no indication of an interaction, multicollinearity, nonlinearity, or lack of fit if these results were not mentioned for each model.

5.4.4.1 Model # 13: Nutrition predictor variables (in quintiles) in association with change in BMI from 4 to 6 years

Table 34 presents the final model to examine the strength of association between the nutrition predictor variables (quintiles were dichotomized) and change in BMI from 4 to 6 years, with adjustments for covariates listed in *Section 5.4.3.* Parameter estimates, standard error, and p-values are present in *Table 34* as well.

No suspected interactions or nutritional predictor variables were significant associated with the outcome. The covariate, which was included in the final model, was family structure. Family structure had a positive relationship with change in BMI from 4 to 6 years (recomposed/single parent vs. intact family structure).

The corresponding adjusted R^2s for this model was 0.0083, thus, this model predicts 0.8% of the variation in the child's change in BMI from 4 to 6 years.

Table 34: Multivariate linear regression† displaying association between nutrition predictor variables (quintiles were dichotomized) and change in BMI in children from 4 to 6 years (with relevant covariates)

Nutritional variable	**Category of variable**	**Beta Estimate**	**Standard error (SE)**	**P-value (Multivariate linear regression)**
Energy (in kilocalories)	Quintile 1-3 (high intake) ‡ Quintile 4-5 (low intake)	-0.017	0.052	0.75 ¶
Family structure	Intact‡ Recomposed/single parent	0.26	0.10	0.0116*

*Significant difference present between predictors and change in BMI from 4 to 6 years (p≤0 05)
† Weighted data
‡ Reference category
¶ Variable forced into the model to control for its confounding effect
Source Data courtesy of the Québec Institute of Statistics, QLSCD 1998-2010

5.4.4.2 Model # 14: Nutrition predictor variables (continuous) in association with change in BMI from 4 to 6 years

Table 35 presents the final model to examine the strength of association between the nutrition predictor variable, energy intake (quintiles dichotomized), and change in BMI from 4 to 6 years, with adjustments for covariates listed in *Section 5.4.3*. Parameter estimates, standard error, and p-values are presented in *Table 35.*

No suspected interactions or nutritional predictor variables were significantly associated with the outcome. No covariates were included in the final model. The corresponding adjusted R^2s for this model was 0.0001, thus, this model predicts 0.01% of the variation in the child's change in BMI from 4 to 6 years.

Table 35: Multivariate linear regression† displaying association between nutrition predictor variables (quintiles were dichotomized) and change in BMI in children from 4 to 6 years

Nutritional variable	**Category of variable**	**Beta Estimate**	**Standard error (SE)**	**P-value (Multivariate linear regression)**
Energy (in kilocalories)	Quintile 1-3 (high intake) ‡ Quintile 4-5 (low intake)	0.000022	0.000087	0.80¶

† Weighted data
‡ Reference category
¶ Variable forced into the model to control for its confounding effect
Source Data courtesy of the Québec Institute of Statistics, QLSCD 1998-2010

5.4.4.3 Model # 15: Food groups (in categories according to Canada's Food Guide) in association with change in BMI from 4 to 6 years

Based on the results of the bivariate analyses (see Table 34), there are no food groups which are significantly related to a change in BMI from 4 to 6 years. Since no predictor is related to this outcome, no model was produced.

5.5 Assessing the impact of excluding children with missing covariate values

The main nutrition predictors and all outcomes investigated had no missing responses for the models produced in this study. To examine the impact of excluding children with missing covariate values from multivariate analyses, all models were re-examined with the inclusion (i.e. 'with'- analyses) of missing values on the covariates. This was done by adding a separate 'missing values' subgroup to the covariate categories. All final multivariate models produced with missing covariate values can be found in *Appendix B*.

Of the covariates used in the modeling process, five of them had missing data >5%. These variables were initial BMI at 2 years (16.01% missing), mother overweight/obesity (9.67% missing), household annual income (13.05% missing), child care (12.69% missing), and level of physical activity at 6 years (32.97% missing).

Model #1: Nutritional predictors (in quintiles) in association with overweight/obese at 4 years

The 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) for model #1. There was a difference in the overall significance of one particularly covariate in this model, category of birth weight. Initially, in the 'without' model, this variable was slightly significant (p=0.0404), however, when taking into account the missing data for this variable, this covariate became insignificant (p=0.1016). This covariate has only 1.62% of its data missing, however, the overall significance of this variable difference between the 'with' and 'without' analyses. Additionally, a nutritional predictor variable, linoleic acid, changed in significance as well (from p=0.0378 to p=0.0792).

The direction of the associations remained the same across all variables in both the 'with' and 'without' analyses.

Model #2: Nutritional predictors (in quintiles) in association with overweight/obese at 6 years

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) for model #2. There was no difference in the overall significance of any covariate or nutrition predictor in this model. The direction of the associations remained the same across all variables in both the 'with' and 'without' analyses. Saturated fat did become less significant (p=0.0401) and remained negatively associated with the outcome as well.

Model #3: Nutritional predictors (continuous) in association with overweight/obese at 4 years

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) for model #3. There was no difference in the overall significance of any covariate or nutrition predictor in this model. The direction of the associations remained the same across all variables in both the 'with' and 'without' analyses.

Model #4: Nutritional predictors (continuous) in association with overweight/obese at 6 years

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) for model #4. There was no difference in the overall significance of any covariate or nutrition predictor in this model. The direction of the associations remained the same across all variables in both the 'with' and 'without' analyses.

Model #5: Overweight/obese in association with food groups as outlined by Canada's Food Guide

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) for model #5. There was no difference in the overall significance of any covariate or nutrition predictor in this model. The direction of the associations remained the same across all variables in both the 'with' and 'without' analyses.

Model #6: Food groups (according to Canada's Food Guide) in association with overweight/obesity at 6 years

The 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) for model #6. There was no difference in the overall significance of any covariate or nutrition predictor in this model. The direction of the associations remained the same across all variables in both the 'with' and 'without' analyses with the exception of mother's immigrant status which became negative in the 'with' analysis.

Model #7: Nutritional predictors (quintiles were dichotomized) in association with BMI at 4 years

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) for model #7. There was a difference in the overall significance of three covariates in this model: initial BMI of child at 2 years (p=0.7513), mother overweight/obese (p=0.4543), and child care (p=0.4353). Initially, in the 'without' model, these variables were all significant, however, when taking into account the missing data for this variable, these covariates became insignificant. Additionally, a nutritional predictor variable, total saturated fat, changed in significance as well (from p=0.0097 to p=0.1933).

All the remaining nutritional predictor variables remained significant in the 'with' model. The direction of the significant associations remained the same across for all variables in the 'with' model in comparison to the 'without' model.

The corresponding adjusted R^2s for the 'with' model was 0.0330, as opposed to 0.1285 for the 'without' analysis.

Model #8: Nutritional predictors (quintiles were dichotomized) in association with BMI at 6 years

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) for model #8. There was a difference in the overall significance of the covariate, level of physical activity at 6 years (p=0.6580). All the remaining nutritional predictor variables remained significant in the 'with' model. The direction of the significant associations remained the same across for all variables in the 'with' model in comparison to the 'without' model.

The corresponding adjusted R^2s for the 'with' model was 0.2438 as opposed to 0.1663 for the 'without' analysis.

Model #9: Nutritional predictors (continuous) in association with BMI at 4 years

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) for model #9. However, there was a difference in the overall significance for child care (p=0.465) and total carbohydrate intake (grams) x initial BMI at 2 years (p=0.5075). All the remaining nutritional predictor variables remained significant in the 'with' model. The direction of the significant associations remained the same across for all variables in the 'with' model in comparison to the 'without' model.

The corresponding adjusted R^2s for the 'with' model was 0.0620, as opposed to 0.1497 for the 'without' analysis.

Model #10: Nutritional predictors (continuous) in association with BMI at 6 years

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) for model #10. There was a difference in the overall significance of the covariate, level of physical activity at 6 years (p=0.774). All the remaining nutritional predictor variables remained significant in the 'with' model. The direction of the significant associations remained the same across for all variables in the 'with' model in comparison to the 'without' model.

The corresponding adjusted R^2s for the 'with' model was 0.0620, as opposed to 0.1873 for the 'without' analysis.

Model #11: Food groups (according to Canada's Food Guide) in association with BMI at 4 years

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) for model #11. However, there was a difference in the overall significance one covariate, mother overweight/obese (p=0.5134). The direction of the significant associations in the 'with' model remained the same across for all variables in comparison to the 'without' model except for mother overweight or obese.

The corresponding adjusted R^2s for the 'with' model was 0.0454, as opposed to 0.1441 for the 'without' analysis.

Model #12: Food groups (according to Canada's Food Guide) in association with BMI at 6 years

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) for model #12. However, there was a difference in the overall significance of the following covariates: level of physical activity (p=0.4566), and mother overweight/obese (p=0.1803). The direction of the significant associations in the 'with' model remained the same across for all variables in comparison to the 'without' model.

The corresponding adjusted R^2s for the 'with' model was 0.2707, as opposed to 0.1805for the 'without' analysis.

No missing data analysis was examined for *Model #13: Nutritional predictors (in quintiles) in association with change in BMI from 4 to 6 years* and *Model #14: Nutritional predictors (continuous) in association with change in BMI from 4 to 6 years* since there were no covariates or nutrition predictors in the models.

5.6 Examining the diets of normal and overweight/obese children from different socioeconomic groups to the new DRI standards of various nutrients

This section aims to examine and compare the diets of normal and overweight/obese children from different socioeconomic groups to the new DRI standards for various nutrients (objective #4).

5.6.1 Analysis of micronutrients by outcomes of interest

At the bivariate level, chi-square tests of independence showed that the following micronutrients (in quintiles) are significantly associated with overweight/obesity at 4 years: zinc ($p<0.0001$), magnesium ($p=0.0004$), phosphorous ($p=0.0156$), iron ($p<0.0001$) and vitamin B_{12} ($p=0.0319$). See *Table 36* for details of the bivariate analysis of the total sample for micronutrient predictor variables (in quintiles) by overweight/obesity at 4 years.

Table 36: Bivariate analysis † of the total sample in analyses for micronutrient predictor variables (in quintiles) by overweight/obese at 4 years

Nutritional variable	Quintiles	% (normal weight)	% (overweight/obese)	P-value (Chisq.)
Zinc (mg)	Quintile 1	94.03 [2,3,4,5]	5.97[2,3,4,5]	<0.0001*
	Quintile 2	86.77 [1,5]	13.23[1,5]	
	Quintile 3	88.15 [1,5]	11.85[1,5]	
	Quintile 4	86.40 [1]	13.60[1]	
	Quintile 5	78.83 [1,2,3]	21.17[1,2,3]	
Calcium (mg)	Quintile 1	89.66 [5]	10.34[5]	0.0938
	Quintile 2	88.14 [5]	11.86[5]	
	Quintile 3	87.04	12.96	
	Quintile 4	87.77	12.23	
	Quintile 5	81.51 [1,2]	18.49 [1,2]	
Magnesium (mg)	Quintile 1	91.72 [4,5]	8.28[4,5]	0.0004*
	Quintile 2	90.34 [5]	9.66[5]	
	Quintile 3	88.25 [5]	11.75[5]	
	Quintile 4	84.68 [1]	15.32[1]	
	Quintile 5	79.18 [1,2,3]	20.82[1,2,3]	
Phosphorous (mg)	Quintile 1	90.30[5]	9.70[5]	0.0156*
	Quintile 2	88.83 [5]	11.17[5]	
	Quintile 3	87.87 [5]	12.13[5]	
	Quintile 4	86.87	13.13	
	Quintile 5	80.26 [1,2,3]	19.74[1,2,3]	
Iron (mg)	Quintile 1	93.31 [4,5]	6.69[4,5]	<0.0001*
	Quintile 2	90.85 [4,5]	9.15[4,5]	
	Quintile 3	90.10 [5]	9.90[5]	
	Quintile 4	85.10 [1,2]	14.90[1,2]	

Table 36: Bivariate analysis † of the total sample in analyses for micronutrient predictor variables (in quintiles) by overweight/obese at 4 years				
Nutritional variable	**Quintiles**	**% (normal weight)**	**% (overweight/obese)**	**P-value (Chisq.)**
	Quintile 5	74.73 [1,2,3]	25.27[1,2,3]	
Vitamin A (IU)	Quintile 1	89.95	10.05	
	Quintile 2	87.94	12.06	0.3874
	Quintile 3	83.96	16.04	
	Quintile 4	86.43	13.57	
	Quintile 5	85.88	14.12	
Vitamin B_{12} (ug)	Quintile 1	89.73 [5]	10.27[5]	
	Quintile 2	86.65	13.35	0.0319*
	Quintile 3	88.63 [5]	11.37[5]	
	Quintile 4	88.41	11.59	
	Quintile 5	80.67 [1,3]	19.33[1,3]	
Vitamin C (mg)	Quintile 1	88.42	11.58	
	Quintile 2	89.57 [4]	10.43 [4]	0.2862
	Quintile 3	86.84	13.16	
	Quintile 4	83.10 [2]	16.90 [2]	
	Quintile 5	86.30	13.70	

*Significant difference present within the group category (Chi-square, two-sided p≤0 05)
[1 2 3 4 5] There is a significant difference (CHISQ p≤0 05) present in the nutritional predictor variables (in quintiles) according to overweight/obesity as marked by variable subgroups with the same superscript letter
† Weighted data
‡ Warning ≥ 25 % of the cells have an expected count less than 5 Chi-square ma not be a valid test
Source Data courtesy of the Québec Institute of Statistics, QLSCD 1998-2010

At the bivariate level, simple logistic regressions showed that the following micronutrients (continuous) are significantly associated with overweight/obesity at 4 years: zinc (p<0.0001), calcium (p=0.0005), magnesium (p<0.0001), phosphorous (p<0.0001), iron (p<0.0001) and vitamin B_{12} (p=0.019). See *Table 37* for details of the bivariate analysis of the total sample in analyses for micronutrient predictor variables (continuous) by overweight/obesity at 4 years.

Table 37: Bivariate analysis † of the total sample in analyses for micronutrient predictor variables (continuous) by overweight/obese at age 4 years			
Nutritional variable	**Beta estimate**	**Standard error (SE)**	**P-value (Simple logistics regression)**
Zinc (mg)	0.2353	0.042	<0.0001*
Calcium (mg)	0.00107	0.000307	0.0005*
Magnesium (mg)	0.00867	0.0017	<0.0001*

Table 37: Bivariate analysis † of the total sample in analyses for micronutrient predictor variables (continuous) by overweight/obese at age 4 years			
Nutritional variable	**Beta estimate**	**Standard error (SE)**	**P-value (Simple logistics regression)**
Phosphorous (mg)	0.0014	0.00031	<0.0001*
Iron (mg)	0.2552	0.0375	<0.0001*
Vitamin A (IU)	0.000031	0.000029	0.2801
Vitamin B_{12} (ug)	0.2036	0.066	0.0019*
Vitamin C (mg)	0.00158	0.0016	0.3099

*Significant difference present within the group category (Simple linear regression $p \leq 0.05$)
[1 2 3 4 5] There is a significant difference (CHISQ $p \leq 0.05$) present in the nutritional predictor variables according to overweight/obesity as marked by variable subgroups with the same superscript letter
† Weighted data
Source Data courtesy of the Québec Institute of Statistics, QLSCD 1998-2010

5.6.2 Assessment of children's diet at 4 years in accordance to DRI standards for various macro and micronutrients

The diets of normal weight and overweight/obese children were compared to the new DRI standard for total fiber, linoleic acid, linolenic acid, total protein, total carbohydrate intake, zinc (mg), calcium (mg), magnesium (mg), phosphorous (mg), iron (mg), vitamin A (IU), vitamin B_{12} (ug), and vitamin C (mg). These variables were chosen for examination since they are the variables available from the QLSCD that have a DRI outlined by Health Canada. These DRI's are specific for children between 4-8 years of age and were retrieved from the 2007 Canada's Food Guide for Healthy Eating.

Additionally, this examination refers to the children at 4 years since this is the only time point that the QLSCD conducted a 24-hour diet recall which was part of a nutrition survey. Each of the variables were dichotomized into two groups: "meets the DRI (coded 1)" or "does not meet the DRI (coded 0)". This division was based on the most current DRI's outlined by Health Canada. See *Table 4* (*Methods*) for a list of the DRI's for each of the variables mentioned above. The IOTF definition of overweight/obesity was used to assess the diet quality of children at 4 years. This dichotomous variable is categorized into two subcategories, children of normal weight or children who are overweight or obese.

At the bivariate level, chi-square test of independence showed a:

1) Significant difference in linolenic acid (grams) consumption between children of normal weight in comparison to children who are overweight/obese (p=<0.0001). Children who were overweight/obese are more likely to meet the DRI requirement for linolenic acid in comparison to children of normal weight. Specifically, overweight/obese children (58.67%) were almost twice as likely to meet the DRI for linolenic acid (gram) in comparison to children of normal weight (35.18%).

2) Significant difference in phosphorous (mg) consumption between children of normal weight in comparison to children who are overweight/obese (p=0.0214). Children who were overweight/obese are more likely to meet the DRI requirement for phosphorous (mg) in comparison to children of normal weight. Specifically, of the children who were overweight/obese, 92.42% meet the DRI requirement for phosphorous (mg). In contrast, 85.64% of normal weight children meet the DRI requirement for phosphorous (mg).

3) Significant difference in iron (mg) consumption between children of normal weight in comparison to children who are overweight/obese (p=<0.001). Children who were overweight/obese are more likely to meet the DRI requirement for iron (mg) in comparison to children of normal weight. Specifically, overweight/obese children (60.18%) were almost twice as likely to meet the DRI for iron (mg) in comparison to children of normal weight (37.47%).

See *Table 38* for details of the bivariate analysis of the total sample in analyses for nutritional variables (meet DRI, do not meet DRI) by overweight/obesity at age 4 years.

Table 38: Bivariate analysis † of the total sample in analyses for nutritional variables (meet DRI, do not meet DRI) by overweight/obese at age 4 years				
Nutritional variable	**Categories**	**% (normal weight)**	**% (overweight/obese)**	**P-value (Chisq.)**
Total fiber intake (grams)	Does not meet DRI Meets DRI	99.93 0.07	100 0	0.7425‡
Linoleic acid (grams)	Does not meet DRI Meets DRI	96.42 3.58	93.22 6.78	0.0582
Linolenic acid (grams)	Does not meet DRI Meets DRI	64.82 35.18	41.33 58.67	<0.0001*
Total protein intake (grams)	Does not meet DRI Meets DRI	0.06 99.94	0 100	0.7670‡
Total carbohydrate intake (grams)	Does not meet DRI Meets DRI	0.89 99.11	0.36 99.64	0.4953‡
Zinc (mg)	Does not meet DRI Meets DRI	7.58 92.42	3.83 96.17	0.0907
Calcium (mg)	Does not meet DRI Meets DRI	40.46 59.54	34.24 65.76	0.1412
Magnesium (mg)	Does not meet DRI Meets DRI	2.86 97.14	1.82 98.18	0.4584‡
Phosphorous (mg)	Does not meet DRI Meets DRI	14.36 85.64	7.58 92.42	0.0214*
Iron (mg)	Does not meet DRI Meets DRI	62.53 37.47	39.82 60.18	<0.0001*
Vitamin A (IU)	Does not meet DRI Meets DRI	2.01 97.99	1.15 98.85	0.4687‡
Vitamin B_{12} (ug)	Does not meet DRI Meets DRI	2.20 97.80	0.43 99.57	0.1390‡
Vitamin C (mg)	Does not meet DRI Meets DRI	0.97 99.03	0 100	0.2197‡

*Significant difference present between nutritional variable and overweight/obesity (Chi-square, two-sided p≤0 05)
† Weighted data
‡ Warning ≥ 25 % of the cells have an expected count less than 5 Chi-square ma not be a valid test
Source Data courtesy of the Québec Institute of Statistics, QLSCD 1998-2010

5.6. 3 Assessment of the demographic and socioeconomic background of children meeting the DRI standards for various macro and micronutrients

Bivariate analyses were conducted in order to determine whether a significant relationship exists between various demographic and socioeconomic variables and the new DRI standards for the nutrients listed above (section 5.6.1). Nutrient variables were dichotomous; those who meet the DRI requirement for the variable and those who do not. The demographic and socioeconomic factors that were examined included household annual income, socioeconomic status, urban dwelling, family structure, and mother's level of education.

At the bivariate level, there is a significant difference between:

1) Linoleic acid intake (grams) and household annual income (p=0.0087). Children who come from families in the highest income quintile ($80,000-more) were less likely to meet the DRI requirement for linoleic acid in comparison to children who come from families in the 2^{nd} lowest quintile of income ($30,000-$49,999).
2) Linoleic acid intake (grams) and socioeconomic status (p=0.0042). Children who come from families in the highest socioeconomic status quintile were less likely to meet the DRI for linoleic acid in comparison to children who come from the 1^{st} socioeconomic quintile.
3) Linoleic acid intake (grams) and urban dwelling (p=0.0157). Children who live in urban dwellings were more likely to meet the DRI for linoleic acid than children come from rural dwellings.

4) Linoleic acid intake (grams) and family structure (p=0.0008). Children who come from single parent families were more likely to meet the DRI for linoleic acid in comparison to children from intact households.
5) Linoleic acid intake (grams) and mother's level of education (highest diploma obtained when the child was 4 years) (p=<0.0001). Children whose mother completed university were less likely to meet the DRI for linoleic acid in comparison to children whose mother has no secondary school education or who have a college or professional degree.
6) Magnesium intake (grams) and urban dwelling (p=0.0082). Children who lived in urban dwellings were less likely to meet the DRI for magnesium than children come from rural dwellings.
7) Magnesium intake (grams) and mother's level of education (highest diploma obtained when the child was 4 years) (p=<0.0018). Children whose mother completed university were more likely to meet the DRI for magnesium in comparison to children whose mother had no secondary school education.
8) Phosphorous intake (mg) and socioeconomic status (p=0.0103). Children who came from families in the highest socioeconomic quintile were more likely to meet the DRI for phosphorous intake (mg) in comparison to children from the 1^{st}.2^{nd}, and 3^{rd} socioeconomic status quintile.
9) Vitamin A (IU) and socioeconomic status (p=0.0006). Children who came from families in the highest socioeconomic status quintile were more likely to meet the DRI for vitamin A (IU) in comparison to children from the 1^{st} and 3^{rd} socioeconomic status quintiles.

10) Vitamin A (IU) and mother's level of education (highest diploma obtained when the child was 4 years) (p=0.0003). Children whose mother completed university were more likely to meet the DRI for vitamin A in comparison to children whose mother has no secondary school education.

See *Table 39*, for an in-depth bivariate analysis of the demographic variables by each DRI standard for the nutrients listed above.

Table 39: Bivariate analysis† of demographic variables by DRI variables

Demographic Variable	Categories	% Do not meet DRI for fiber	%Meet DRI for fiber	P-value (Chisq.)
DRI variable: Total fiber intake (dichotomous: meet DRI, do not meet DRI)				
Household annual income	Less than $30,000	100	0	0.8082‡
	$30,000-$49,999	100	0	
	$50,000-$79,999	100	0	
	$80,000-more	99.86	0.14	
Socioeconomic status	Quintile 1	100	0	0.5927‡
	Quintile 2	100	0	
	Quintile 3	100	0	
	Quintile 4	99.70	0.30	
	Quintile 5	100	0.00	
Urban dwelling	Rural	100	0	0.5337‡
	Urban	99.91	0.09	
Type of family	Intact	99.93	0.07	0.9157‡
	Recomposed	100	0	
	Single parent	100	0	
Mother's level of education (highest diploma obtained when the child was 4 years old)	No secondary school	100	0	0.5858‡
	Secondary school	100	0	
	College or professional	100	0	
	University	99.78	0.22	
DRI variable: Linoleic acid intake (dichotomous: meet DRI, do not meet DRI)				
Demographic Variable	**Categories**	**% Do not meet DRI for linoleic acid**	**% Meet DRI for linoleic acid**	**P-value (Chisq.)**
Household annual income	Less than $30,000	94.76	5.24	0.0087*
	$30,000-$49,999	92.56 [4]	7.44 [4]	
	$50,000-$79,999	95.60	4.40	
	$80,000-more	97.76 [2]	2.24 [2]	
Socioeconomic status	Quintile 1	91.89 [3,4,5]	8.11 [3,4,5]	0.0042*
	Quintile 2	95.54 [4]	4.46 [4]	
	Quintile 3	96.61 [1]	3.39 [1]	
	Quintile 4	98.91 [1,2]	1.09 [1,2]	
	Quintile 5	96.31 [1]	3.69 [1]	
Urban dwelling	Rural	97.74	2.26	0.0157*

	Urban	94.78	5.22	
Type of family	Intact	96.75 [3]	3.25 [3]	0.0008*
	Recomposed	94.74	5.26	
	Single parent	88.99 [1]	11.01 [1]	
Mother's level of education (highest diploma obtained when the child was 4 years old)	No secondary school	90.73 [2,4]	9.27 [2,4]	<0.0001*
	Secondary school	97.22 [1]	2.78 [1]	
	College or professional	94.95 [4]	5.05 [4]	
	University	98.81 [1,3]	1.19 [1,3]	

DRI variable: Linolenic acid intake (dichotomous: meet DRI, do not meet DRI)

Demographic Variable	**Categories**	**% Do not meet DRI for linolenic acid**	**% Meet DRI for linolenic acid**	**P-value (Chisq.)**
Household annual income	Less than $30,000	56.22	43.78	0.3732
	$30,000-$49,999	59.86	40.14	
	$50,000-$79,999	61.11	38.89	
	$80,000-more	64.03	35.97	
Socioeconomic status	Quintile 1	59.31	40.69	0.2549
	Quintile 2	57.28 [5]	42.72 [5]	
	Quintile 3	63.98	36.02	
	Quintile 4	61.63	38.37	
	Quintile 5	66.44 [2]	33.56 [2]	
Urban dwelling	Rural	62.76	37.24	0.6390
	Urban	61.36	38.64	
Type of family	Intact	62.90 [3]	37.10 [3]	0.0728
	Recomposed	60.10	39.90	
	Single parent	51.36 [1]	48.64 [1]	
Mother's level of education (highest diploma obtained when the child was 4 years old)	No secondary school	57.32	42.68	0.6328
	Secondary school	62.11	37.89	
	College or professional	62.21	37.79	
	University	62.76	37.24	

DRI variable: Zinc intake (dichotomous: meet DRI, do not meet DRI)

Demographic Variable	**Categories**	**% Do not meet DRI for zinc**	**% Meet DRI for zinc**	**P-value (Chisq.)**
Household annual income	Less than $30,000	9.93	90.07	0.1356
	$30,000-$49,999	7.15	92.85	
	$50,000-$79,999	9.12 [4]	90.88 [4]	
	$80,000-more	5.39 [3]	94.61 [3]	
Socioeconomic status	Quintile 1	10.25 [5]	89.75 [5]	0.0706
	Quintile 2	8.42 [5]	91.58 [5]	
	Quintile 3	7.75	92.25	
	Quintile 4	5.64	94.36	
	Quintile 5	3.90 [1,2]	96.10 [1,2]	
Urban dwelling	Rural	6.05	93.95	0.2517
	Urban	7.87	92.13	
Type of family	Intact	6.90	93.10	0.6484
	Recomposed	7.79	92.21	
	Single parent	9.31	90.69	
Mother's level of	No secondary	12.32 [3,4]	87.68 [3,4]	

education (highest diploma obtained when the child was 4 years old)	school Secondary school College or professional University	7.66 5.86 [1] 5.31 [1]	92.34 94.14 [1] 94.69 [1]	0.0163
DRI variable: Calcium intake (dichotomous: meet DRI, do not meet DRI)				
Demographic Variable	**Categories**	**% Do not meet DRI for calcium**	**% Meet DRI for calcium**	**P-value (Chisq.)**
Household annual income	Less than \$30,000 \$30,000-\$49,999 \$50,000-\$79,999 \$80,000-more	45.01 41.27 40.62 36.88	54.99 58.73 59.38 63.12	0.3209
Socioeconomic status	Quintile 1 Quintile 2 Quintile 3 Quintile 4 Quintile 5	44.55 [5] 41.60 41.83 36.29 34.01 [1]	55.45 [5] 58.40 58.17 63.71 65.99 [1]	0.1136
Urban dwelling	Rural Urban	37.79 40.48	62.21 59.52	0.3696
Type of family	Intact Recomposed Single parent	39.15 41.82 40.83	60.85 58.18 59.17	0.8079
Mother's level of education (highest diploma obtained when the child was 4 years old)	No secondary school Secondary school College or professional University	43.69 41.53 39.42 35.76	56.31 58.47 60.58 64.24	0.2981
DRI variable: Magnesium intake (dichotomous: meet DRI, do not meet DRI)				
Demographic Variable	**Categories**	**% Do not meet DRI for magnesium**	**% Meet DRI for magnesium**	**P-value (Chisq.)**
Household annual income	Less than \$30,000 \$30,000-\$49,999 \$50,000-\$79,999 \$80,000-more	6.05 [4] 3.03 2.62 2.03 [1]	93.95 [4] 96.97 97.38 97.97 [1]	0.1128
Socioeconomic status	Quintile 1 Quintile 2 Quintile 3 Quintile 4 Quintile 5	4.82 [5] 3.62 [5] 2.52 2.14 0.56 [1,2]	95.18 [5] 96.38 [5] 97.48 97.86 99.44 [1,2]	0.0582
Urban dwelling	Rural Urban	1.11 3.81	98.89 96.19	0.0082*
Type of family	Intact Recomposed Single parent	2.52 [3] 2.53 5.97 [1]	97.48[3] 97.47 94.03[1]	0.1360‡
Mother's level of education (highest diploma obtained when the child was 4 years old)	No secondary school Secondary school College or professional University	7.05 [2,3,4] 1.37 [1] 2.16 [1] 2.44 [1]	92.95[2,3,4] 98.63[1] 97.84[1] 97.56[1]	0.0018*

DRI variable: Phosphorous intake (dichotomous: meet DRI, do not meet DRI)				
Demographic Variable	**Categories**	**% Do not meet DRI for phosphorous**	**% Meet DRI for phosphorous**	**P-value (Chisq.)**
Household annual income	Less than $30,000 $30,000-$49,999 $50,000-$79,999 $80,000-more	17.17 15.53 13.92 11.24	82.83 84.47 86.08 88.76	0.2071
Socioeconomic status	Quintile 1 Quintile 2 Quintile 3 Quintile 4 Quintile 5	15.27 [5] 18.03 [5] 13.95 [5] 12.59 7.22 [1,2,3]	84.73 [5] 81.97 [5] 86.05 [5] 87.41 92.78 [1,2,3]	0.0103*
Urban dwelling	Rural Urban	11.42 14.60	88.58 85.40	0.1280
Type of family	Intact Recomposed Single parent	13.22 15.31 13.02	86.78 84.69 86.98	0.7919
Mother's level of education (highest diploma obtained when the child was 4 years old)	No secondary school Secondary school College or professional University	18.01 [4] 13.25 13.58 10.85 [1]	81.99 [4] 86.75 86.42 89.15 [1]	0.1595
DRI variable: Iron intake (dichotomous: meet DRI, do not meet DRI)				
Demographic Variable	**Categories**	**% Do not meet DRI for iron**	**% Meet DRI for iron**	**P-value (Chisq.)**
Household annual income	Less than $30,000 $30,000-$49,999 $50,000-$79,999 $80,000-more	57.59 59.91 57.34 61.05	42.41 40.09 42.66 38.95	0.7265
Socioeconomic status	Quintile 1 Quintile 2 Quintile 3 Quintile 4 Quintile 5	55.71 62.87 58.17 60.29 60.30	44.29 37.13 41.83 39.71 39.70	0.5947
Urban dwelling	Rural Urban	59.87 58.99	40.13 41.01	0.7703
Type of family	Intact Recomposed Single parent	59.90 62.91 50.47	40.10 37.09 49.53	0.6465
Mother's level of education (highest diploma obtained when the child was 4 years old)	No secondary school Secondary school College or professional University	61.97 60.93 59.21 56.81	38.03 39.07 40.79 43.19	0.6465
DRI variable: Vitamin A (dichotomous: meet DRI, do not meet DRI)				
Demographic Variable	**Categories**	**% Do not meet DRI for vitamin A**	**% Meet DRI for vitamin A**	**P-value (Chisq.)**
Household annual	Less than $30,000	3.54 [4]	96.46 [4]	

income	$30,000-$49,999	3.16 [4]	96.84[4]	0.1018
	$50,000-$79,999	1.48	98.52	
	$80,000-more	1.06 [1,2]	98.94[1,2]	
Socioeconomic status	Quintile 1	4.16 [2,4,5]	95.84[2,4,5]	
	Quintile 2	0.94 [1,3]	99.06[1,3]	0.0006*‡
	Quintile 3	3.88 [2,4,5]	96.12[2,4,5]	
	Quintile 4	0.58 [1,3]	99.42[1,3]	
	Quintile 5	0 [1,3]	100[1,3]	
Urban dwelling	Rural	1.93	98.07	0.9557
	Urban	1.88	98.12	
Type of family	Intact	1.81	98.19	0.2351‡
	Recomposed	0.83	99.17	
	Single parent	3.81	96.19	
Mother's level of education (highest diploma obtained when the child was 4 years old)	No secondary school	5.67 [2,3,4]	94.33[2,3,4]	0.0003*‡
	Secondary school	1.26 [1]	98.74[1]	
	College or professional	1.67 [1]	98.33[1]	
	University	0.44 [1]	99.56[1]	
DRI variable: Vitamin B_{12} (dichotomous: meet DRI, do not meet DRI)				
Demographic Variable	**Categories**	**% Do not meet DRI for vitamin B_{12}**	**% Meet DRI for vitamin B_{12}**	**P-value (Chisq.)**
Household annual income	Less than $30,000	2.97	97.03	0.6591‡
	$30,000-$49,999	2.52	97.48	
	$50,000-$79,999	1.62	98.38	
	$80,000-more	1.60	98.40	
Socioeconomic status	Quintile 1	2.51	97.49	
	Quintile 2	2.57	97.43	0.7344‡
	Quintile 3	2.09	97.91	
	Quintile 4	1.53	98.47	
	Quintile 5	1.10	98.90	
Urban dwelling	Rural	1.12	98.88	0.1215
	Urban	2.43	97.57	
Type of family	Intact	1.63	98.37	
	Recomposed	3.11	96.89	0.3133‡
	Single parent	3.22	96.78	
Mother's level of education (highest diploma obtained when the child was 4 years old)	No secondary school	3.87 [3]	96.13 [3]	
	Secondary school	1.85	98.15	0.1741
	College or professional	1.16 [1]	98.84 [1]	
	University	1.94	98.06	
DRI variable: Vitamin C intake (dichotomous: meet DRI, do not meet DRI)				
Demographic Variable	**Categories**	**% Do not meet DRI for vitamin C**	**% Meet DRI for vitamin C**	**P-value (Chisq.)**
Household annual income	Less than $30,000	1.71	98.29	
	$30,000-$49,999	1.29	98.71	0.4609‡
	$50,000-$79,999	0.51	99.49	
	$80,000-more	0.58	99.42	
Socioeconomic status	Quintile 1	0.96	99.04	
	Quintile 2	0.23	99.77	0.2872‡

	Quintile 3 Quintile 4 Quintile 5	1.47 1.23 0	98.53 98.77 100	
Urban dwelling	Rural Urban	0.52 1.02	99.48 98.98	0.3726
Type of family	Intact Recomposed Single parent	0.87 0 1.55	99.13 100 98.45	0.4095‡
Mother's level of education (highest diploma obtained when the child was 4 years old)	No secondary school Secondary school College or professional University	1.18 0.27 1.48 0.26	98.82 99.73 98.52 99.74	0.2018‡

*Significant difference present within the group category (Chi-square, two-sided p≤0 05)
[1 2 3 4 5]There is a significant difference (CHISQ p≤0 05) present in the nutritional predictor variables (in quintiles) according to weight status as marked by variable subgroups with the same superscript letter, †Weighted data, ‡ 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 Québec Institute of Statistics, QLSCD 1998-2010

Chapter 6: Discussion

6.1 Summary of Findings for Objective #1-3

To our knowledge, this is the first study to investigate the association between dietary intake and obesity status in a representative sample of Canadian children. Using the IOTF definition for overweight/obesity in boys and girls at age 4 and 6 years, approximately 13% (11% of boys; 14% of girls) of the sample was classified as overweight/obese at age 4 years, and 16% (13% of boys; 15% of girls) of the sample was considered overweight/obese at 6 years of age. These prevalence rates are lower than that of the Canadian population between 2-17 years of age in 2004 (26% overweight/obese), in addition to the 23% overweight/obesity rate in the province of Québec in that same year (Shields, 2005). However, the prevalence rates presented in this study may be reflective of those found in this particular age group (4 and 6 years of age) with the province of Québec as opposed to Canadian children between 2-17 years of age.

In contrast with the studies' hypotheses, numerous predictors of diet quality were rejected from the final models. This includes dietary fiber, fruits and vegetables, monounsaturated fat, polyunsaturated fat, and cholesterol. Thus, the hypotheses in regards to these nutrients are not relevant in terms of the final models presented in this study. However, bivariate analyses did show associations between these nutrients and the outcomes of interest.

Table 40 presents the significant associations found between various nutrients and overweight/obesity and BMI. In contrast with our hypotheses, linoleic acid was positively associated with overweight/obesity at 4 years of age. We assumed that this nutrient would be negatively associated with this outcome in addition to BMI at 4 and 6 years and with a change in BMI between these years. Linolenic acid, however, was positively associated with overweight/obesity at 4 and 6 years, and BMI at 4 years and 6 years. This finding also differs from our original hypotheses since we assumed that the relationship would be negative as opposed to positive.

Saturated fat was associated with overweight/obesity at 4 and 6 years of age, and BMI at 4 and 6 years of age. This positive association is in line with our original hypotheses set out for this study.

Carbohydrates and proteins were positively associated with BMI at 4 years of age as expected. An interaction was present between total carbohydrates and mother overweight/obese in this model as well as in the model with BMI at 6 years of age as the primary outcome. An interaction between total carbohydrates and initial BMI of child at 2 years of age was also present in the model with BMI at 6 years of age as the primary outcome.

The food group consistently associated with both overweight/obesity at 4 and 6 years and BMI at 4 and 6 years was grain products. An interaction between meat and alternatives and mother's overweight/obesity when the outcome of interest was BMI at 4 years of age was present.

Each model was adjusted for energy-intake and various covariates known to affect BMI and dietary intake in childhood. Among all 14 models investigated in this study the covariates which appeared to consistently be associated with overweight and BMI are: sex of child, category of birth weight, initial BMI of child at 2 years of age, mother overweight/obesity, child care, mother's immigrant status, and family structure. Physical activity was only associated with BMI in 3 of the 14 models. Surprisingly, the relationship between physical activity and BMI in these models was positive.

In conclusion, the nutrition variables which appear to consistently be associated with overweight and/or BMI are linolenic acid, total saturated fat and grain products. Thus, the interpretation of our findings will focus on these nutritional variables.

Table #40: Direction of association of significant predictors in each model created †															
Model #		**# 1**	**#2**	**#3**	**#4**	**#5**	**#6**	**#7**	**#8**	**#9**	**#10**	**#11**	**#12**	**#13**	**#14**
		4 yrs	**6 yrs**	**4 yrs**	**6 yrs**	**4 yrs**	**6 yrs**	**4 yrs**	**6 yrs**	**4 yrs**	**6 yrs**	**4 yrs**	**6 yrs**	**Δ 4 to 6 yrs**	**Δ 4 to 6 yrs**
		Nutrition predictors (quintile)		Nutrition predictors (continuous)		Food groups		Nutrition predictors (quintile)		Nutrition predictors (continuous)		Food groups		Nutrition predictors (quintile)	Nutrition predictors (continuous)
		Overweight/obese models						BMI at 4 and 6 years models						Change in BMI from 4 - 6 years	
Quintile or Continuous Variables															
Energy (kcal)	Q2 vs. Q1			+	+			+	+	+	+	+	+		
	Q3 vs. Q1														
	Q4 vs. Q1														
	Q5 vs. Q1	+				+									
Linoleic acid (grams)	Q2 vs. Q1	+													
	Q3 vs. Q1														
	Q4 vs. Q1														
	Q5 vs. Q1														
Linolenic acid (grams)	Q2 vs. Q1			+	+			+	+	+	+				
	Q3 vs. Q1														
	Q4 vs. Q1	+													
	Q5 vs. Q1	+	+												

Table #40: Direction of association of significant predictors in each model created †															
Model #		**# 1**	**#2**	**#3**	**#4**	**#5**	**#6**	**#7**	**#8**	**#9**	**#10**	**#11**	**#12**	**#13**	**#14**
		4 yrs	**6 yrs**	**4 yrs**	**6 yrs**	**4 yrs**	**6 yrs**	**4 yrs**	**6 yrs**	**4 yrs**	**6 yrs**	**4 yrs**	**6 yrs**	**Δ 4 to 6 yrs**	**Δ 4 to 6 yrs**
		Nutrition predictors (quintile)		Nutrition predictors (continuous)		Food groups		Nutrition predictors (quintile)		Nutrition predictors (continuous)		Food groups		Nutrition predictors (quintile)	Nutrition predictors (continuous)
		Overweight/obese models						BMI at 4 and 6 years models						Change in BMI from 4 - 6 years	
Total saturated fat (% of total energy)	Q2 vs. Q1														
	Q3 vs. Q1														
	Q4 vs. Q1														
	Q5 vs. Q1		-												
Total lipid intake	Q2 vs. Q1			-	-										
	Q3 vs. Q1														
	Q4 vs. Q1														
	Q5 vs. Q1														
Total saturated fats (grams)	Q2 vs. Q1	+						+	+	+					
	Q3 vs. Q1														
	Q4 vs. Q1	-													
	Q5 vs. Q1														
Total carbohydrates (grams)										+					

Table #40: Direction of association of significant predictors in each model created †															
Model #		**# 1**	**#2**	**#3**	**#4**	**#5**	**#6**	**#7**	**#8**	**#9**	**#10**	**#11**	**#12**	**#13**	**#14**
		4 yrs	**6 yrs**	**4 yrs**	**6 yrs**	**4 yrs**	**6 yrs**	**4 yrs**	**6 yrs**	**4 yrs**	**6 yrs**	**4 yrs**	**6 yrs**	**Δ 4 to 6 yrs**	**Δ 4 to 6 yrs**
		Nutrition predictors (quintile)		Nutrition predictors (continuous)		Food groups		Nutrition predictors (quintile)		Nutrition predictors (continuous)		Food groups		Nutrition predictors (quintile)	Nutrition predictors (continuous)
		Overweight/obese models						BMI at 4 and 6 years models						Change in BMI from 4 - 6 years	
Total proteins (grams)										+					
Food Groups															
Grain products						+	+					+	+		
Meats and alternatives															
Covariates															
Sex of child (males as reference)		+		+		+									
Category of birth weight	<2.5kg‡														
	≥2.5kg to ≤4kg	-		-		-									
	>4kg														
Initial BMI of child at 2 yrs	Normal‡							+	+			+			
	Overweight /Obese	+	+	+	+	+	+								

Table #40: Direction of association of significant predictors in each model created †															
Model #		**# 1**	**#2**	**#3**	**#4**	**#5**	**#6**	**#7**	**#8**	**#9**	**#10**	**#11**	**#12**	**#13**	**#14**
		4 yrs	**6 yrs**	**4 yrs**	**6 yrs**	**4 yrs**	**6 yrs**	**4 yrs**	**6 yrs**	**4 yrs**	**6 yrs**	**4 yrs**	**6 yrs**	**Δ 4 to 6 yrs**	**Δ 4 to 6 yrs**
		Nutrition predictors (quintile)		Nutrition predictors (continuous)		Food groups		Nutrition predictors (quintile)		Nutrition predictors (continuous)		Food groups		Nutrition predictors (quintile)	Nutrition predictors (continuous)
		Overweight/obese models						BMI at 4 and 6 years models						Change in BMI from 4 - 6 years	
Mother overweight /obese	No‡	+	+	+	+	+	+	+		+	+		+		
	Yes														
Chronic illness								+							
Household annual income			-		-	-									
Child care								+	+		+		+		
Mother's immigrant status			+		+		+		+		+		+		
Family structure									+		+		+	+	
Level of physical activity at 6 years									+				+		
Interactions															
Total carbohydrates (grams) x Mother										+					

Table #40: Direction of association of significant predictors in each model created †														
Model #	**# 1**	**#2**	**#3**	**#4**	**#5**	**#6**	**#7**	**#8**	**#9**	**#10**	**#11**	**#12**	**#13**	**#14**
	4 yrs	**6 yrs**	**4 yrs**	**6 yrs**	**4 yrs**	**6 yrs**	**4 yrs**	**6 yrs**	**4 yrs**	**6 yrs**	**4 yrs**	**6 yrs**	**Δ 4 to 6 yrs**	**Δ 4 to 6 yrs**
	Nutrition predictors (quintile)		Nutrition predictors (continuous)		Food groups		Nutrition predictors (quintile)		Nutrition predictors (continuous)		Food groups		Nutrition predictors (quintile)	Nutrition predictors (continuous)
	Overweight/obese models						BMI at 4 and 6 years models						Change in BMI from 4 - 6 years	
overweight/obese														
Total carbohydrates (grams) x Initial BMI of child at 2 years										+				
Meat and alternatives x mother overweight /obese											+			

† Weighted data
Source *Data courtesy of the Québec Institute of Statistics, QLSCD 1998-2010*
Q1-Q5= quintile 1- quintile 5
‡ reference category

6.2 Summary of Findings for Objective #4

In correspondence with the studies' hypotheses for objective #4, no children meet the DRI requirement for fiber (Table 38). However, majority of children who are overweight or obese did meet the DRI requirement for various micronutrients such as vitamin A, vitamin C, vitamin B_{12}, linolenic acid, zinc, calcium, magnesium, phosphorous, and iron (Table 38). A significant difference in linolenic acid (p=<0.0001), phosphorous (p=0.0214) and iron (p=<0.0001) consumption exists between children of normal weight in comparison to children who are overweight/obese. Specifically, children who are overweight/obese are more likely to meet the DRI requirement for linolenic acid (58.67%), phosphorous (92.42%) and iron (60.18%) in comparison to children of normal weight. This contradicts previous findings that obese children tend to consume nutrient-dilute diets and thus tend to have inadequate intakes of numerous micronutrients. Lastly, almost all children meet the DRI for total carbohydrates and protein intake as expected. Therefore, children who are overweight and obese do not exceed those who are of normal weight in terms of meeting the DRI for total carbohydrate and protein intake.

It was found that children from families with low socioeconomic status are less likely to meet the DRI for various nutrients as expected. Children whose mother completed a university degree were more likely to meet the DRI for magnesium (p=<0.0018) and vitamin A (p=0.0003) in comparison to children whose mother has no secondary school education. Children who came from families in the highest socioeconomic quintile were more likely to meet the DRI for magnesium (p=0.0103) and vitamin A (p=0.0003) in comparison to those from lower socioeconomic quintiles. On the contrary, parts of the study's hypotheses in regards to objective #4 were not supported by the study results. Children who came from families in the highest household income quintile ($80,000 or more) (p=0.0087), the highest socioeconomic quintile (p=0.0042), live in urban dwellings (p=0.0157), and whose mother completed university (p=<0.0001), were less likely to meet the DRI requirement for linoleic acid. Also, children that come from single-parent families were more likely to meet the DRI requirement for linoleic acid (p=0.0008). Despite this unexpected result, it is plausible that children from families of low socioeconomic status consumed more fat in general since children from this social group are more likely to be overweight/obese. Thus, the consumption of more fat would lead to higher linoleic acid intake since this nutrient is a polyunsaturated fat. For example, Gazzaniga and Burns (1993) found that percentage of body fat was positively correlated with intakes of total fat ($p<0.001$), total saturated fat ($p<0.001$), total monounsaturated fat ($p<0.00001$), and total polyunsaturated fat ($p<0.01$). Gillis et al., (2006) also found that obese children consume significantly higher total fat (in grams) and saturated fatty acids (in grams) than non-obese children. Therefore, the higher intake of linoleic acid among children from lower socioeconomic status is conceivable considering that overweight/obese children consume significantly more total dietary fat.

6.3 Interpretation

To date, most studies assessing dietary composition and body fatness have focused on adults. Given the rapid growth of the obesity epidemic in children, it is essential to focus on diet composition as a significant contributing factor to childhood obesity. The rationale behind the relationship between food consumption and weight status are based on several theories. This includes the fact that macronutrients can affect weight status by either promoting or suppressing energy intake based on the nutrients influence on satiety (Rodriguez and Moreno, 2006). For example, macronutrients with high energy-density, such as fat, can increase the amount of food consumed depending on the palatability of the food (Rodriguez and Moreno, 2006). The thermal effect of food; the energy required to digest food, varies substantially for different food components as well, and as a consequence, the amount of food consumed (Rodriguez and Moreno, 2006). Lastly, slow metabolic efficiency of foods, such as fat, can cause a greater deposition of body fat (Rodriguez and Moreno, 2006). These theories, among many others, have initiated various studies in research today which investigated the relationship between macronutrient consumption and weight status.

Studies suggest that carbohydrate quantity and quality significantly contribute to excess weight gain in the adult population (Hare-Brunn et al., 2006; Koh-Banerjee et al., 2004; Liu et al., 2003; Ludwig et al., 1999; Ma et al., 2005; Nooyens et al., 2005). Furthermore, studies in children have also found a positive relationship between carbohydrates and BMI (Maillard et al., 2000; Skinner et al., 2004) and overweight status (Rocandio et al., 2001; Scaglioni et al., 2000) in children. Maillard et al., (2000) found a significant relationship between high percentage of energy intake from carbohydrates and BMI in girls ($p <0.02$). It was also found that children who were overweight at 5 years old had a lower percentage intake of carbohydrates at 1 year old than non-overweight children ($p=0.031$) (Scaglioni et al., 2000). Mean carbohydrate intake (which was recorded between 2 and 8 years) were negatively associated with children's BMI at 8 years of age as well (Skinner et al., 2004). Therefore, the findings from this study are in line with studies focused on carbohydrate intake and childhood obesity (Maillard et al., 2000; Rocandio et al., 2001; Scaglioni et al., 2000; and Skinner et al., 2004).

In our study, protein intake was demonstrated to be associated with BMI at 4 years of age. This was also observed by Ohlund et al., (2010), which found that protein intake at 4 years of age was a predictor of BMI at 4 years of age. Nevertheless, in our study, protein intake at 4 years of age was not associated with BMI or overweight status at 6 years of age. Studies that observed an association between previous protein intake and current BMI had a larger duration of years between the exposure and outcome measure. For example, Scaglioni et al., (2000) indicated that children who were overweight at 5 years old had a higher percentage intake of protein at 1 years old than non-overweight children (p=0.024). Skinner et al., (2004) observed that mean protein intake (which was recorded between 2 and 8 years of age) was positively associated with children's BMI at 8 years of age. Gunther et al., 2007 observed that higher animal protein intake at 12 months was associated with a higher BMI at 7 years of age (p=0.03), and a higher dairy protein intake at 12 months was associated with a higher BMI at 7 years of age (p=0.02). This may explain our null relationship between protein intake at 4 years and BMI at 6 years of age.

To date, most studies assessing dietary fat composition and body fatness have focused on adults. In this population, saturated fatty acids, and polyunsaturated fatty acids are positively associated with the prevalence of obesity as well (Moussavi et al., 2007). It has also been found that the risk of obesity increased when populations shifted their diets from a high intake of monounsaturated fat to polyunsaturated fat (Moussavi et al., 2007). In our study, linolenic acid, an essential polyunsaturated fat required for normal growth and development, was significantly associated with overweight at 4 years, and BMI at 4 and 6 years. The relationship however, was positive, indicating that linolenic acid intake is higher among those who are overweight/obese or have a higher BMI. This finding is in line with a study conducted in adults which found that polyunsaturated fatty acids are positively associated with the prevalence of obesity as mentioned above (Moussavi et al., 2007). A study conducted by

Gazzaniga and Burns (1993) indicates that percentage of body fat was positively correlated with intakes of total ($p<0.001$), saturated total ($p<0.001$), monounsaturated total ($p<0.00001$), and polyunsaturated total ($p<0.01$) fatty acids in children. This suggests that diet composition does play a role in childhood obesity. This study focused on children 9-11 years of age and measured body fatness, an indicator of BMI, with tricep skinfold thickness measures. Thus, obese children tend to consume significantly more dietary fat, and fewer carbohydrates than non-obese children (Gazzaniga and Burns, 1993). Gillis et al., (2006) also found that obese children consume significantly higher total fat (in grams) and saturated fatty acids (in grams) than non-obese children. Therefore, our finding that overweight children consume a significantly greater percentage of saturated fat and linolenic acid was not surprising since overweight children consume significantly more total dietary fat overall.

Despite the findings mentioned above, studies have also found no significant difference between macronutrient intake (protein, fat, carbohydrates) and obesity in children (Grant et al., 2004, Magarey et al., 2001) or percentage of body fatness (Atkin and Davies., 2000). In a longitudinal study conducted by Magarey et al., (2001) no relationship was observed between any energy-adjusted macronutrient intakes (protein, fat, carbohydrates) at previous ages and BMI at subsequent ages (across 2-15 years of age). Thus, the relationship between specific macronutrient consumption and overweight in children is certainly not clear.

Additionally, our study aimed to examine and compare the diets of normal and overweight/obese children according to the new DRI standards set by Health Canada. A similar Canadian study conducted by Gillis and Gillis (2005) also compared the micronutrient intake of obese and non-obese children according to the Dietary References standards. They found that obese and non-obese children had very similar inadequate intake of vitamin E, magnesium, calcium and vitamin D (Gillis and Gillis, 2005). These findings suggest that despite the higher energy intake of obese children, they are not meeting all their micronutrient needs. Gillis and Gillis (2005) compared the prevalence of inadequate nutrient consumption in obese and non-obese children for energy and the following macro/micronutrients: fat, vitamin A, thiamin, riboflavin, niacin, vitamin B_6, vitamin B_{12}, folate, vitamin C, vitamin D, vitamin E, calcium, iron, magnesium, phosphorous and zinc. A significant difference was present between obese and non-obese children in terms of total dietary energy intake ($p<0.0001$) and fat ($p<0.0001$) intake. They found that obese children consumed about 24% more energy then they needed (124% of their estimated need of energy in total), where 32% of this energy was from fat consumption. Of the micronutrients assessed, a significant difference was present between obese and non-obese children for vitamin E and iron, with inadequacy of these micronutrients being more common among non-obese children. Generally, vitamin E levels tend to be lower in obese subjects since they consume packaged and processed foods more readily (Kljno et al., 1998; Desci and Molnar, 1997). Vitamin E in these foods tends to be destroyed during the processing of these unhealthy foods (Murphy et al., 1990). This study supports our finding that a difference exists in iron (mg) ($p=<0.0001$) consumption between normal weight and overweight/obese children. However, in contrast to Gillis and Gillis (2005), we found a significant difference in phosphorous (mg) ($p=0.0214$) intake between children of normal weight in comparison to children who are overweight/obese. Also, our study found that children who are overweight/obese are more likely to meet the DRI requirement for linolenic acid (mg) (58.67%), phosphorous (mg) (92.42%) and iron (mg) (60.18%) in comparison to children of normal weight. This is most likely due to the fact that obese children tend to consume more energy, and thus are more likely to consume foods with these micronutrients, such as meat products. Almost all the children in our study (whether overweight/obese or normal weight) meet the DRI recommendations for magnesium, vitamin A, vitamin B12, and vitamin C. Thus, no significant difference between the two groups was present. Gillis and Gillis (2005) also found no significant differences between these same nutrients among obese and non-obese children.

A very interested finding of this study is that no child, whether overweight/obese or normal weight, met the requirement for fiber intake (25mg/day). This is a very important finding since fiber can play a role in the prevention of constipation (Kimm 1995; Loening-Baucke et al., 2004; Vitolo et al., 2007), diabetes, cardiovascular diseases, hiatus hernia, colon cancer and obesity (Vitolo et al., 2007). Dietary recommended intakes (DRI) estimated by Health Canada are based on both dietary and functional fibers (Health Canada, 2006). Most high fiber sources include whole grain products, fruits and vegetables. Studies have found that children unlikely to meet the DRI for fiber include older children compared to younger children, and girls compared to boys (Kranz, 2006; Vitolo et al., 2007), and children from low and medium incomes families (Kranz, 2006). Vitolo et al., (2007) found that the factors associated with low intake of fiber among boys were non-habitual consumption of bean, and excessive fat intake (Vitolo et al., 2007). They also found that the factors associated with low intake of fiber among girls were increased age, non-habitual consumption of beans, excessive fat intake, dieting for weight loss and presence of overweight (Vitolo et al., 2007). Dietary fiber is also used as an indicator of diet quality (Biltoft-Jensen et al., 2008). The Child Health Center from the American Health Foundation recommends that children older than 2 years increase their dietary fiber intake equal to their current age plus 5g/day (Hampl et al., 1998; Williams et al., 2005). This recommendation is significantly lower than the 25g/day recommended by Health Canada. Therefore, the higher Canadian recommendation for daily intake of fiber may have contributed to the finding that no child in our study met the requirement for this nutrient.

6.4 Strengths

To our knowledge, this is one of the first Canadian studies to compare diets of children that are overweight/obese and normal weight (while taking into account the most recent dietary reference standards). This study also includes a large representative sample of children with a broad range of variables collected longitudinally. In our analyses, we controlled for energy intake and various other confounders associated with BMI as well. Furthermore, the children in the sample are all of the same age, and height and weight at 4 and 6 years of age were measured by a trained nutritionist rather than self-reported. We used data compiled and managed by Santé Québec, which is considered to be of high quality.

All the statistical tests conducted in this study were weighed using survey weights provided by Santé Québec. This allows us to account for non-responses. None of the final models contained highly influential data points that could potentially skew the final results. Additionally, the adequacy of fit was assessed for all final models. Lastly, to allow for comparisons with other studies, we used the most common definitions of childhood overweight/obesity used in literature today (Chinn, 2006).

6.5 Limitations

The limitations of our study include cross-sectional nutrition data, which describes only one time point. It would be ideal to have information about dietary intake at more than one time point; however, the Québec Longitudinal Study of Child Development did not collect this information. Despite this limitation, a relationship can still be observed if present and will be suggestive of a causal relationship. In order to overcome the limitations of cross-sectional data, we choose to correlate food intake with change in BMI, particularly, to determine whether diet at 4 years of age will predict weight change. BMI change in a longitudinal analysis is aimed to measure weight gain or loss. If certain modifiable variables predict weight gain, these variables can be explored as tools to improve health. However, it is important to note that this analysis is not a standard longitudinal study since the exposure variables (dietary factors) is only measured at one age. Even though we cannot infer causation due to the nature of the variables used for this study, this type of design does provide robust evidence for the case of causation.

Additionally, the primary outcome of interest in this study is BMI (in percentiles based on the 2000 CDC growth charts). Although BMI is not a good measure of body fat percent, it is an acceptable measure of body weight. 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), or bioelectrical impedance analysis (BIA); however, these methods are costly and unsuitable for large children studies (Lobsetin et al., 2004; Lobstein and Leach, 2007.) Body mass index (BMI) is the most practical indirect measure of body fatness and is most commonly used for population-based studies. At the individual level, BMI may not accurately measure body fatness in people that are muscular, short, tall, or those of old age with degenerative muscle loss. BMI, however, is considered by the World Health Organization as the most useful population-level measure of obesity in adults and in children when taking into account age and sex.

The exposure of interest in this study, children's dietary intake, is based on the parent deemed most knowledgeable of the child, generally the mother. All self-reported survey data involves some error in reporting. Therefore, there is the possibility of reporting and misclassification bias, which affects the internal validity of the study.

Physical inactivity is a well-known risk factor for childhood obesity. The importance of exercise is considerable since weight status is heavily dependent on both energy input and output. Information regarding exercise is present in the database for each year of the study starting at 6 years of age. Thus, we included this variable as a potential confounder in our regression analyses. However, physical activity was assessed by the perception of the mother. Mothers were asked how the level of physical activity of their child compared to other children. This measure of physical activity is subjective and does not indicate the frequency or the intensity of physical activity of each child. Since the measure of physical activity in this study was only present at 6 years of age, physical activity could not be controlled for in the cross-sectional models when the child was 4 years of age. Additionally, this variable contained a lot of missing data (32.97%) and was a significant covariate in only 3 of the 14 final models created. Thus, a better measure of physical activity may have more appropriately controlled for this potential confounder.

Lastly, the adjusted R^2s for the final linear regression models ranged between0.0001 - 0.1873. These values are quite small and indicate that the independent variables do not account for much of the model fit. Additionally, the measure of baseline weight was only 2 years earlier than the year in which diet intake was assessed. Also, a change in weight was assessed at 6 years, only a two-year difference from when diet intake was recorded as well. Previous studies have used a larger time difference to assess the relationship between diet intake and weight change (see literature review, Table 3.2 and 3.3).

6.6 Conclusion

The ever-growing epidemic of obesity has imposed a direct and indirect economic burden on the health-care system of Canada (Katzmarzyk & Janssen, 2004; Lobstein et al., 2004; Wolf & Colditz, 1998; Wolf, 1998). Direct medical costs include diagnostic and treatment services related to the disease and the complications associated with it (Lobstein et al., 2004). Indirect costs are related to the morbidity and mortality associated with obesity (Lobstein et al., 2004). This includes lost economic productivity as a result of absentee due to illness and premature death (Lobstein et al., 2004). In children, indirect costs result from school absentee, changes to goods and services provides by schools and low employee attendance of a caregiver with a child with obesity-related medical expenditures (Lobstein et al., 2004).

These findings will help promote new research to improve nutrition as a means of preventing overweight/obesity in childhood and reducing present and future health-care costs over time. New research can also focus on assessing the efficacy of good quality diets, particularly, types of macronutrients and micronutrients, in the prevention and treatment of childhood obesity. Prevention and management of obesity, at the individual level and population level, is necessary to control the growing prevalence of this epidemic. Changes at the individual level include interventions in obesogenic home environments by diet and exercise modifications (Lobstein et al., 2004), a reduction in television and video viewing time particularly during meals (Henry, 2004; Robinson, 1999), and preventing breakfast skipping among children (Dubois et al., 2007). Prevention at the population level include changes to neighbourhood design to encourage safe physical play (Sakkis, 2000), the development of health-promoting policies implemented in school vending machines (French et al., 2001) and cafeterias (Ellison et al., 1989; Ellison et al., 1990; Hoeslcher et al., 2004), educating children in school about healthy food choices and the long-term effects of poor food choices (Lobstein et al., 2004), educating school cafeteria workers on improving school nutrition standards (Hoeslcher et al., 2004), targeting food advertising aimed at encouraging poor food choices among children (Lobstein et al., 2004) and encouraging primary care givers to participate in the development of programs aimed to education the parent's of child with this disease (Lobstein et al., 2004). Public education or private counseling of patients should focus on decreasing intakes of these low-quality carbohydrates and fats as a mean of improving health and weight control.

Since obesity is a risk factor for numerous chronic diseases this study presents an attractive public health possibility in terms of chronic disease prevention. Additionally, by examining the association between socioeconomic determinants of obesity and poor diet quality, this study provides further knowledge of the health inequalities present in today's society. Future research can focus on the development of the most cost-effective and sustainable strategies aimed at mitigating the spread of this epidemic. Thus, by determining ways to reduce the prevalence of obesity and prevent its progression into adulthood, we can in return reduce the prevalence of chronic disease associated with this condition and improve population health as a whole.

Appendix A- MEDLINE search strategy

Database: Ovid MEDLINE(R) In-Process & Other Non-Indexed Citations and Ovid MEDLINE(R) <1950 to Present>
Search Strategy:

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1 Dietary Carbohydrates/ (19278)
2 dietary fats/ or cholesterol, dietary/ or dietary fats, unsaturated/ (45075)
3 exp Dietary Proteins/ (69510)
4 Energy Intake/ (25083)
5 Dairy Products/ (3638)
6 Cereals/ (9734)
7 food/ or dietary fiber/ or fruit/ or meat/ or vegetables/ (72930)
8 or/1-7 (209006)
9 Obesity/ (90717)
10 body weight changes/ or overweight/ (4763)
11 body mass index/ (51360)
12 9 or 10 or 11 (126160)
13 8 and 12 (11959)
14 limit 13 to (English language and yr="2000 -Current" and ("preschool child (2 to 5 years)" or "child (6 to 12 years)")) (936)

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Appendix B: Assessing the impact of excluding children with missing covariate values

Model # 1 'With' Analysis at 4 years: Nutrition predictor variables (in quintiles) in association with overweight/obesity

Table 41: Adjusted† odds ratios£ and 95% confidence intervals for overweight/obesity at 4 years, according to nutrition predictor variables (in quintiles) for model # 1

Model 1: Nutritional predictor variables and covariates (adjusted for potential confounders)

Variable	Adjusted ORξ	95% CIξ
Energy (in kilocalories)		
Quintile 1 ‡	1.000	--
Quintile 2	2.110	1.065-4.181*
Quintile 3	3.239	1.570-6.682*
Quintile 4	2.505	1.138-5.513*
Quintile 5	6.045	2.617-13.960*
Linoleic acid (grams)		
Quintile 1 ‡	1.000	--
Quintile 2	0.936	0.504-1.740
Quintile 3	0.435	0.215-0.881*
Quintile 4	0.539	0.269-1.080
Quintile 5	0.525	0.247-1.118
Linolenic acid (grams)		
Quintile 1 ‡	1.000	--
Quintile 2	3.956	1.877-8.337*
Quintile 3	3.389	1.503-7.639*
Quintile 4	5.210	2.287-11.871*
Quintile 5	8.674	3.651-20.610*
Total saturated fats (grams)		
Quintile 1 ‡	1.000	--
Quintile 2	1.171	0.659-2.083
Quintile 3	0.607	0.316-1.166

Quintile 4	0.423	0.217-0.822*
Quintile 5	0.479	0.237-0.969*
Sex of child		
Female‡	1.000	--
Male	1.535	1.103-2.135*
Category of birth weight		
<2.5kg ‡	1.00	--
≥2.5kg to ≤4kg	0.513	0.243-1.081
>4kg	0.713	0.306-1.660
Initial BMI of child at 2 years		
Normal weight ‡	1.000	--
Overweight	2.851	1.802-4.510*
Obese	4.210	2.787-6.359*
Missing	1.641	0.896-3.005
Mother overweight or obese (BMI ≥ 25kg/m^2)		
No ‡	1.000	--
Yes	2.311	1.631-3.274*
Missing	1.045	0.361-3.029

*Significantly different from the reference category (p≤ 0 05)
† Adjusted for all variables in the model as well as covariates
‡ Reference category
ξ OR, odds ratio, CI, confidence interval
£ Weighted data

Model # 2 'With' Analysis at 6 years: Nutrition predictor variables (in quintiles) in association with overweight/obesity

Table 42: Adjusted† odds ratios£ and 95% confidence intervals for nutrition predictor variables (in quintiles) according to overweight/obesity at 6 years		
Model 2: Nutritional predictor variables and covariates (adjusted for potential confounders)		
Variable	**Adjusted ORξ**	**95% CIξ**
Energy (in kilocalories)		
Quintile 1 ‡	1 000	--
Quintile 2	0 692	0 351-1 366
Quintile 3	0 948	0 491-1 830
Quintile 4	0 807	0 410-1 591
Quintile 5	1 330	0 676-2 618
Linolenic acid (grams)		
Quintile 1 ‡	1 000	--
Quintile 2	1 814	0 908-3 627
Quintile 3	1 623	0 755-3 487
Quintile 4	2 444	1 183 5 048*
Quintile 5	3 260	1 569-6 774*
Saturated fat (as a % of total energy)		
Quintile 1 ‡	1 000	--
Quintile 2	0 454	0 248 0 831*
Quintile 3	0 662	0 378-1 158
Quintile 4	0 692	0 396-1 211
Quintile 5	0 450	0 249-0 812*
Initial BMI of child at 2 years		
Normal weight ‡	1 000	--
Overweight	2 878	1 670-4 960*
Obese	3 203	1 957 5 242*
Missing	1 463	0 754-2 842
Mother's immigrant status		

No‡	1.000	--
Yes	2.500	1.441-4.337*
Mother overweight or obese (BMI ≥ 25kg/m²)		
No ‡	1.000	--
Yes	1.755	1.179-2.613*
Missing	0.940	0.189-4.671
Household annual income		
Less than $30,000 ‡	1.000	--
$30,000-$49,999	0.649	0.348-1.209
$50,000-$79,999	0.504	0.267-0.953*
$80,000-more	0.401	0.219-0.734*
Missing	<0.001	<0.001->999.999^

*Significantly different from the reference category ($p \leq 0.05$)
† Adjusted for all variables in the model as well as covariates
‡ Reference category
ξ OR, odds ratio, CI, confidence interval
£ Weighted data
^ No missing data present for overweight/obese children, just those that are of normal weight, result can be incorrect

Model # 3 'With' Analysis at 4 years: Nutrition predictor variables (continuous) in association with overweight/obesity

Table 43: Adjusted† odds ratios£ and 95% confidence intervals for overweight/obesity at 4 years, according to nutritional predictor variables (continuous)		
Model 3: Nutritional predictor variables and covariates (adjusted for potential confounders)		
Variable	**Adjusted ORξ**	**95% CIξ**
Energy (in kilocalories)	1.002	1.001-1.004
Linolenic acid (grams)	7.886	3.650-17.039*
Total lipid intake (grams)	0.955	0.928-0.982*
Sex of child		
Female‡	1.000	--
Male	1.929	1.380-2.698*
Category of birth weight		
<2 5kg ‡	1.000	--
≥2 5kg to ≤4kg	0.462	0.226-0.944*
>4kg	0.682	0.302-1.537
Initial BMI of child at 2 years		
Normal weight ‡	1.000	--
Overweight	2.929	1.872-4.582*
Obese	4.150	2.773-6.209*
Missing	1.608	0.874-2.959
Mother overweight or obese (BMI ≥ 25kg/m²)		
No ‡	1.000	--
Yes	2.219	1.581-3.114*
Missing	1.076	0.369-3.134

*Significantly different from the reference category ($p \leq 0\ 05$)
† Adjusted for all variables in the model as well as covariates
‡ Reference category
ξ OR, odds ratio, CI, confidence interval
£ Weighted data

Model # 4 'With' Analysis at 6 years: Nutrition predictor variables (continuous) in association with overweight/obesity

Table 44: Adjusted† odds ratios£ and 95% confidence intervals for overweight/obesity at 6 years, according to nutritional predictor variables (continuous) for Model #4		
Model 4: Nutritional predictor variables and covariates (adjusted for potential confounders)		
Variable	**Adjusted ORξ**	**95% CIξ**
Energy (in kilocalories)	1.001	1.000-1.003
Linolenic acid (grams)	5.604	2.293-13.698
Total lipid intake (grams)	0.965	0.934-0.997*
Initial BMI of child at 2 years		
Normal weight ‡	1.000	--
Overweight	2.604	1.527-4.440*
Obese	3.263	2.016-5.282*
Missing	1.524	0.793-2.928
Mother's immigrant status		
No ‡	1.000	--
Yes	2.217	1.291-3.807*
Mother overweight or obese (BMI ≥ 25kg/m^2)		
No ‡	1.000	--
Yes	1.841	1.247-2.720*
Missing	1.023	0.208-5.036
Household annual income		
Less than $30,000 ‡	1.000	--
$30,000-$49,999	0.644	0.350-1.185
$50,000-$79,999	0.482	0.259-0.897*
$80,000-more	0.379	0.209-0.684*
Missing	<0.001	<0.001->999.999^

*Significantly different from the reference category (p≤ 0 05)
† Adjusted for all variables in the model as well as covariates
‡ Reference category
ξ OR, odds ratio, CI, confidence interval , £ Weighted data
^ No missing data present for overweight/obese children, just those that are of normal weight, result can be incorrect

Model # 5 'With' Analysis at 4 years: Food groups (according to Canada's Food Guide) in association with overweight/obesity

Table 45: Adjusted† odds ratios£ and 95% confidence intervals for overweight/obesity at 4 years, according to food groups for model #3		
Model 5: Nutritional predictor variables and covariates (adjusted for potential confounders)		
Variable	**Adjusted ORξ**	**95% CIξ**
Energy (in kilocalories)		
Quintile 1 ‡	1.000	--
Quintile 2	1.637	0.872-3.075
Quintile 3	1.91	1.044-3.518*
Quintile 4	1.339	0.714-2.508
Quintile 5	2.817	1.550-5.123*
Grain Products		
< 4 servings /day ‡	1.000	--
≥ 4 servings/day	2.659	1.795-3.937*
Sex of child		
Female ‡	1.000	--
Male	2.045	1.436-2.911*
Category of birth weight		
<2.5kg ‡	1.000	--
≥2.5kg to ≤4kg	0.461	0.224-0.947*
>4kg	0.762	0.337-1.721
Initial BMI of child at 2 years		
Normal weight ‡	1.000	--
Overweight	3.072	1.955-4.827*
Obese	4.136	2.766-6.186*
Missing	2.004	1.107-3.627*
Mother overweight or obese (BMI ≥ 25kg/m^2)		
No ‡	1.000	--
Yes	2.138	1.524-2.998*

Missing	1.147	0.397-3.319

*Significantly different from the reference category (two-sided p≤ 0 05)
† Adjusted for all variables in the model as well as covariates
ǂ Reference category
ξ OR, odds ratio, CI, confidence interval, £ Weighted data

Model # 6 'With' Analysis at 6 years: Food groups (according to Canada's Food Guide) in association with overweight/obesity

Table 46: Adjusted† odds ratios£ and 95% confidence intervals for overweight/obesity at 6 years, according to food groups for Model #6		
Model 6: Food groups and covariates (adjusted for potential confounders)		
Variable	**Adjusted ORξ**	**95% CIξ**
Energy (in kilocalories)		
Quintile 1 ‡	1.000	--
Quintile 2	0.709	0.370-1.359
Quintile 3	0.999	0.537-1.858
Quintile 4	0.761	0.401-1.442
Quintile 5	1.350	0.738-2.470
Grain Products		
< 4 servings/day ‡	1.000	--
≥ 4 servings/day	2.444	1.613-3.704*
Initial BMI of child at 2 years		
Normal weight ‡	1.000	--
Overweight	2.706	1.58-4.65*
Obese	3.235	1.99-5.25*
Missing	1.672	0.88-3.19
Mother overweight or obese (BMI ≥ 25kg/m^2)		
No ‡	1.000	--
Yes	1.796	1.21-2.66*
Missing	1.227	0.25-5.97
Mother's immigrant status		
No ‡	1.000	--
Yes	0.406	0.238-0.691*
Household annual income		
Less than $30,000 ‡	1.000	--
$30,000-$49,999	0.684	0.372-1.257

$50,000-$79,999	0.468	0.252-0.867*
$80,000-more	0.362	0 201-0.651*
Missing	<0.001	<0.001->999.99

*Significantly different from the reference category (two-sided p≤ 0 05)
† Adjusted for all variables in the model as well as covariates
‡ Reference category
ξ OR, odds ratio, CI, confidence interval
£ Weighted data
^ No missing data present for overweight/obese children, just those that are of normal weight, result can be incorrect

Model # 7 'With' Analysis at 4 years: Nutrition predictor variables (quintiles were dichotomized) with BMI

Table 47: Multivariate linear regression† displaying association between nutrition predictor variables (quintiles were dichotomized) and BMI in children at 4 years (with relevant covariates)†				
Nutritional variable	**Category of variable**	**Beta Estimate**	**Standard error (SE)**	**P-value (Multivariate linear regression)**
Energy (in kilocalories)	Quintile 1-3 (high intake) ‡ Quintile 4-5 (low intake)	0.61	0.12	<0.0001*
Initial BMI of child at 2 years	Normal weight‡ Overweight/obese	-0.00057	0.00018	0.7513
Mother overweight or obese (BMI ≥ 25kg/m²)	Normal weight‡ Overweight/obese	-0.00025	0.00033	0.4543
Child care	Not in day-care‡ Outside of home/daycare centre	-0.0085	0.0010	0.4353
Chronic illness (excluding allergies, but including asthma) at age 6 years)	No‡ Yes	0.43	0.17	0.0101*
Total saturated fat (grams)	Quintile 1-3 (high intake) ‡ Quintile 4-5 (low intake)	0.15	0.11	0.1933
Linolenic acid (grams)	Quintile 1-3 (high intake) ‡ Quintile 4-5 (low intake)	0.23	0.11	0.0322*

*Significant difference present between nutrition predictor and BMI (p≤0 05)
† Weighted data
‡ Reference category of variable
Source Data courtesy of the Quebec Institute of Statistics, QLSCD 1998-2010

Model # 8 'With' Analysis at 6 years: Nutrition predictor variables (quintiles were dichotomized) with BMI

Table 48: Multivariate linear regression† displaying association between nutrition predictor variables (quintiles were dichotomized) and BMI in children at 6 years (with relevant covariates)†				
Nutritional variable	**Category of variable**	**Beta Estimate**	**Standard error (SE)**	**P-value (Multivariate linear regression)**
Energy (in kilocalories)	Quintile 1-3 (high intake) ‡ Quintile 4-5 (low intake)	1.69	0.46	0.006*
Initial BMI of child at 2 years	Normal weight‡ Overweight/obese	0.0019	0.00056	0.0008*
Level of physical activity at 6 years	Same/lower/much lower than other children‡ Higher/much than other children	-0.00020	0.00042	0.9635
Child care	Not in day-care‡ Outside of home/daycare centre	1.20	0.38	0.0022*
Mother's immigrant status	No‡ Yes	0.95	0.22	0.6598
Family structure	Intact‡ Recomposed/single parent	0.34	0.65	0.0459*
Total saturated fat (grams)	Quintile 1-3 (high intake) ‡ Quintile 4-5 (low intake)	0.16	0.47	0.036*
Linolenic acid (grams)	Quintile 1-3 (high intake) ‡ Quintile 4-5 (low intake)	0.47	0.42	0.020*

*Significant difference present between nutrition predictor and BMI ($p \leq 0.05$)
† Weighted data
‡ Reference category of variable
Source Data courtesy of the Québec Institute of Statistics, QLSCD 1998-2010

Model # 9 'With' Analysis at 4 years: Nutrition predictor variables (continuous) in association with BMI

Table 49: Multivariate linear regression† displaying association between nutrition predictor variables (continuous) and BMI in children at 4 years (with relevant covariates)†				
Nutritional variable	**Category of variable**	**Beta Estimate**	**Standard error (SE)**	**P-value (Multivariate linear regression)**
Energy (in kilocalories)	Quintile 1-3 (high intake) ‡ Quintile 4-5 (low intake)	0.0051	0.0014	0.0003*
Initial BMI of child at 2 years	Normal weight‡ Overweight/obese	0.000071	0.0018	0.68
Mother overweight or obese (BMI ≥ 25kg/m²)	Normal weight‡ Overweight/obese	0.0028	0.0024	0.2363
Total protein intake (grams)	Quintile 1-3 (high intake) ‡ Quintile 4-5 (low intake)	0.033	0.0081	<0.0001*
Total saturated fat (grams)	Quintile 1-3 (high intake) ‡ Quintile 4-5 (low intake)	0.040	0.016	0.0092*
Total carbohydrate intake (grams)	Quintile 1-3 (high intake) ‡ Quintile 4-5 (low intake)	1.20	0.25	<0.0001*
Linolenic acid (grams)	Quintile 1-3 (high intake) ‡ Quintile 4-5 (low intake)	1.21	0.25	<0.0001*
Total carbohydrate intake (grams) x Mother overweight or obese	Interaction	0.00015	0.00011	0.019*

*Significant difference present between nutrition predictor and BMI (p≤0 05)
† Weighted data
‡ Reference category of variable
Source Data courtesy of the Québec Institute of Statistics, QLSCD 1998-2010

Model # 10 'With' Analysis at 6 years: Nutrition predictor variables (continuous) in association with BMI

Table 50: Multivariate linear regression† displaying association between nutrition predictor variables (continuous) and BMI in children at 4 years (with relevant covariates)†				
Nutritional variable	**Category of variable**	**Beta Estimate**	**Standard error (SE)**	**P-value (Multivariate linear regression)**
Energy (in kilocalories)	Quintile 1-3 (high intake) ‡ Quintile 4-5 (low intake)	0.0023	0.0039	0.035*
Initial BMI of child at 2 years	Normal weight‡ Overweight/obese	-0.0096	0.0042	0.228
Mother overweight or obese (BMI ≥ 25kg/m²)	Normal weight‡ Overweight/obese	0.0027	0.0014	0.0494*
Mother's immigrant status	No ‡ Yes (an immigrant)	0.43	0.58	0.4455
Level of physical activity at 6 years	Same/lower/much lower than other children‡ Higher/much than other children	0.00012	0.00041	0.774
Child care	Not in day-care‡ Outside of home/daycare centre	1.24	0.37	0.0012*
Family structure	Intact‡ Recomposed/single parent	1.31	0.59	0.029*
Total carbohydrate intake (grams)	Quintile 1-3 (high intake) ‡ Quintile 4-5 (low intake)	0.026	0.14	0.8535
Linolenic acid (grams)	Quintile 1-3 (high intake) ‡ Quintile 4-5 (low	2.03	1.21	0.0476*

	intake)			
Total carbohydrate intake (grams) x Initial BMI of child at 2 years	Interaction	0.00051	0.0018	0.0056*

*Significant difference present between nutrition predictor and BMI ($p \leq 0.05$)
† Weighted data
‡ Reference category of variable
Source Data courtesy of the Québec Institute of Statistics, QLSCD 1998-2010

Model # 11 'With' Analysis at 4 years: Food groups (in categories according in Canada's Food Guide) in association with BMI

Table 28: Multivariate linear regression† displaying association between food groups and BMI in children at 4 years (with relevant covariates)†				
Nutritional variable	**Category of variable**	**Beta Estimate**	**Standard error (SE)**	**P-value (Multivariate linear regression)**
Energy (in kilocalories)	Quintile 1-3 (high intake) ‡ Quintile 4-5 (low intake)	0.0010	0.00021	<0.0001*
Initial BMI of child at 2 years	Normal weight‡ Overweight/obese	-0.0011	0.00018	0.5134
Mother overweight or obese (BMI ≥ 25kg/m²)	Normal weight‡ Overweight/obese	0.0011	0.0045	0.183
Meats and alternatives	0-2 serving ‡ ≥ 2 servings	0.00038	0.10	0.9970
Grain products	<4 servings/day‡ ≥ 4 servings/day	0.35	0.11	0.0009*
Meats and alternatives x Mother overweight or obese	Interaction	0.0014	0.00068	0.0369*

*Significant difference present between nutrition predictor and BMI (p≤0 05)
† Weighted data
‡ Reference category of variable
Source Data courtesy of the Québec Institute of Statistics, QLSCD 1998-2010

Model # 12 'With' Analysis at 6 years: Food groups (in categories according in Canada's Food Guide) in association with BMI

Table 29: Multivariate linear regression† displaying association between food groups and BMI in children at 6 years (with relevant covariates)†

Nutritional variable	Category of variable	Beta Estimate	Standard error (SE)	P-value (Multivariate linear regression)
Energy (in kilocalories)	Quintile 1-3 (high intake) ‡ Quintile 4-5 (low intake)	0.0017	0.00070	0.0198*
Level of physical activity at 6 years	Same/lower/much lower than other children‡ Higher/much than other children	0.00031	0.00042	0.4566
Child care	Not in day-care‡ Outside of home/daycare centre	1.41	0.37	0.0002*
Mother's immigrant status	No ‡ Yes (an immigrant)	0.17	0.53	0.7533
Mother overweight or obese (BMI ≥ 25kg/m²)	Normal weight‡ Overweight/obese	0.0019	0.0014	0.1803
Family structure	Intact‡ Recomposed/single parent	0.98	0.57	0.090*
Grain products	<4 servings/day‡ ≥ 4 servings/day	0.89	0.41	0.0351*

*Significant difference present between nutrition predictor and BMI (p≤0 05)
† Weighted data
‡ Reference category of variable
Source Data courtesy of the Québec Institute of Statistics, QLSCD 1998-2010

Appendix C: Authorization to use copyright material for "Table 1. International BMI Classification According to IOTF Standards Based on Sex and Age for Children Between 2-18 Years" --(*Paste of email communication*)

From: Tim Cole <tim.cole@ich.ucl.ac.uk>
To: Lilly Yonadam <lyona060@uottawa.ca>

Date: Wed, Jul 28, 2010 at 5:37 AM
Subject Re: Requesting permission to use copyright material (urgent request, please)

Dear Lilly,

I am happy to give you permission to reproduce Table 2 of my BMJ 2000 paper in your Master's thesis.

Best wishes,
Tim Cole

From: Lilly Yonadam <lyona060@uottawa.ca>
To: tim.cole@ich.ucl.ac.uk

Date: Tue, Jul 27, 2010 at 4:05 PM
Subject: Requesting permission to use copyright material (urgent request, please)
mailed-bygmail.com

Dear Dr. Cole,

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 Table 2 (Table 2. International cut off points for body mass index for overweight and obesity by sex between 2 and 18 years, defined to pass through body mass index of 25 and 30 kg/m2 at age 18, obtained by averaging data from Brazil, Great Britain, Hong Kong, Netherlands, Singapore, and United States) from your article:

Cole TJ, Bellisi C, Flegal KM, Dietz WH. Establishing a standard definition for child overweight and obesity worldwide: International survey. BMJ 2000; 320:1240-1243.

My Master's Thesis is entitled: "Diet quality and body mass index in 4and 6 year old children: a prospective study using data from the Quebec Longitudinal Study of Child Development". The table would be included as part of my literature review. 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 table 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 table into my Thesis?
My name and contact information is:

Lilianna Yonadam
Institute of Population Health (University of Ottawa)
1 Stewart St., suite 304
Ottawa, ON K1N 6N5
Canada
Tel: 1-(613)-562-5800 ext. 2712
Email:lyona060@uottawa.ca

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

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