University of Alberta

Determinants and Consequences of Childhood Overweight in Canada

by

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Abstract

The prevalence of childhood obesity has increased dramatically over the last three decades in Canada with substantial consequences for the physical, mental, and economic wellbeing of the population. The overarching objective of this thesis was to examine the various aspects of childhood obesity in Canada, from prevalence trends and risk factors to economic and medical consequences. A systematic review (Objective 1) showed that the prevalence of childhood obesity in Canada has tripled since 1980. Using a prediction model (Objective 2), I demonstrated that the prevalence of overweight and obesity will further increase by 10% over the next 15 years if current trends continue unabated. An analysis of a population-based survey data among Grade 5 students in Nova Scotia linked with a perinatal database (Objective 3) showed that perinatal factors (large-for-gestational age, maternal pre-pregnancy weight) play an important role in the development of childhood overweight. Calculating the population attributable risk fractions for these risk factors (Objective 4), I was able to show that excess screen time and maternal pre-pregnancy weight offer the largest potential for prevention. Our analysis of the health care costs associated with childhood obesity (Objective 5) found that the obese children incurred 21% higher costs than normal weight children. Using data from the Canadian Health Measures Survey (Objective 6) I showed that the higher

health care use is paralleled by a more frequent use of prescription medications in obese compared to normal weight children. An analysis of the medical reasons for this cost differential (Objective 7) found that obese children had higher health care utilization for internalizing disorders, asthma, other respiratory disorders, obesity, and chronic adenoid/tonsil disorder. I was further able to show, for the first time, that childhood obesity is strongly associated with otitis media (Objective 8), one of the most frequent childhood disorders. In our analysis of the diagnostic properties of an ICD code for obesity for the detection of measured obesity (Objective 9), the sensitivity was 10%. Children correctly identified as obese by an ICD code had a higher BMI and higher health care utilization.

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Abbreviations

AGA	Appropriate for gestational age
BMI	Body Mass Index
C$	Canadian Dollar
CAHPERD	Canadian Association for Health, Physical Education, Recreation and Dance
CCHS	Canadian Community Health Survey
CDC	Centers for Disease Control and Prevention
CFS	Canadian Fitness Survey
CHMS	Canadian Health Measures Survey
CI	Confidence interval
CIHI DAD	Canadian Institute for Health Information Discharge Abstract Database
CLASS	Children's Lifestyle and School Performance Study
ELEMQ	Longitudinal Study of Kindergarten Children in Quebec
GSS	General Social Survey
HSBC	Health Behaviour in School-Aged Children Study
ICD	International Classification of Diseases
IOTF	International Obesity Task Force
LGA	Large for gestational age
MEPS	Medical Expenditure Panel Survey
MSI	Medical Services Insurance
NHANES	National Health and Nutrition Examination Survey
NLSCY	National Longitudinal Survey of Children and Youth
NPHS	National Population Health Survey
NSAPD	Nova Scotia Atlee Perinatal Database
OHS	Ontario Health Survey
OR	Odds Ratio
PACY	Physical Activity and Dietary Intake of Children and Youth
PARF	Population-attributable risk fraction
PUMF	Public Use Microdata File
QCAHS	Quebec Child and Adolescent Health and Social Survey
QLSCD	Quebec Longitudinal Study of Child Development
REAL Kids	Raising Health Eating and Active Living Kids
SES	Socioeconomic status
SGA	Small for gestational age
SNAP	School Nutrition and Activity Project
Web-SPAN	Web-Survey of Physical Activity and Nutrition
YAQ	Youth/Adolescent Food Frequency Questionnaire

1 Introduction

The prevalence of overweight and obesity has increased dramatically over the last two decades in the Western hemisphere as well as in developing countries [1–3]. Obesity has been identified by the WHO as a global epidemic and the greatest threat to public health in developed countries [4]. While lifestyle behaviors of the individual are important determinants for the development of overweight and obesity, the critical role of an *"obesogenic environment"* that promotes unhealthy lifestyle behaviors is undeniable [5].The increasing prevalence of obesity leads to dramatic consequences both for the health and the economic wellbeing of the population: Obesity is a risk factor for many chronic diseases, such as type 2 diabetes mellitus, cardiovascular disease, sleep disorders, and some forms of cancer [6]. The rising disease burden will result in decreased life expectancy [7] and put further stress on the ailing health care systems in many Western countries [8].

The obesity epidemic affects all age groups and children are no exception. While overweight and obesity rates in children are still less frequent than in adults, the prevalence has increased considerably over the last three decades [9]. Overweight and obesity in children are of particular concern for a number of reasons: Obesity tracks throughout childhood and many obese children become obese adults [10, 11]. The earlier onset of obesity in turn will lead to an earlier onset of complications of obesity with a longer and more severe disease burden. Finally, the unfavorable lifestyle habits that these children learnt from early on will be passed on to their children, thereby perpetuating the epidemic.

The overarching objective of this thesis was to further our understanding of the childhood obesity epidemic in Canada. After a short summary of the current state of the evidence, the objectives of the current research are introduced. The core of this manuscript-based thesis consists of nine independent papers that investigate past, present, and future disease burden, associated risk factors as well as medical and economic consequences of the childhood obesity epidemic in Canada. The final chapter of the thesis discusses the findings and their implications, highlights strengths and limitations of the presented research, and provides suggestions for further research in the area.

1.1 The prevalence of childhood overweight and obesity in Canada

In Canada, the combined prevalence of overweight and obesity in children between 2 and 17 years was 26% in 2004/2005 [9] which corresponds to a twofold increase compared to the prevalence in the 1981 Canada Fitness Survey [12]. Even more alarming, obesity rates in Canadian children have tripled since 1981 [9]. The most recent figures based on physical measurements from a nationally representative survey for the prevalence of overweight and obesity are 17 and 9%, respectively [13]. However, that survey (the Canadian Health Measures Survey 2007 to 2009) included a laboratory and fitness testing component that may have attracted a more motivated and healthy sample than the Canadian Community Health Survey and as a result, these numbers may be underestimates.

Overweight and obesity are slightly more common in boys than in girls (27 vs. 25%) but the increases in the prevalence over the last three decades have been similar for both sexes [9]. Considerable differences in the overweight and obesity prevalence exist across the provinces of Canada [14]: The lowest prevalences are found in Alberta (22%), Quebec (23%), and British Columbia (26%). The reasons for the low prevalence in these provinces are likely diverse and may include economic wealth, cultural differences, ethnic distribution and rural/urban ratio. At the other end of the spectrum are the Maritimes with Newfoundland (36%) and New Brunswick (34%) having the highest prevalence of overweight [14].

The social gradient that is seen for many health conditions [15–17] appears not to apply to childhood overweight and obesity: Children and adolescents from middle income households had a higher prevalence of overweight and obesity (28%) than those from low income households (25%) in the 2004/2005 Canadian Community Survey. Similar findings have recently been reported in the US [18]. This finding futher underlines the environmental nature of the obesity epidemic that transcends social classes and individual lifestyle behaviors. Differences can also be found between ethnic groups in Canada: 41% of aboriginal children living off-reserve are overweight or obese but only 18% of children of Southeast Asian or East Asian origin are overweight or obese [9].

1.2 Measurement of overweight and obesity

The ideal measure of overweight and obesity should have two properties: i) accurately measure the amount of body fat; and ii) predict adverse health outcomes.

There are several ways to measure the amount of body fat. The more accurate methods comprise densitometry (underwater weighing), magnetic resonance imaging or computer tomography, bioelectrical impedance, dual energy X-ray Absorptiometry (DXA), and hydrometry (deuterium dilution). These techniques share the major drawback that they are impractical for use outside a clinical setting, let alone for use in large epidemiological studies in children because of costs, compliance problems, or radiation exposure [19]. Among the simpler but less accurate methods to assess body fatness are the waist circumference, waist-to-hip ratio, skinfold thickness, and the body mass index (BMI).

Waist circumference is easily measured with a tape measure and has been shown to correlate well with intraabdominal fat mass and to predict health outcomes in adolescents and adults [20, 21]. Pediatric reference values are available for a number of populations [22–24]. A drawback of the method is the need to make intimate contact with the child, which makes waist measurement difficult to use in pediatric epidemiologic studies. A recent systematic review found no evidence that waist circumference is superior to BMI for diagnosing excess body fat in children [25]. Similar to waist circumference, the waist-to-hip ratio is readily obtained with a measuring tape. Several studies have shown that the waist-to-hip ratio can predict markers of metabolic syndrome and cardiovascular disease in children and adults but there is no clear evidence to support superiority of the waist-to-hip ratio over BMI [26–28].The same drawback as for waist circumference applies for use of the waist-to-hip ratio in pediatric epidemiologic studies. Measurement of skinfold thickness can also be used to predict body fatness. Skinfold thickness is commonly measured either at the arms, thighs, or trunk, and can therefore not assess visceral fat. Correlation of skinfolds measurement with metabolic disease markers is good [29, 30]. The measurements are easy to perform but inter- and intraobserver reliability are limited [31, 32]. Similar to the waist circumference and waist-to-hip ratio, the need to partially undress the child may make the method unacceptable for parents.

Despite some shortcomings [33, 34], the BMI (defined as body weight / height^2 [kg/cm^2]) has now been widely accepted as the most useful, albeit crude, population-level measure for overweight and obesity. The BMI is correlated with the amount of body fat [35] but cannot distinguish between central and peripheral obesity, or between fat and non-fat mass (muscles, bones). An advantage of the BMI is that height and weight can be readily measured in virtually any setting and can even be obtained by self or proxy report. Age- and gender-specific reference values for the BMI are available for many populations [36–38]. In Canada, the growth charts established by the US Centers for Disease Control and Prevention (CDC) [36], the WHO growth charts [37], and the age- and gender-specific reference values proposed by the International Obesity Task Force (IOTF) [38] are commonly used. The College of Family Physicians and the Canadian Pediatric Society recently issued a consensus statement to endorse the use of the WHO's growth curves instead of the CDC's growth charts in medical practice [39]. The WHO developed their growth charts from two data sources, namely the Multicentre Growth Reference Study (children $<$ 5 years of age) [40] and the National Health and Examination Survey (children 5 years and older) [37]. The WHO growth curves are considered "prescriptive", that is they provide a standard for the growth of a child under ideal conditions. By contrast, the CDC and IOTF growth charts are more "descriptive", i.e. are meant to provide a reference for national and international comparisons. The CDC growth curves were last updated in 2000 and are based on cross-sectional measurements of five national samples of US children [36]. Overweight and obesity are defined as a BMI above the 85^{th} and 95^{th} percentile for age and gender. Disadvantages of using this approach to define BMI cutoffs are that it is based on arbitrary statistical measures and that cutoffs will move upwards as the population gets heavier. The IOTF set out in 2000 to define an internationally applicable set of cutoffs for pediatric overweight and obesity by combining 6 large ($n > 10{,}000$) nationally representative surveys from Brazil, the UK, Hong Kong, the Netherlands, Singapore, and the United States [38]. Data for these surveys were collected in the 70s, 80s and early 90s before the prevalence of overweight surged. In contrast to the arbitrary $85/95^{th}$ percentile cutoffs used by the CDC growth curves, the BMI cutoff points used by the IOTF correspond to the adult cutoffs of 25 and 30 m/kg^2, which have been shown to correlate with health outcomes in adults [41, 42].

Prevalence estimates for childhood overweight and obesity may differ considerably depending on which reference is used. The IOTF cutoff points for obesity are generally higher than those of the WHO growth charts for all ages whereas the CDC and WHO obesity cutoffs are fairly similar. The cutoff points for overweight for the three references are overall closer than those for overweight. In boys, the CDC and IOTF cutoff points are about one BMI unit higher than the WHO cutoffs, while the cutoffs for girls are less than one BMI unit apart [43]. Therefore, using the WHO growth curves will result in a higher prevalence of overweight/obesity compared to using the IOTF or CDC cutoffs [43]. Application of the CDC cutoffs will lead to higher estimates for overweight/obesity in younger children and lower estimates for older children, respectively, relative to the IOTF cutoffs [44].

1.3 Risk Factors for Childhood Overweight and Obesity

Using Morris' Socioecological Model [45], the obesity epidemic can be conceptualized as a phenomenon that is determined by the interaction of personal behavior, external environmental, and host (biological) factors.

The two most important personal behavior factors (lifestyle factors) for the development of childhood obesity are the increased consumption of high-energy food both in terms of amount and frequency, and reduced physical activity [46–48]. Lifestyle is for a large part determined by socioeconomic status (SES). Children from lower SES families were found to have a higher risk for overweight and obesity compared to higher SES groups [9, 49]. This finding is readily explained by the observation that lower SES may limit the parents' and children's access to resources, knowledge of nutrition and health, food choices, and physical activity off-school.

Lifestyle choices in turn are influenced by the environment. Environmental factors favoring an 'obesogenic' lifestyle include technological development facilitating a sedentary lifestyle through e.g. an increased number of hours spent at the computer (both at work and during leisure time), watching TV or playing video games. Today, there is an increased availability of and easier access to elevators and escalators in workplaces, apartment buildings, and shopping malls. The urban sprawl has made it necessary for families to drive to work or school instead of walking or using the bicycle. The subsidization of agriculture has created food surpluses resulting in easier access to and lower prices for high calorie food [50]. These high-energy foods are marketed more aggressively today than two decades ago. A *"revolution in food preparation"* has enabled people to have more food options and to eat more meals during the day [51]. At the same time, there has been a considerable increase in food portion sizes [52]. Finally, a negative role model environment in the family, among peers or in the neighborhood will perpetuate the obesity trend [53].

The biological basis (*"host factors"*) for the development of overweight and obesity is a positive energy balance (i.e. energy intake exceeding energy expenditure) over a prolonged period of time. However, as outlined above, lifestyle and social-environmental factors have a significant impact on this biological factor. Other, albeit rare, biological factors include e.g. genetic polymorphisms or diseases associated with obesity such as Prader-Willi syndrome. Leptin, a hormone made by adipocytes for the regulation of body weight has also been implicated in the etiology of obesity [54]. The hypothesis of a genetic effect contributing to the development of obesity is supported by a number of sibling, twin and adoption studies [55–58]. However, the contribution of a genetic effect to the current obesity epidemic is likely small as the gene pool would not undergo dramatic changes within two decades. The association between birth weight and childhood or adult obesity has recently gained attention. Both high ($>$ 4,500 g or macrosomia) and low ($<$ 2,500 g) birth weight have been described as risk factors for later obesity [59–62]. It has been suggested that fetal hyperglycemia and hyperinsulinemia may alter the hypothalamic-pituitary-adrenal axis resulting in a postnatal hypothalamic dysregulation of appetite in former large-for-gestational age infants and infants of diabetic mothers [63, 64].

1.4 Obesity-Associated Health Problems

Childhood overweight and obesity negatively affect cognitive and social development, quality of life as well as physical health [65–67]. As a result, conditions such as type II diabetes mellitus, hypertension and hypercholesterolemia which were previously considered exclusively adult disorders are now seen with increasing frequency in children [68]. Other obesity-associated conditions in children may include polycystic ovary syndrome, gallstone formation, hepatic steatosis, asthma, sleep apnea, and psychological problems [68]. More importantly, childhood overweight and its associated conditions often persist into adulthood [69] which will result in an increased number of overweight-related conditions in adults such as cardiovascular disease, osteoarthritis and certain types of cancer. These disorders will in turn result in a considerable decrease in quality of life and life expectancy [70, 71]: Obesity at age 40 costs 7.1 years in women and 5.8 years in men [7].

1.5 Health Care Utilization and Economic Burden

Overweight and obese children use health care services more often than their normal weight peers [72–75]. Wijga et al. [76] found that obese children had more GP visits, missed school more often, and had more health-related limitations than their normal weight peers. Estimates of the cost of childhood overweight/obesity in Canada are not available. The direct annual costs of adult obesity in Canada have been estimated at $1.8 billion in 1997, corresponding to 2.7% of the total health care expenditures for all diseases [77]. Another study using 2001 data estimated the total costs at $4.3 billion ($1.6 billion of direct costs and $2.7 billion of indirect costs) [8]. A cost analysis in the US reported that the annual hospital costs for treatment of obesity and obesity-associated conditions in 6 to 17 year old children increased from $35 million (0.43% of total hospital costs) during 1979-1981 to $127 million (1.70% of total hospital costs) during 1997-1999 [78]. It is evident that the childhood onset of obesity will result in a longer burden of illness and thus an increased economic burden and health care utilization from obesity-related disorders.

1.6 Objectives

In this thesis, I will examine disease burden, risk factors as well as medical and economic consequences of childhood obesity in Canada. Specifically, I will investigate the following nine objectives:

Objective 1

Rationale: Over the last two decades, a number of high quality population-based surveys in Canada examining the prevalence of and risk factors for childhood overweight. However, in order to get a better understanding of the burden of childhood overweight in Canada and to possibly predict long term trends, the available evidence needs to be compiled and evaluated in a systematic fashion.
Objective: To review temporal trends in the prevalence of childhood overweight in Canada from 1980 to present.

Objective 2

Rationale: Obesity has substantial direct and indirect consequences on the Canadian economy. Predicting the future development of the obesity epidemic will help policy makers to better plan resource allocation and prevention efforts. Despite the great benefit and the availability of high quality data sources, so far no study has attempted to model the future trends of overweight and obesity in Canada.
Objective: To forecast the prevalence of overweight and obesity in Canada over the next 15 years.

Objective 3

Rationale: With many of the studies on childhood overweight risk factors being retrospective in nature and largely relying on self-reported data for prenatal factors, their ability to simultaneously and accurately adjust for all important confounders was limited.
Objective: To investigate the differential impact of prenatal, child, and family and socioeconomic factors on the development of overweight in Canadian children.

Objective 4

Rationale: In order to maximize the effect of prevention initiatives for childhood overweight, policy makers not only require information about risk factors but also require an understanding of their preventive potential, an information that is not provided by relative risks and odds ratios. An investigation into the population-attributable risk fraction (PARF) of common risk factors for childhood overweight would help to better understand the magnitude of the effect of a risk factor at the population level.
Objective: To estimate the population attributable risk fraction for childhood overweight risk factors in Canadian children.

Objective 5

Rationale: All North American studies so far on health care utilization in overweight children have been performed in the US whose provider-based health care systems differs considerably from the Canadian health care system. Over and above the limited applicability of US data, the Canadian publicly funded health care system provides an ideal setting for studying health care utilization at a population level. The use of health services across categories of weight status needs to be examined to determine whether overweight or obesity are associated with increased utilization patterns in this population. An understanding of these associations would be highly relevant to Canadian policy makers and healthcare delivery organizations who are faced with the question of whether or not to invest into overweight prevention programs among children and adolescents.
Objective: To assess health service utilization across categories of weight status

to determine whether overweight or obesity are associated with increased utilization patterns in Canadian children.

Objective 6

Rationale: The second largest cost share behind hospital costs in the Canadian health care system is medication use. Prescription drug costs account for 17% of health care spendings in Canada and their share has doubled over the last two decades. So far, no study has compared medication use between weight status groups in children in a publicly funded health care system. Investigating disparities in medication use will provide a more complete picture on the burden of the current childhood obesity epidemic and can aid with health care planning and resource allocation.
Objective: To compare medication use between normal weight and overweight children in a nationally representative sample from Canada.

Objective 7

Rationale: While adult obesity-related diseases such as type 2 diabetes mellitus and cardiovascular disease are seen with increasing frequency in children, they are still relatively rare and unlikely to account for the higher health care utilization in overweight children. Rather, more frequent and complex episodes of common pediatric diseases are likely responsible but this hypothesis has not been studied yet.
Objective: To assess health care use for prevalent medical conditions in normal weight and overweight Canadian children.

Objective 8

Rationale: Recently, an association between childhood obesity and otitis media has been reported in a small, selected clinical sample. As otitis media is a very common pediatric condition and recurrent otitis media may result in long-term sequelae such as learning disability, impaired linguistic development or hearing disorder, this association and its impact on health care utilization should be examined in a larger, population-based sample.
Objective: To examine the association between overweight and otitis media in a population-based sample of Canadian school children.

Objective 9

Provincial administrative health databases are an invaluable data source in Canadian health research. In times of the obesity epidemic, one shortcoming is the lack of weight data. ICD-9 and ICD-10 codes exist for obesity and may potentially be useful in identifying obese children. However, the diagnostic properties of an ICD-coded diagnosis of obesity have not been investigated yet in a population-based sample.

Objective: To investigate the diagnostic properties of ICD code-based diagnosis of obesity relative to the gold standard measured BMI at age 10/11 years in Canadian children.

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2 The prevalence of childhood overweight and obesity in Canada between 1980 and 2010

2.1 Introduction

The prevalence of childhood overweight and obesity in Western countries has increased dramatically over the last two decades [1]. Obesity is a risk factor for many chronic disases, such as type 2 diabetes mellitus, cardiovascular disease, sleep disorders, and some forms of cancer [2]. The growing disease burden will result in decreased life expectancy [3] and an increase in health care expenditures [4] for decades to come. Being able to understand the past and current development of the obesity epidemic can help to plan prevention strategies and allocate resources in the future. In Canada, a number of high quality studies at the national and provincial level have examined the prevalence of overweight and obesity during childhood [5–7]. Interpreting the data is hampered by different sampling methodologies, geographical differences, and varying methods of weight status classification. The objective of the present paper was to compile and review the available data on the prevalence of childhood overweight from 1980 to present to get a better understanding of the disease burden to possibly predict future trends.

2.2 Methods

2.2.1 Search strategy for identification of studies

Detailed individual search strategies were developed for the bibliographic databases MEDLINE, EMBASE, Web of Science, SCOPUS, ERIC, Dissertations & Theses, and Canadian Research Index. In addition, the Statistics Canada website (http://www.statcan.gc.ca) was searched for relevant surveys and prevalence estimates. For a grey literature search, the websites of the Canadian Institute for Health Information, the Public Health Agency of Canada, the Canadian Population Health Initiative, and the provincial ministries of health were searched. Proceedings from the annual meetings of the Canadian Public Health Association were handsearched. Reference lists from eligible studies were cross-checked to identify additional studies.

2.2.2 Inclusion criteria

All studies with data collection periods between 1980 and 2010 that use the Canadian or a Canadian provincial population as the denominator or sampling frame were considered for inclusion in the review. No language restrictions were applied.

Participants

Children between 2 and 17 years of age with a measured or reported BMI (self-report or parental) were eligible for inclusion. A mix of up to 20% of 18 year-olds in a sample was considered acceptable.

Outcomes

The primary outcome was overweight as defined by the International Obesity Task Force (IOTF) [8] or Centers for Disease Control (CDC) [9] definition or percentile cutoffs (e.g. 85th percentile) derived from measured or reported BMI (self-report or by proxy). The secondary outcome was obesity as defined by the above cutoffs.

2.2.3 Methods of the review

Relevance

Titles and abstracts of the records retrieved by the electronic searches were screened independently by two reviewers (the author and Kerry Vander Ploeg). For potentially relevant articles the full-text was obtained and reviewed by both reviewers for possible inclusion in the study. Disagreement between reviewers was solved by discussion. No third party adjudication was necessary. Only one report per study was included. Where more than one published result was available, the publication with the larger sample size was chosen. For longitudinal studies, preference was given to publications reporting baseline data.

Quality assessment

Due to the lack of formal criteria for the quality assessment of prevalence studies, quality of the included studies was assessed based on

1. Type of BMI assessment (measured vs. self-report/proxy-report)
2. Sampling frame
3. Correction for non-response (yes/no)
4. Response rate

Data extraction

Data extraction was performed by the author using a pre-tested standard paper form. The following data will be extracted from the studies:
Methods: Design; year; response rate; non-response weighting; study quality assessment; sampling strategy.

Participants: Setting (national/provincial); sample size; age group; gender.
Outcome: Details of outcome assessment (self-/proxy-report or measured); number of participants and proportion of participants with the outcomes.
Where available, data were supplemented by information from other papers on the same study or miscellaneous other sources (e.g. Statistics Canada public use microdata or CANSIM tables).

2.2.4 Data analysis

Stata/SE 11 was used to analyze the study data. Prevalence data were grouped by age into one of three categories (2 to 5 years, 6 to 11 years, 12-17 years) based on the mean age of the study participants. The paucity and heterogeneity of results with regard to BMI assessment and cutoffs used precluded pooling of data or a meta-regression. Results are therefore presented descriptively only.

2.3 Results

2.3.1 Study selection

The bibliographic database search found 2384 studies. A further 13 studies were identified through the search of the grey literature and Statistics Canada website. After screening, 366 articles were deemed potentially relevant and their full-text version was obtained. Based on the review of the 366 papers, 26 eligible studies were identified. Published prevalence estimates for children as per inclusion criteria were available for the final sample of 22 studies.

2.3.2 Study characteristics

About half of the included studies (n=12) were performed at the national level, the remainder consisted of studies in Nova Scotia (n=3), Quebec (n=3), Ontario (n=2), and Alberta (n=2). The majority were cross-sectional studies, only four studies were longitudinal studies. Of the 19 cross-sectional studies, 15 were performed in the last ten years. The three longitudinal studies were all initiated in the mid/late 1990's. The majority of studies were conducted between 2000 and 2010 (n=16). Only 2 and 4 studies were performed in the 1980s and 1990s, respectively. Two studies with a total of 2868 children reported prevalences for the 2 to 5 year age group. For the 6 to 11 year olds, eight studies reported results on 20817 children. In the 12 to 17 years age group, prevalence data for 66,757 children from 14 studies was available. The report of the children's weight status based on the IOTF cutoffs in 16 cases, CDC growth charts in 4 cases, and $85^{th}/95^{th}$ percentile of a reference population in 2 cases.

2.3.3 Study quality

In general, studies done by Statistics Canada were of the highest quality with regard to the choice of sampling frame, correction for non-response, and the response rate ($>$ 70% in almost all studies). Studies done by Statisticis Canada commonly used the Labour Force Survey area frame as the primary sampling frame while others usually chose all public schools in a province as the sampling frame. Correction for non-response was performed in almost all studies by Statistics Canada but only in one other study (CLASS). Response rates were variable and ranged from 31% (PACY-2, Nova Scotia) to 88% (OHS, Ontario) with a median of 76 %. Eleven studies used measured BMI, the other half relied on the participants' or their proxy's self report of BMI.

2.3.4 Prevalence

2 to 5 Years Only two studies reported the overweight/obesity prevalence in the age group of the 2 to 5 year olds, thus not allowing for any prevalence comparisons over time. Results for this age group are summarized in Table 2.2.

6 to 11 years The five Canada-wide studies with published results for the 6 to 11 years age group allow for a good comparison over time as all but one study used the IOTF BMI cutoffs. The prevalence of both overweight and obesity exhibits a distinct increase from 1981 to the 2000s: Relative to the 1981 Canadian Fitness Survey, overweight is twice as common while obesity saw a four-fold rise (Table 2.2). The prevalence rate from the 2003 CLASS survey in Nova Scotia was above the Canadian average at the time while the two remaining provincial level surveys only reported figures based on the CDC cutoffs. Details for this age groups are shown in Table 2.2.

12 to 17 years The national studies in the 12 to 17 years age group all reported data based on the IOTF cutoffs but the paucity of studies before the 2000s made comparisons over time difficult. For the studies done after 2000, no trend was discernible as the variability due to differing cutoffs and methods of BMI assessment was considerable: the prevalence of overweight and obesity ranged from 20 to 30% and from 4 to 10%, respectively. Detailed data for this age group is displayed in Table 2.3.

2.4 Discussion

The current study had set out to review published prevalences of childhood overweight and obesity for the last 30 years in Canada in order to possibly predict future trends. Despite a large number of studies that assessed children's BMI, results from the eligible studies were too heterogenous to make any inferences about the future development of the obesity epidemic.

One of the major challenges in compiling and evaluating prevalence data for overweight and obesity in children is that, unlike in adults, the definition of what constitutes overweight and obesity is less standardized. During the study period, three different sets of body mass index cutoffs have been in use: i) the 85^{th} and 95^{th} of a reference population; ii) the CDC growth charts [9]; and iii) the cutoffs suggested by the IOTF in 2000 [8]. Not surprisingly, prevalence estimates may vary considerably depending on which definition is used [10]. While the use of the IOTF cutoffs has been recommended for research purposes [11], studies published before 2000 were not able to include them for obvious reasons (unless the data were re-analyzed after 2000), and some authors simply had a preference for using the CDC growth curves. In the future, comparability may be further hampered as a result of the recent replacement of the CDC growth curves by the WHO growth charts in clinical pediatrics in Canada [12].

Another compounding factor was the need to compare of BMI data that were based on either measured, self-reported, or proxy-reported weight and height. Measured BMI has become the quasi standard for population-based assessment of overweight and obesity. The drawbacks of the use of measured BMI are the higher costs, a lower response rate due to the 'invasiveness' of the assessment, and more complex logistics in obtaining the information compared to reported height and weight. Accordingly, only half of the included studies used reported BMI instead of measured BMI. Self-reported BMIs tend to be lower than measured BMI as respondents tend to overestimate their height and underestimate their weight [13]. Matters are further complicated by the way data were collected as self-reported data gathered during face-to-face interviews tends to yield higher obesity rates than those from phone interviews [14].

The prevalence of overweight in 6 to 11 year old children in Canada has doubled since 1981, while the prevalence of obesity increased about three- to four-fold over the same period [15]. These estimates can be considered reliable as the corresponding studies all used measured BMI and the IOTF cut-off points for children and youth [8]. Similar trends have been reported in the US based on the data from the National Health and Nutrition Examination Survey [16, 17]. A direct comparison of the US and Canadian prevalences was not possible due to different definitions of overweight and obesity used [9]. For the 12 to 17 years age group, on comparison over time was possible due to insufficient data. The most recent numbers based on measured BMI from the 2007/2009 Canadian Health Measures Survey (CHMS) [15] are reason for concern as the overweight and obesity prevalences found are the highest ever recorded for national data in that age group. Moreover, the CHMS was a survey that due to its physical measures component (fitness testing and blood sampling) [18] required a high compliance from the participants. Thus, the CHMS sample probably represented even a more healthy sample of Canadian children than those of previous surveys.

The recognition of obesity as a serious public health problem around the turn of the millenium [19] is reflected in a three-fold increase in the number of studies from before the year 2000 to 2000 to 2010. For the purposes of this study, the larger number of studies has not translated into more accurate information on current and future trends. Apart from the aforementioned between-study differences in measuring overweight, there were also considerable within-study differences in reporting prevalences (data not shown). Future studies that aim to investigate trends in the childhood obesity epidemic in Canada should base their analyses only on primary data from Statistics Canada data to avoid these inconsistencies.

In summary, in the last decade research efforts to investigate the childhood obesity epidemic have increased considerably. Today, about one quarter of children in Canada are overweight and a further 10% are obese. Whether this trend has reached a plateau or will continue to increase cannot be determined owing to between-study differences in the assessment and definition of overweight in children.

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2.6 Tables

	Study	Year	Population	Sampling frame	Response rate	Non-response bias correction	BMI	Ref.
	Eligible studies with published results							
1	CAHPERD	1983	Canada	Public Schools	NA	No	Measured	[20]
2	CCHS 1.1	2000/01	Canada	LFS sampling frame	84.7 %	Yes	Self/proxy report	[21]
3	CCHS 2.1	2003	Canada	LFS sampling frame	80.7 %	Yes	Self/proxy report	[22]
4	CCHS 2.2	2004	Canada	LFS sampling frame	76.5 %	Yes	Measured	[23]
5	CCHS 3.1	2005	Canada	LFS sampling frame	79 %	Yes	Self/proxy report	[24]
6	CCHS 4.1	2007	Canada	LFS sampling frame	76 %	Yes	Self/proxy report	[25]
7	CFS	1981	Canada	"Area-stratified sample"	76 %	No	Measured	[6, 26]
8	CHMS	2007/09	Canada	LFS sampling frame	51.7 %	Yes	Measured	[18]
9	CLASS	2003	Nova Scotia	Public Schools	51.1 %	Yes	Measured	[27]
10	ELEMQ Cycle 1-3	1993/94 to 1995/96	Quebec	Unclear	NA	Unclear	Self/proxy report	[28]
11	GSS	1991	Canada	Households with phones	80.2 %	No	Self/proxy report	[29]
12	Hanning et al. 2007	2004?	Ontario	Public Schools	39 %	No	Self/proxy report	[30]
13	HSBC	2001/02	Canada	Public Schools	74.2 %	No	Self/proxy report	[31]
14	HSBC	2005/06	Canada	Public Schools	74.2 %	No	Self/proxy report	[32]
15	NLSCY Cycle 1-8	1994/95 to 2008/09	Canada	LFS sampling frame	NA	Yes	Self/proxy report	[33]
16	OHS	1990	Ontario	Public health units	87.5%	No	Measured	[34]
17	PACY	2001	Nova Scotia	Sport & Recreation Regions	38.2 %	No	Measured	[35]
18	PACY-2	2005	Nova Scotia	Sport & Recreation Regions	31.4 %	No	Measured	[36]
19	QCAHS	1999	Quebec	Public Schools	81.2 %	No	Measured	[37, 38]
20	QLSCD	1998 to 2004	Quebec	Public health units	85 %	No	Measured	[39]
21	REAL Kids Alberta	2008	Alberta	Public schools	63.5 %	No	Measured	[40]
22	Web-SPAN	2005	Alberta	Public Schools	27 %	Unclear	Self/proxy report	[41, 42]
	Eligible studies without published results							
23	CAHPERD	1979	Canada	Public Schools	NA	No	Measured	[20]
24	Campbell's Survey	1988	Canada	"Area-stratified sample"	NA	No	Measured	[43]
25	NPHS Cycle 1-8	1994/95 to 2008/09	Canada	LFS sampling frame	85.2 %	Yes	Self/proxy report	[44]
26	SNAP	2007	PEI	Public Schools		No	Measured	[45]

Table 2.1: Characteristics of studies assessing the prevalence of overweight and obesity in Canadian children between 1980 and 2010.
Abbreviations: *BMI* Body Mass Index; *Ref.* Reference; *NA* Not available; *CAHPERD* Canadian Association for Health, Physical Education, Recreation and Dance; *CCHS* Canadian Community Health Survey; *CFS* Canadian Fitness Survey; *CHMS* Canadian Health Measures Survey; *CLASS* Children's Lifestyle and School Performance Study; *ELEMQ* Longitudinal Study of Kindergarten Children in Quebec; *GSS* General Social Survey; *HSBC* Health Behavior in School-Aged Children Study; *NLSCY* National Longitudinal Survey of Children and Youth; *OHS* Ontario Health Survey; *PACY* Physical Activity and Dietary Intake of Children and Youth; *QCAHS* Quebec Child and Adolescent Health and Social Survey; *QLSCD* Quebec Longitudinal Study of Child Development; *REAL Kids Alberta* Raising Healthy Eating and Active Living Kids in Alberta; *Web-SPAN* Web Survey of Physical Activity and Nutrition; *NPHS* National Population Health Survey; *SNAP* School Nutrition and Activity Project.

Study	Year	Population	BMI Assessment	Cutoffs	n	Overweight	Obese	Ref.
2 to 5 years								
CCHS 2.2	2004	Canada	Measured	IOTF	1348	21.5 %	6.3 %	[7]
QLSCD 3rd wave	2002	Quebec	Measured	IOTF	1520	14.3 %	5.5 %	[39]
6 to 11 years								
CFS	1981	Canada	Measured	IOTF	2879	13.4 %	2.0 %	[6]
CAHPERD	1983	Canada	Measured	85th/95th percentile[1]	1925	21.0 %	5.8 %	[20]
NLSCY Cycle 2	1996	Canada	Self/proxy report	IOTF	6277	31.0 %	10.0 %	[6]
CCHS 2.2	2004	Canada	Measured	IOTF	2321	27.8 %	8.0 %	[7]
CHMS	2007	Canada	Measured	IOTF	1074	23.2 %	6.4 %	[15]
PACY	2001	Nova Scotia	Measured	CDC	800	44.2 %	22.8 %	[46]
CLASS	2003	Nova Scotia	Measured	IOTF	4298	32.9 %	9.9 %	[27]
QCAHS	1999	Quebec	Measured	CDC	1243	23.0 %	9.0 %	[37]

Table 2.2: Study characteristics and reported prevalences of overweight (incl. obesity) and obesity in Canadian children (2 to 5 years and 6 to 11 years) between 1980 and 2010.
[1] Based on CAHPERD 1979 [20]
Abbreviations: *BMI* Body Mass Index; *Ref.* Reference; *IOTF* International Obesity Task Force; *CAHPERD* Canadian Association for Health, Physical Education, Recreation and Dance; *CCHS* Canadian Community Health Survey; *CFS* Canadian Fitness Survey; *CHMS* Canadian Health Measures Survey; *CLASS* Children's Lifestyle and School Performance Study; *NLSCY* National Longitudinal Survey of Children and Youth; *PACY* Physical Activity and Dietary Intake of Children and Youth; *QCAHS* Quebec Child and Adolescent Health and Social Survey; *QLSCD* Quebec Longitudinal Study of Child Development.

Study	Year	Population	BMI Assessment	Cutoffs	n	Overweight	Obese	Ref.
12 to 17 years								
GSS	1991	Canada	Self/proxy report	IOTF	381	4.7 %	0.5 %	PUMF
CCHS 1.1	2000	Canada	Self/proxy report	IOTF	12715	NA	4.2 %	[47]
HSBC	2001	Canada	Self/proxy report	IOTF	5890	19.6 %	4.6 %	[31]
CCHS 2.2	2004	Canada	Measured	IOTF	2515	29.2 %	9.4 %	[7]
CCHS 3.1	2005	Canada	Self/proxy report	IOTF	11350	19.4 %	4.8 %	PUMF
HSBC	2005	Canada	Self/proxy report	IOTF	7281	21.7 %	5.7 %	[32]
CHMS	2007	Canada	Measured	IOTF	1013	27.9 %	10.5 %	[15]
CCHS 4.1	2007	Canada	Self/proxy report	IOTF	9552	19.0 %	4.4 %	PUMF
PACY	2001	Nova Scotia	Measured	CDC	1496	33.5 %	13.9 %	[46]
PACY-2	2005	Nova Scotia	Measured	CDC	1517	30.0 %	13.0 %	[36]
QCAHS	1999	Quebec	Measured	CDC	2327	21.7 %	8.2 %	[37]
OHS	1990	Ontario	Measured	IOTF	6065	18.9 %*	3.8 %*	[34]
Hanning et al. 2007	2004	Ontario	Self/proxy report	CDC	524	15.3 %	5.2 %	[30]
Web-SPAN	2005	Alberta	Self/proxy report	IOTF	4131	21.1 %	6.1 %	[41]

Table 2.3: Study characteristics and reported prevalence of overweight (incl. obesity) and obesity in Canadian children (12 to 17 years) between 1980 and 2010.

* Imputed from male/female prevalences assuming a 1:1 ratio of the sexes.

Abbreviations: *BMI* Body Mass Index; *Ref.* Reference; *IOTF* International Obesity Task Force; *PUMF* Public Use Microdata File; *NA* Not available; *CCHS* Canadian Community Health Survey; *CHMS* Canadian Health Measures Survey; *GSS* General Social Survey; *HSBC* Health Behavior in School-Aged Children Study; *OHS* Ontario Health Survey; *PACY* Physical Activity and Dietary Intake of Children and Youth; *Web-SPAN* Web Survey of Physical Activity and Nutrition.

3 Forecasting the prevalence of overweight and obesity in Canada

3.1 Introduction

In recent times, an alarming increase in obesity has been a major health and economic concern in Canada [1]. According to Statistics Canada, rates of overweight have increased from 13% to 29% over the last two decades [2]. The myriad psychological and physiological consequences of obesity hamper the ability of an individual to function as a healthy and productive member of the society. The physiological consequences include chronic and often fatal diseases such as cardiovascular disease, type 2 diabetes mellitus, and various cancers [3]. The psychological consequences include low self-esteem which often leads to clinical depression [4]. Moreover, since obese or overweight mothers have a higher probability of having overweight babies [5, 6], the problem aggravates into a vicious circle. Due to these ill-effects, obesity also poses various direct and indirect consequences on the Canadian economy [7]. Predicting the future development of the obesity epidemic would therefore help policy makers to better plan resource allocation and prevention efforts, and target specific vulnerable groups. Despite the great potential benefit and the availability of high quality data sources, so far no study has attempted to model the future trends of overweight and obesity in Canada. The purpose of this study is to forecast the prevalence of overweight and obesity in Canada over the next 15 years.

3.2 Methods

3.2.1 General Model Structure

A Markov Chain Monte Carlo (MCMC) model [8] was developed to model the development of the prevalence of overweight and obesity in Canada from 2006 to 2026.

Individuals in the model can be in one of five states: underweight, normal weight, overweight, obese, or dead. All states are reversible with the exception of death. The length of each cycle is 2 years. The model is a probabilistic model, that is the probability for an individual to be in a certain state in the next cycle given the current state (transition probability) is randomly sampled from a probability distribution to incorporate the error of the estimate. As our model uses five mutually

exclusive states, the Dirichlet distribution was chosen: The Dirichlet distribution takes the number of k rival events (in this case the number of individuals in a certain state given the previous state) as parameters and returns k probabilities for these events [9]. Individuals entered the model at age 2 years and were removed from the model when they reached the state "death" or turned 80 years, whichever event came first.
The model was implemented using the open source object-oriented programming language Python 2.6 [10] with the language extensions NumPy [11] and SciPy [12].

3.2.2 Calculation of transition probabilities

The parameters for the Dirichlet distribution for each age and gender were obtained from the National Population Health Survey (NPHS) 1994-2008. The NPHS is a longitudinal, nationally representative dynamic cohort of Canadians that is conducted biannually [13]. Data on 9982 persons from all 8 cycles was used for the present study. Calculations were weighted using the longitudinal sampling weights provided by Statistics Canada for each survey.

3.2.3 Initial distribution

The initial distribution of age, sex, and weight status in the Canadian population was determined using Statistics Canada data sources from 2006 and 2007/2008.

2 to 9 years For the 2 to 9 year olds, data on 20740 children from Cycle 7 of the National Longitudinal Survey of Children and Youth (NLSCY) [14] was used. Similar to the NPHS, the NLSCY is a representative, longitudinal, dynamic cohort. The cohort consists of children between 0 and 17 years of age. The NLSCY cohort has a longitudinal subsample, which comprises of children who entered at the inception of the cohort in 1994/95, and an "early childhood development" subsample of children that are between 0 and 7 (or 9) years old (depending on the survey cycle) and have entered the cohort after 1994/95.
Body mass index was calculated based on proxy-reported weight and height. Weight status was categorized as either underweight, normal weight, overweight, or obese using the cut-offs established by the International Obesity Task Force [15, 16].

10 to 11 years As the 10 to 11 years age bracket was not covered by either the early childhood subsample or the longitudinal subsample of any cycle of the NLSCY, data from 9 year-old children in the "early childhood development" subsample of Cycle 7 of the NLSCY was used. Body mass index measurement and classification were based on the same methods as described above for the 2 to 9 years age group.

12 to 80 years The Canadian Community Health Survey (CCHS) 3.1 (n=132947) was used to calculate the distribution of weight status by age and sex for the 12 to 80 years age group. The CCHS 3.1 is a cross-sectional, representative survey of the Canadian population that was held in 2006 [17].
Body mass index was calculated based on self-reported weight and height (or proxy-reported where necessary). Weight status was categorized as either underweight, normal weight, overweight, or obese using the cut-offs established by the International Obesity Task Force [15, 16] (children 12 to 17 years) or standard adult cut-offs (underweight: $\leq$ 18.5 kg/m^2; overweight: $\geq$ 25 kg/m^2; obesity: $\geq$ 30 kg/m^2) (18 years and older).

The prevalence of each weight status by age and sex was calculated within the three subsamples using the respective survey sampling weights provided by Statistics Canada. These subsamples were then merged and the prevalences were scaled to the full population size using population count data by age and sex from the 2006 Census [18].

3.2.4 Birth rate and mortality data

With each cycle, new subjects aged 2 years were added to the population to reflect new births. The "birth" rate in the model was fixed at the 2007/2008 birth rate in Canada (11.0 per 1000 individuals) [19]. The weight status prevalences for 2 year-olds calculated from the CCHS 3.1 (see above) were applied to the new subjects.
Statistics Canada mortality rates from 2008 [] were applied to the subjects in the model. To account for the BMI-associated differences in the risk of death, the risk of death was scaled according to the weight status-specific hazard ratio obtained from a pooled analysis of 19 prospective studies that included 1.46 million white adults in the US [20].

3.2.5 Sensitivity analyses

To test the influence of alternative scenarios on our results, we performed three sensitivity analyses:
1. The transition probabilities for being overweight or obese in the next cycle were reduced by 10% to simulate the influence of an effective public health intervention and to test the robustness of the model results in a less obesogenic environment.
2. The transition probabilities for being overweight or obese in the next cycle were increased by 10% to offset a potential underestimation of BMI due to self report.
3. The risk of death was assumed to be 10% lower for overweight relative to normal weight individuals in order to evaluate the recently observed protective effect of overweight on the risk of death [21–23].

3.2.6 Data analysis

Results from the model were based on 10 cycles (2-year cycle length $\times$ 2 = 20 years) and 100,000 Monte Carlo replications. The prevalence of overweight and obesity in each cycle was calculated for the full sample, for males and females, and for four distinct age groups (2 to 5 years, 6 to 11 years, 12 to 17 years, 18 to 65 years). Stata/MP 11 (Stata Corp., College Station, TX, USA) was used to analyze the model output.

3.3 Results

The simulation started out in 2006 with 100,000 subjects aged 2 to 80 years in the model; in 2026, this number had dropped to 90,695 subjects. Predictions from the base model indicate that the prevalence of overweight and obesity in Canada will increase by approximately 10% from 45.5% (2006) to 55.0% in 2026 (Table 1 and Figure 1). This increase is carried in equal parts by the overweight and obesity (5% each). The prevalence of normal weight will drop from 49.2% (2006) to 41.0% in 2026, while the percentage of underweight persons will remain fairly constant around 4%. No difference in the forecasts was found between men and women.

The pediatric age groups contributed less to the overall increase in overweight and obesity. The prevalence of normal weight in childhood even increased, mostly due to a concurrent drop in the proportion of underweight children. Changes in the adult group (18 to 65 years) paralleled the changes observed in the overall sample.

The two sensitivity analyses that examined a i) 10% higher and ii) 10% lower probability, respectively, for the whole sample of being overweight or obese in the next cycle yielded prevalences for normal weight of 39% (i) and 43% (ii) in 2026. The change in the proportion of normal weight subjects was almost exclusively due to changes in the prevalence of obesity in the sample. The third analysis that investigated a 10% lower risk in overweight relative to normal weight individuals showed no significant differences compared to the base model.

3.4 Discussion

The current study has, for the first time, attempted to model the future burden of overweight and obesity in Canada based on current trends. The MCMC model shows a further increase in the combined prevalence of overweight and obesity by approximately 10%. The model results remained robust when subjected to three sensitivity analyses.

The population size in the model shows a decline of about 9% over the course of 20 years, which appears to be in contrast to published population growth scenarios from Statistics Canada [24] that see the Canadian population grow by at least 10% until 2026 [25]. This apparent discrepancy is readily explained by two facts: Firstly, the model contains only individuals up to age 80 years and thus misses an increasingly larger part of the population. Secondly, our model did not consider the effects of immigration, which accounts for an annual population growth of about 0.8% [25]. The birth rate used in the model was fixed relative to the population size. Projections by Statistics Canada see the birth rate decline slightly from currently 11.3 per 1000 to about 9.4 per 1000 in 2026 [25]. Our choice of using 11 per 1000 can therefore be considered a reasonable estimate. The second determinant of population growth (or decline, rather) is mortality. The mortality rate used in our model (based on 2008 data) is age-dependent and thus can take into account the changing age structure in the population. The latter property is important considering that between 2006 and 2026 the proportion of persons between 66 and 80 years increased from 10% to 21% (Table 3.1). These numbers are in keeping with Statistics Canada projections for this age group [26]. Overall, in terms of population growth, our model compares well to existing forecasts from Statistics Canada.

The starting date of the model in the past (2006) offers an opportunity to compare early projections with actual data from the present day. While no data from 2011 are available, the 2009 CCHS showed that the proportion of Canadians 18 years and older increased from 15% in 2003 to 18% in 2009 [27], which is comparable to the increase seen in our model (Table 3.1). Another finding when assessing the face validity of our model findings is the shape of the age distribution of overweight (Figure 3.2) and obesity (Figure 3.3) between 2 and 20 years. The high prevalence of obesity between 2 and 10 years and the comparatively low proportion of overweight children during the same period are probably due to measurement-related factors. As there is no recent Canadian survey that spans all age groups from 2 to 80 years, the initial distribution of weight status in our simulation was constructed from two data sources, namely the Early Childhood Development cohort from the NLSCY and the Canadian Community Health Survey 3.1. The NLSCY recorded the BMI based on proxy report from parents or guardians [14], while the CCHS 3.1 used largely self report, with some of the younger children being assisted by a parent [17]. Comparison between parent-reported BMI and direct measurements have shown that parents tend to underestimate their child's height, resulting in a higher proportion of overweight and obesity [28]. Conversely, self report tends to underestimate the actual BMI as individuals commonly report reporting a lower weight [28]. A second factor that may have contributed to the unusual shape of the prevalence distribution was the use of sampling weights from two different sources. Use of 2004/2005 CCHS 2.2, which used measured BMI and spanned all age groups, may be a viable alternative. Drawbacks, on the other hand, are the relatively small sample size (n $\approx$ 20,000 with measured BMI [29]), the need to apply transition probabilities based on self report (from the NPHS) to measured weight status, and the age of the data (7 years).

The results from the prediction model show an increase of overweight and obesity of about 10% from 45.5% to 54.0%, corresponding to a relative increase of 19%. These numbers may appear relatively modest considering that the prevalence of overweight and obesity doubled in the last 20 years [30]. However, the transition probabilities in our model were based on data collected between 1994 and 2008. Ideally, only the most current cycle of the NPHS should have been included but due to the the large number of different states in the model (5 states [underweight, normal weight, overweight, obese] in 2 sexes and 40 different age categories) and the need for a large sample size, all 8 available cycles from the NPHS were included. We assume that over the 14 year study period the growth of the obesity epidemic probably slowed down, which would then be reflected in a less steep increase in our projection. Our findings are in apparent sharp contrast to a recent projection in the US [31] that estimated that by the year 2030, 86% of Americans will be overweight or obese. The authors used a simple linear regression to model future prevalences based on past prevalence estimates from the NHANES survey between 1970 and 2004. The asssumption of unhindered growth and equal susceptibility of each individual that underlies this modeling approach is not justified. The probabilistic MCMC model used in the current study can better accomodate the fact that a proportion of individuals will always remain resistant to change. A Swiss study used a logistic model based on nationally representative surveys from Switzerland, France, United Kingdom, US and Australia concluded that the prevalence of overweight and obesity will stabilize around 2020 [32]. While the model chosen by the authors allowed for a more flexible shape of the prediction curve, the methodology is still more rigid than our approach. A modeling approach similar to ours was employed in a 2010 study by Basu [33]. Using US data from the Medical Expenditure Panel Survey (MEPS) 2001/2002 and 2004/2005, the author forecasted the prevalence of overweight and obesity from 2004 to 2014 using a probabilistic simulation model. His findings see the prevalence rates for adults stabilize while those of younger children appeared to slightly increase. A similar stabilizing trend in the prevalence of overweight was observed in a Markov model simulation of the diabetic population in the US [34]. Taken together, projections for the obesity epidemic rather indicate that the surge has slowed down.

The strengths of the current study are the use of large population-based data sources and the use of a probabilistic decision model, which takes into account uncertainties in the transition probabilities. A few limitations need to be acknowledged. All predictions from the model are conditional on the transition probabilities and weight status-related mortality risks used. A change in the transition probabilities or mortality risk associated with overweight or obesity in the future will alter the model results. However, our sensitivity analyses showed that the findings are relatively robust to moderate changes in the model parameters. Another limitation is the use of self and proxy reported BMI from different data sources. The inability to consider population changes due to immigration may have resulted in an overestimation of overweight and obesity as immigrants commonly have a lower BMI than their Canadian-born counterparts due to ethnic differences and higher socioeconomic status. This effect wears off within a decade of immigration [35]. Finally, a Markov model inherently has no memory, that is transitions only depend on the current state but do not take into account previous experiences. Therefore, Markov models are only of limited use in the study of weight status.

To conclude, predictions from the first Canadian projection of overweight prevalences show a further increase of the proportion of overweight individuals but at a slower rate than in the last 30 years. Future research should also examine health care costs in the model and should incorporate a "memory" into the simulation to account for the long-term effects of learnt health behaviors.

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3.6 Table

	2006	2010	2014	2018	2022	2026
Full sample						
N	100,000	98,753	97,301	95,472	93,321	90,695
Underweight	5.3 %	4.4 %	4.3 %	4.4 %	4.3 %	4.0 %
Normal weight	49.2 %	46.7 %	44.8 %	42.5 %	41.7 %	41.0 %
Overweight	30.4 %	32.3 %	33.5 %	34.8 %	35.0 %	35.9 %
Obese	15.1 %	16.6 %	17.4 %	18.3 %	19.0 %	19.1 %
Males						
N	50,180	49.547	48,798	47,831	46,735	45,345
Underweight	3.4 %	4.0 %	3.9 %	3.9 %	3.9 %	3.8 %
Normal weight	44.4 %	39.8 %	37.4 %	35.3 %	34.5 %	33.6 %
Overweight	36.1 %	38.6 %	40.4 %	41.7 %	41.6 %	42.7 %
Obese	16.1 %	17.6 %	18.3 %	19.2 %	20.0 %	19.9 %
Females						
N	49,820	49,206	48,503	47,641	46,586	45,350
Underweight	7.2 %	4.8 %	4.7 %	4.9 %	4.6 %	4.2 %
Normal weight	54.0 %	53.6 %	52.1 %	49.8 %	48.9 %	48.4 %
Overweight	24.7 %	26.0 %	26.6 %	27.9 %	28.4 %	29.0 %
Obese	14.1 %	15.7 %	16.6 %	17.5 %	18.1 %	18.4 %
2 to 5 years						
N	3,667	2,201	2,215	2,226	2,232	2,236
Underweight	17.1 %	11.1 %	10.7 %	10.7 %	10.9 %	9.4 %
Normal weight	46.6 %	50.7 %	48.7 %	50.6 %	50.3 %	51.3 %
Overweight	16.7 %	18.0 %	19.8 %	17.7 %	18.1 %	19.4 %
Obese	19.6 %	20.2 %	20.8 %	20.9 %	20.7 %	19.9 %
6 to 11 years						
N	9,115	6,469	3,274	3,316	3,314	3,345
Underweight	15.4 %	6.0 %	6.5 %	6.6 %	6.0 %	6.0 %
Normal weight	49.9 %	57.5 %	57.3 %	56.8 %	57.8 %	59.6 %
Overweight	19.7 %	22.5 %	22.4 %	22.1 %	21.6 %	21.1 %
Obese	15.1 %	14.1 %	13.8 %	14.6 %	14.6 %	13.4 %
12 to 17 years						
N	7,871	8,703	8,575	4,759	3,304	3,325 %
Underweight	7.9 %	3.1 %	2.7 %	2.3 %	2.7 %	2.4 %
Normal weight	68.6 %	70.4 %	70.6 %	69.7 %	70.8 %	70.8 %
Overweight	17.4 %	17.6 %	17.9 %	18.2 %	17.0 %	18.4 %
Obese	6.2 %	8.9 %	8.8 %	9.8 %	9.5 %	8.5 %
18 to 65 years						
N	68,971	69,841	69,854	70,113	67,633	62,904
Underweight	3.5 %	4.2 %	4.2 %	4.2 %	4.0 %	3.8 %
Normal weight	48.3 %	44.4 %	42.7 %	41.5 %	40.9 %	39.9 %
Overweight	32.6 %	34.0 %	34.8 %	35.4 %	35.5 %	36.3 %
Obese	15.6 %	17.5 %	18.4 %	18.9 %	19.6 %	20.1 %

Table 3.1: Modeled prevalences of weight status categories in Canada from 2006 to 2026 by age group. Numbers presented are based on 100,000 Monte Carlo replications from a Markov model.

3.7 Figures

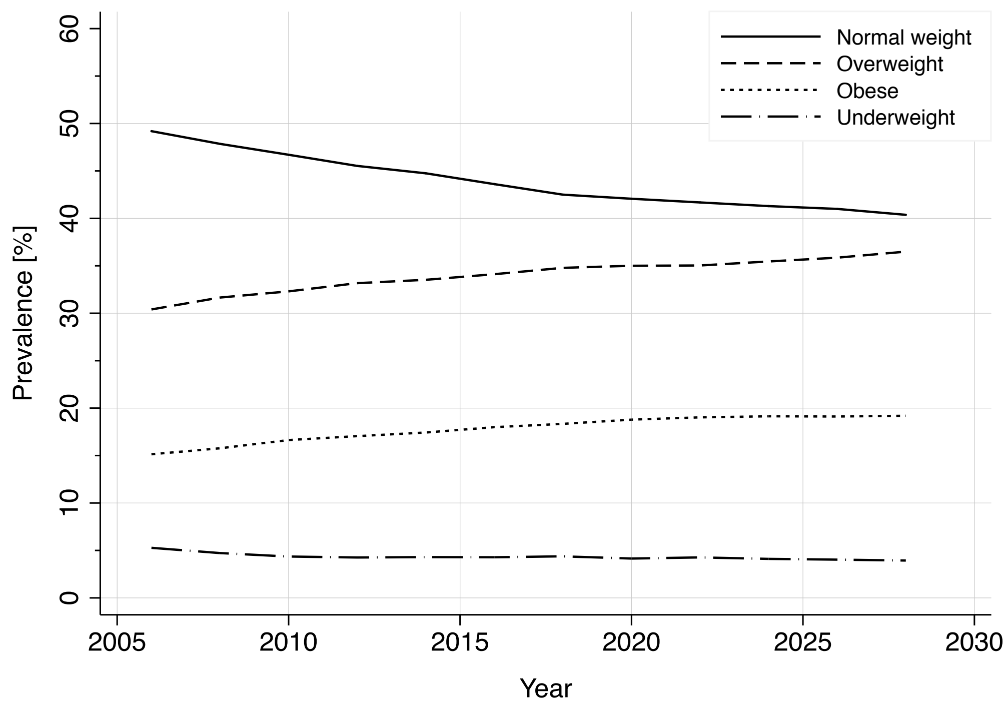

Figure 3.1: MCMC model-based predictions for the prevalence of underweight, normal weight, overweight, and obesity in Canada from 2006 to 2026: Base model. Abbreviations: *MCMC* Markov Chain Monte Carlo

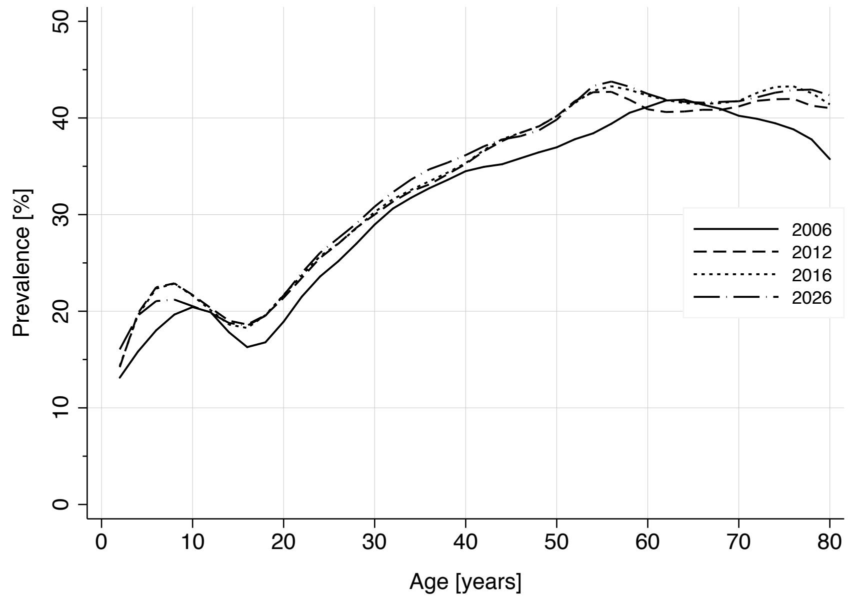

Figure 3.2: MCMC model-generated prevalence of overweight by year of life for the years 2006, 2012, 2016, and 2026. Note that some smoothing has been applied to the graph to enhance readability.
Abbreviations: *MCMC* Markov Chain Monte Carlo

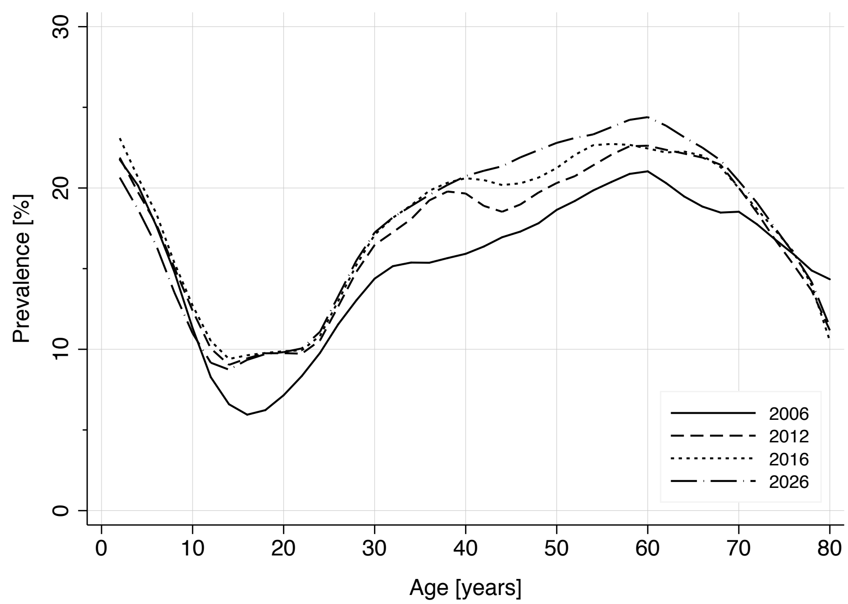

Figure 3.3: MCMC model-generated prevalence of obesity by year of life for the years 2006, 2012, 2016, and 2026. Note that some smoothing has been applied to the graph to enhance readability.
Abbreviations: *MCMC* Markov Chain Monte Carlo

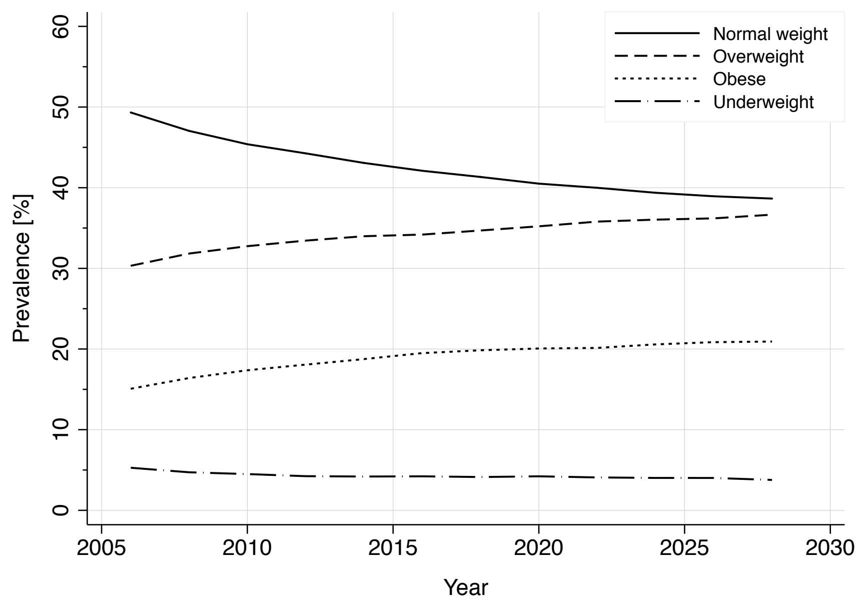

Figure 3.4: MCMC model-based predictions for the prevalence of underweight, normal weight, overweight, and obesity in Canada from 2006 to 2026: Sensitivity analysis assuming 10% higher probabilities for becoming overweight or obese. Abbreviations: *MCMC* Markov Chain Monte Carlo

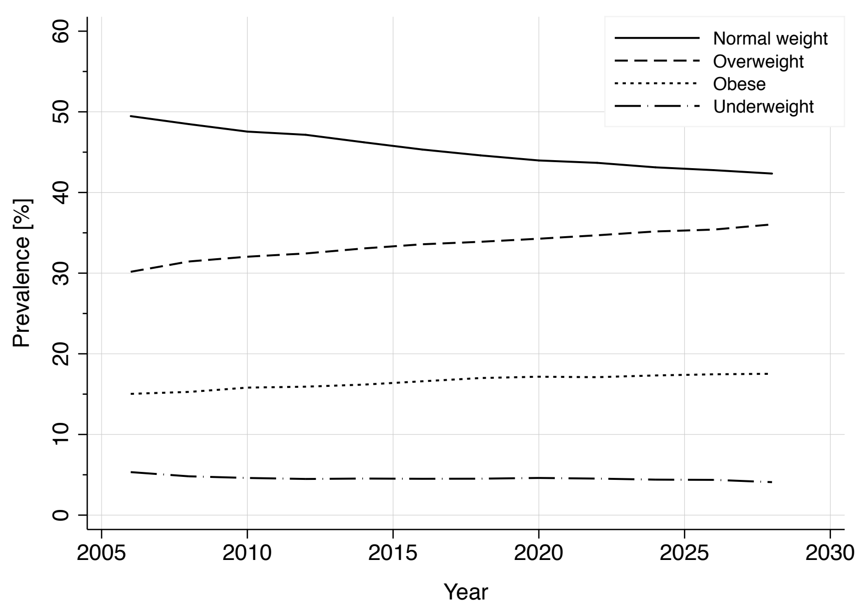

Figure 3.5: Markov model-based predictions for the prevalence of underweight, normal weight, overweight, and obesity in Canada from 2006 to 2026: Sensitivity analysis assuming 10% lower probabilities for becoming overweight or obese. Abbreviations: *MCMC* Markov Chain Monte Carlo

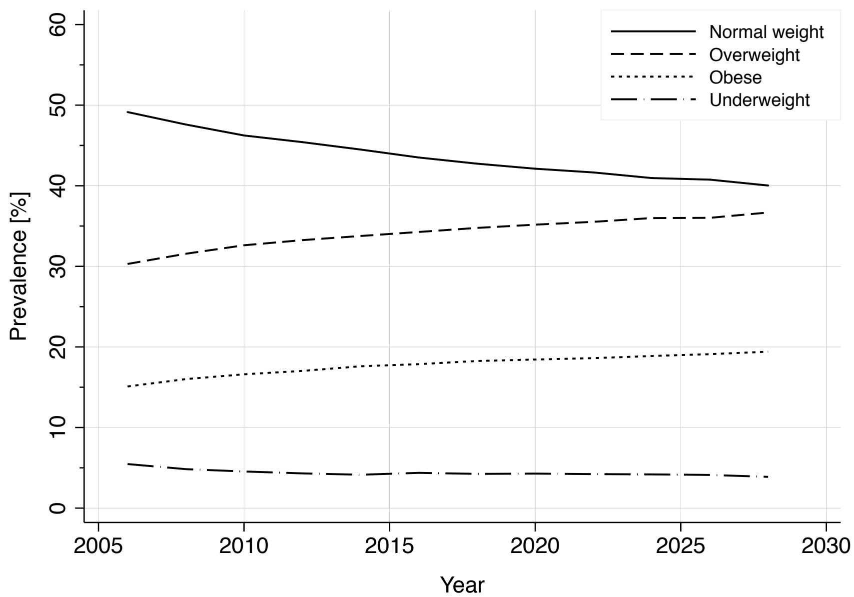

Figure 3.6: Markov model-based predictions for the prevalence of underweight, normal weight, overweight, and obesity in Canada from 2006 to 2026: Sensitivity analysis assuming 10% lower mortality rate for overweight relative to normal weight individuals.
Abbreviations: *MCMC* Markov Chain Monte Carlo

4 Perinatal and childhood risk factors for overweight in a provincial sample of Canadian Grade 5 students

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4.1 Introduction

The prevalence of obesity in both children and adults is increasing in industrialized nations [1]. The consequences of obesity for adverse health outcomes such as type II diabetes mellitus, cardiovascular disease and cancer are well documented [2]. There is mounting evidence that childhood overweight often persists into adulthood, and that the foundation for adult cardiovascular disease and other obesity-related diseases is laid in childhood [3–6]. Thus, early intervention is the key to prevention of childhood obesity.

Nutritional imbalances in fetal life, breast-feeding practices and childhood dietary and physical activity patterns have all been shown to be associated with obesity later in life. In particular, the association between birth weight and childhood or adult obesity has recently gained attention. Both high ($>$ 4,500 g or macrosomia) and low ($<$ 2,500 g) birth weight have been described as risk factors for later obesity [7–10]. However, only a few studies had accurate recordings of gestational age, and thus only a few were able to distinguish whether low or high birth weight resulted from disturbances in intrauterine growth or from preterm or late term birth, respectively [11–16]. Further, associations between birth weight and obesity later in life may be confounded by other factors such as socioeconomic status (SES), breast-feeding practices, the child's dietary and activity patterns, smoking during pregnancy, and maternal pre-pregnancy weight. With many of the studies being retrospective in nature and largely relying on self-reported data for prenatal factors, their ability to simultaneously and accurately adjust for all important confounders was limited. To further our understanding and to direct prevention policies, we investigated the differential impact of prenatal, child, and family and socioeconomic factors on the development of overweight in Grade 5 school children in the Canadian province of Nova Scotia by linking data from a population-based study and a provincial perinatal registry.

4.2 Methods

4.2.1 Study Design/Setting

The current study was a population-based study in the Canadian province of Nova Scotia using data from the cross-sectional 2003 Children's Lifestyle and School Performance Study (CLASS) that were linked to the Nova Scotia Atlee Perinatal Database.

4.2.2 Children's Lifestyle and School Performance Study

The CLASS is a population-based survey of grade 5 students and their parents in the Canadian province of Nova Scotia. The study consisted of a home questionnaire that was completed a by the parents; a Canadianized version of the Harvard Youth/Adolescent Food Frequency Questionnaire (YAQ) [17] validated for this age group administered to the students in the schools by study assistants; and a measurement of the students' height and weight. The home questionnaire collected information on sociodemographic factors, the child's place of birth and residency, as well as household income level, highest parental educational attainment, breastfeeding practice, self-rated parental physical activity and diet quality, and validated questions on the frequency of their child's physical activities and the number of hours of sedentary activities (watching television, working on a computer, playing video games) taken from the National Longitudinal Survey of Children and Youth [18]. Standing height was measured by a research assistant to the nearest 0.1 cm after students had removed their shoes; body weight was measured to the nearest 0.1 kg on calibrated digital scales (Tanita HD-314, Tokyo, Japan). In addition to the above information, participating parents were asked to provide their Nova Scotia Health Insurance number and informed consent to allow future linkage of the data with administrative health databases.

More than 97% of students in Nova Scotia attend public schools. Of the 291 public schools in Nova Scotia with grade 5 classes, 282 (96.9%) participated in the study. The average rate of return of questionnaire and consent form was 51.1% per school. One of the seven provincial school boards did not allow measurements of height and weight. A total of 4298 students (38.5% of 11178 Grade 5 students in the participating schools) participated in the study and had their height and weight measured.

4.2.3 Perinatal Data

The Nova Scotia Atlee Perinatal Database (NSAPD) collects demographics, procedures, interventions, maternal and newborn diagnoses, and morbidity and mortality information for all pregnancies and births occurring in hospitals in Nova Scotia since 1988 [19]. Data is collected from hospital charts by trained health records personnel using standardized data collection forms. As part of an ongoing data quality-assurance program for the NSAPD, routine data checks and edits are made at the time of data collection, and reabstraction studies are performed regularly [20, 21]. A validation study has shown agreement between information on infant death in the Atlee database and the Statistics Canada Birth and Mortality registries [22]. Data are collected from the hospitals using a standardized prenatal record and a discharge summary. Linkage of the CLASS data with the NSAPD was carried out by the Reproductive Care Program of Nova Scotia that administers the database. A combination of deterministic and probabilistic matching was used to link the two datasets. Of the 4298 students in the CLASS study with measured height and weight data, 3426 (79.7%) could be linked with information in the NSAPD. The most common reason for an unsuccessful linkage was that children were born outside the province of Nova Scotia (12.4%); for the remaining children, parents had provided an invalid or no health insurance number. When comparing the original CLASS sample with the linked sample, the two groups did not differ appreciably; the prevalence of overweight was the same in both samples. Seventy-five students (2.2%) were excluded due to missing or improbable data for birth weight and gestational age, leaving a final sample of 3351 children (30.0% of 11178 Grade 5 students in the participating schools).

4.2.4 Overweight and Obesity

The primary outcome was the presence of overweight in grade 5; the secondary outcome was the presence of obesity (excluding overweight individuals) in grade 5. The outcomes were defined using the age- and gender-specific body mass index (BMI) cut-off points for children and youth established by the International Obesity Task Force [23] based on health-related adult definitions of overweight ($\geq$ 25 kg/m^2) and obesity ($\geq$ 30 kg/m^2).

4.2.5 Risk Factors

Prenatal Factors

Pre-pregnancy weight (as per maternal self-report at the first prenatal visit; 4 levels: $<$ 60 kg, 60 to $<$ 70 kg, 70 to $<$ 80 kg, $>$ 80 kg); smoking during pregnancy (recorded on admission to the delivery ward; none, half a pack or less, or more than half a pack); parity (I, II, III or higher); maternal hypertension during pregnancy (yes/no); maternal age (5 levels: $<$ 20 years, 20 to 24 years, 25 to 29 years, 30 to 34 years, $>$ 34 years); maternal diabetes (gestational or preexisting; yes/no). Information on prenatal factors is based on data from the Atlee Perinatal Database. Maternal height was not recorded in the database at the time this cohort was born and thus maternal BMI (instead of maternal weight alone) could not be included in the current study.

Child Factors

Gender; physical activity (parental report; 4 levels: $\leq$ 2x per week, $>$ 2 to 4x per week, $>$ 4 to 7x per week, $<$ 7x per week); screen time (time spent watching television or playing computer/video games as per parental report; 4 levels: ≤ 1 hour per day, $>$ 1 to 3 hours per day, $>$ 3 to 6 hours per day, $>$ 6 hours per day); Diet Quality Index [24], a composite index (ranging between 0 and 1, with 1 indicating highest diet quality) that assesses dietary variety, adequacy, moderation, and balance (based on the data from the YAQ, co-adjusted for total daily energy intake [25]; tertiles); preterm birth (i.e. before 37th week of gestation; yes/no) weight-for-gestational-age (based on birth weight data from the Atlee Perinatal Database; classification as small (SGA), appropriate (AGA) or large for gestational age (LGA) according to Canadian reference values [26]); breast-feeding (parental report; 4 levels: $<$ 1 week or none, 1 week to 3 months, $>$ 3 months to 6 months, $>$ 6 months).

Family and Socioeconomic Factors

Parental physical activity (self-rated; low, medium or high); parental diet quality (self-rated; high vs. low); has siblings (yes/no); household income (4 levels: \$0 to \$20,000, \$20,001 to \$40,000, \$40,001 to \$60,000, $>$ \$60,000); parental education attainment (4 levels: Secondary school or less, College, University, Graduate university); neighborhood income and dwelling value (calculated by school as a weighted average of the neighbourhood incomes/dwelling values (available through the 2001 Canada census) of each student in that school; tertiles).

4.2.6 Data Analysis

Data were analyzed using a series of multiple logistic regression models. As the observations from students were nested within those of their schools, multilevel statistical methods were applied. Student and parental factors were considered as first-level covariates. Neighborhood income and dwelling value were considered as area-level factors and treated as second-level covariates. To assess the individual importance of a risk factor in its context, we grouped risk factors into three groups (Prenatal, Child, Family/Socioeconomic) and built separate regression models for each group of covariates using Hosmer and Lemeshow's purposeful selection procedure [27]. Estimates from these models are referred to as "theme-adjusted" odds ratios. All significant risk factors from the three theme-adjusted models were then considered simultaneously to quantify their independent importance for the development of overweight. Stepwise backward regression was applied to achieve a parsimonious model.

As participation rates in residential areas with lower estimates of household income were slightly lower than the average, response weights were calculated to overcome potential non-response bias. On the basis of average household incomes according to postal code data from the 2001 census for both participants and non-participants, response rates per decile of household incomes by postal code were calculated. These response rates were subsequently converted into response weights [28]. As all statistical analyses were weighted regarding non-response, they represent provincial population estimates for grade 5 students in Nova Scotia. Missing values for categorical data were considered as separate covariate categories but results are not presented. Stata Version 9 (Stata Corp, College Station, TX, USA) was used to perform the statistical analyses.

This study, including data collection, parental informed consent forms, and data linkage with the NSAPD was approved by the Health Sciences Human Research Ethics Board of Dalhousie University and the IWK Health Centre Research Ethics Board. The authors certify that all applicable institutional and governmental regulations concerning the ethical use of human volunteers were followed during this research.

4.3 Results

In this provincial sample of Canadian Grade 5 students, 33% and 10% of grade 5 students were overweight and obese, respectively. The descriptive statistics and results for the uni- and multivariable analyses are shown in Table 1.

4.3.1 Prenatal factors

In the univariate as well as in the theme-adjusted and fully adjusted analysis, pre-pregnancy weight, smoking during pregnancy, and parity showed statistically significant associations with overweight in the offspring. The odds of overweight in the offspring increased with increasing pre-pregnancy weight. In the fully adjusted model, there was no dose-response for smoking during pregnancy and overweight in the offspring; smoking during pregnancy had an OR of 1.4 for overweight in the child compared to children of mothers who did not smoke during pregnancy.

4.3.2 Child factors

In the univariate analysis, all child factors with the exception of gender, Diet Quality Index and preterm birth showed strong, statistically significant associations with overweight. There was a clear gradient for the association of physical activity (negative) and screen time (positive), respectively, with overweight. In the theme-adjusted analysis, the associations remained significant but were less strong. In the fully adjusted model, physical activity, screen time and birth weight-for-gestational age remained significant. Being born small for gestational age was protective against the development of overweight at age 11, while former large for gestational age infants were at an elevated risk for overweight later in life. Breast-feeding was no longer significant predictor of overweight in the full model.

4.3.3 Family and socioeconomic factors

In the univariate analysis, all family and environment factors with the exception of having siblings showed statistically significant associations with overweight. In the theme-adjusted model, there was an inverse association for household income, neighborhood dwelling value, and parental physical activity with overweight. After adjustment in the full model, only neighborhood dwelling value remained statistically significantly associated with overweight.

The analyses were repeated comparing obese with normal weight children (excluding overweight children); the results were overall more pronounced when compared to overweight and obesity combined. Odds ratios from the fully adjusted obesity model are presented in Table 2.

4.4 Discussion

The present study assessed risk factors for childhood overweight in Canada using a population-based approach. The study identified perinatal and childhood risk factors that may be suitable targets for obesity prevention in different phases of the child's development. We were able to show that prenatal, child, family and socioeconomic factors are all independent risk factors for the development of overweight in Grade 5 school children. Being born SGA appeared to provide some protection for the development of overweight whereas LGA infants were at an elevated risk for becoming overweight. Breast-feeding was a significant protective factor of overweight at age 10 or 11 when considered in conjunction with other child factors. However, when further considered with prenatal and family factors, it was no longer a significant factor. Maternal pre-pregnancy weight and smoking status at admission were the strongest prenatal predictors of overweight. Children that are physically active were at a lower risk of being overweight.

Maternal energy imbalances during pregnancy have been reported to affect fetal growth whereby both under- and over-nutrition in utero may predispose infants to obesity and chronic diseases. Several studies have demonstrated that newborns with higher birth weights are more likely to develop obesity later in life than those with a normal birth weight [9, 15, 29–31]. It has been suggested that fetal hyperglycemia and hyperinsulinemia may alter the hypothalamic-pituitary-adrenal axis resulting in a postnatal hypothalamic dysregulation of appetite in former LGA infants and infants of diabetic mothers [32, 33]. We did not find a statistically significant association between maternal diabetes (pre-existing or gestational) after adjusting for other prenatal factors, which is probably explained by the confounding effect of maternal pre-pregnancy weight. Our approach to consider birth weight-for-gestational age rather than birth weight in order to differentiate between intrauterine growth disturbances and low or high birth weight due to pre- or late term birth, respectively, was also taken by other investigators [13–16, 34–36]. However, only few of these studies reported risk estimates for overweight/obesity by weight-for-gestational age. Danielzik et al. found that both SGA and LGA infants are at an elevated risk for overweight [13] but the relative frequencies of SGA and LGA infants (5 and 16%, respectively) may indicate some selection bias in their sample. In agreement with our results, both O'Callaghan et al. and Whitaker reported approximately 40-50% lower odds of obesity for SGA infants compared to AGA infants [15, 16]. By contrast, infants born LGA were about twice as likely to be obese in early childhood than former AGA infants [14, 16].

The protective effect of being born SGA found in this study can not be easily explained. Other investigators have described an association of low birth weight with central obesity, insulin resistance, and the metabolic syndrome [7]. The reasons for this association are largely unknown. A genetic predisposition resulting in an increased insulin secretion ("thrifty genotype") has been proposed as a potential mechanism [37]. However, these associations between small size at birth were found only after adjusting for an individual's BMI and were frequently not adjusted for birthweight [7]. Thus, a comparison with the results from the current study would not be appropriate. Also, the BMI and measures of central obesity such as the subscapular skinfold thickness or the waist-hip ratio assess different concepts of obesity. For a given BMI, the percentage of body fat and distribution of body fat may vary widely. One may speculate that the low weight-for-age tracks through childhood thereby providing some protection from overweight. Hediger et al. using data from the National Health and Nutrition Examination Survey III (NHANES III) showed that SGA infants remained smaller than their peers in terms of BMI but their skinfold thickness measurements suggested that their lower BMI is the consequence of a reduction in lean body mass with a relative increase in percentage of body fat [38].

Maternal pre-pregnancy weight was the single most important determinant of overweight and obesity in the current study. Other investigators reported similar findings [11, 13, 16, 39, 40]. The association of the pre-pregnancy weight with later overweight may either indicate a genetic component in the child's overweight [41], may reflect an effect of obesity on the intrauterine environment [42], or may be viewed as a marker for their learnt lifestyle behavior [43]. The present study shows that the association between maternal weight and childhood overweight remains strong after adjusting for a number of lifestyle factors, which suggests that the contribution of the latter is probably limited. The hypothesis of a genetic effect contributing to the development of obesity is supported by a number of sibling, twin and adoption studies [41, 44–46]. However, the contribution of a genetic effect to the rising obesity prevalence is likely small as the gene pool would not undergo dramatic changes within two decades. The most likely explanation for the association between maternal weight and overweight in the offspring is that the hormonal milieu in utero creates an environment that leads to macrosomia and hyperinsulinism in the fetus which in turn would favor the later development of overweight. The role of the prenatal environment is further highlighted by the observation that the associations of parental weight with macrosomia or a child's later overweight are stronger for the mother than for the father [47, 48]. Irrespective of the mechanism, the association of maternal obesity with a child's susceptibility for obesity is alarming as it represents an accumulation of risk for obesity for future generations [49]. Breaking this vicous cycle constitutes a yet unexplored avenue in obesity prevention [50]. Pre-pregnancy counseling should be advocated but not be limited to pre-pregnancy weight management and also include advice on the importance of healthy eating and active living for their (future) kids. Such broader approaches may have the potential to address several of the risk factors simultaneously and thus have a bigger impact.

The effect of breastfeeding for obesity later in life has extensively been investigated and a recent systematic review concluded that breast-feeding seems to have a small but consistent protective effect against obesity in children [51]. However, while a number of studies [39, 40, 52, 53] found a consistent moderate effect after adjusting for a number of confounders, we and others found only a weak or no statistically significant effect [11, 15, 54, 55]. Another Canadian study by Dubois and Girard also showed no statistically significant effect of breast-feeding on overweight in preschool children after adjusting for confounders such as socioeconomic status and parental weight status [56]. Other explanations for the differing results could be varying definitions and assessment methods of breast-feeding, different age periods for outcome assessment, and errors in reporting breast-feeding duration. The current study found a dose-response relationship for breast-feeding in the univariate analysis. This relationship weakened after adjusting for other child factors and was further dampened when also considering prenatal and family factors, indicating that the effect of breast-feeding on obesity may in large part be explained by confounding factors. It is possible that by contrast to previous studies, the current study was better able to minimize confounding owing to the availability of measured weights from both children and their mothers together with various important lifestyle and socioeconomic factors.

In keeping with results from previous studies [14, 57, 58], smoking during pregnancy was associated with higher odds of overweight in the offspring. This finding may appear surprising as mothers who smoke have infants with lower birth weight [59]. The mechansim by which infants of smoking mothers are put at a higher risk for later overweight unclear. It has been suggested that in utero exposure to nicotine may alter appetitive behaviors in the child [14].

The strengths of the current study are the population-based approach, the adjustment for non-response, the use of measured maternal weight, birth weight and BMI, the consideration of perinatal factors through linkage with a perinatal database rather than relying on recall, and the ability to adjust for a broad range of lifestyle and socioeconomic factors. It must be acknowledged, however, that responses remain subjective and may be prone to bias. Also, despite the use of non-response weights, it can not be excluded that some selection bias has occurred in the study. Whereas the NSAPD has now moved to the practice of collecting both pre-pregnancy height and weight, maternal height was not recorded in the database at the time this cohort was born and thus maternal BMI (instead of maternal weight alone) could not be included in the current study. Finally, owing to the study design, we were not able to assess growth during first years of life, which has been shown to be an important determinant of later overweight and obesity [31, 60].

4.5 Conclusion

This Canadian population-based study on early life risk factors for childhood overweight has shown potential targets for prevention of childhood overweight and obesity. Overweight young women should be advised on the importance of healthy eating, active living and maintaining a healthy weight in the pre-pregnancy years to reduce the risk of overweight in their offspring. Growth of LGA infants, especially of those born to overweight mothers, should be closely monitored and early dietary counseling should be provided. Later in childhood, promotion of physical activity may offer substantial potential for prevention or reduction of overweight.

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4.7 Tables

	Prevalence	Univariate	Theme-adjusted	Fully adjusted
Pre-pregnancy weight				
$<$ 60 kg	41 %	1.00	1.00	1.00
60 to 70 kg	25 %	1.53 [1.25,1.88]	1.59 [1.30,1.96]	1.55 [1.26,1.91]
70 to 80 kg	13 %	1.99 [1.58,2.51]	2.06 [1.63,2.60]	1.93 [1.52,2.45]
$>$ 80 kg	10 %	4.57 [3.52,5.94]	4.76 [3.65,6.21]	4.42 [3.38,5.78]
Smoking during pregnancy				
None	69 %	1.00	1.00	1.00
$>$ 0 to 0.5 packs per day	16 %	1.33 [1.11,1.60]	1.47 [1.21,1.78]	1.43 [1.17,1.75]
$>$ 0.5 packs per day	10 %	1.41 [1.08,1.83]	1.51 [1.16,1.98]	1.42 [1.08,1.88]
Parity				
Para I	44 %	1.00	1.00	1.00
Para II	37 %	1.00 [0.85,1.17]	0.98 [0.83,1.16]	0.94 [0.80,1.10]
Para III or higher	19 %	0.73 [0.59,0.92]	0.73 [0.58,0.91]	0.67 [0.54,0.84]
Maternal hypertension during pregnancy				
No	91 %	1.00	–	–
Yes	9 %	1.26 [0.97,1.65]	–	–
Maternal age				
$<$ 20 years	5 %	1.00	–	–
20 to 24 years	20 %	0.81 [0.54,1.20]	–	–
25 to 29 years	38 %	0.76 [0.53,1.10]	–	–
30 to 34 years	28 %	0.72 [0.49,1.08]	–	–
$>$ 34 years	9 %	0.76 [0.49,1.17]	–	–
Maternal diabetes				
No	98 %	1.00	–	–
Yes	2 %	1.40 [0.86,2.27]	–	–
Gender				
Male	48 %	1.00	–	–
Female	52 %	0.96 [0.84,1.09]	–	–
Physical activity				
$\leq$ 2x / week	22 %	1.00	1.00	1.00
$>$ 2 to 4x / week	17 %	0.91 [0.71,1.18]	0.90 [0.69,1.17]	0.89 [0.67,1.17]
$>$ 4 to 7x / week	33 %	0.68 [0.55,0.85]	0.72 [0.58,0.90]	0.73 [0.58,0.91]
$>$ 7x / week	25 %	0.57 [0.46,0.69]	0.60 [0.49,0.74]	0.65 [0.52,0.80]
Screen time (TV/ computer/video games)				
$\leq$ 1 h / day	10 %	1.00	1.00	1.00
$>$ 1 to 3 h / day	57 %	1.39 [1.07,1.81]	1.29 [1.00,1.67]	1.26 [0.97,1.64]
$>$ 3 to 6 h / day	24 %	1.92 [1.41,2.62]	1.69 [1.24,2.31]	1.65 [1.21,2.27]
$>$ 6 h / day	5 %	2.19 [1.41,3.40]	1.76 [1.13,2.75]	1.82 [1.17,2.85]
Diet Quality Index				
Lowest tertile		1.00	–	–
Medium tertile		0.83 [0.68,1.01]	–	–
Highest tertile		0.90 [0.74,1.09]	–	–
Preterm birth				
No	95 %	1.00	–	–
Yes	5 %	0.95 [0.65,1.39]	–	–
Weight-for-gestational age				
SGA	12 %	0.76 [0.60,0.98]	0.71 [0.55,0.92]	0.68 [0.53,0.89]
AGA	77 %	1.00	1.00	1.00
LGA	11 %	1.37 [1.10,1.70]	1.41 [1.14,1.75]	1.23 [1.00,1.57]
Breast-feeding				
$<$ 1 week or none	39 %	1.00	1.00	–
1 week to 3 months	16 %	0.90 [0.70,1.15]	0.90 [0.69,1.16]	–
$>$ 3 months to 6 months	17 %	0.79 [0.63,0.99]	0.83 [0.66,1.05]	–
$>$ 6 months	23 %	0.66 [0.55,0.80]	0.70 [0.58,0.85]	–

	Prevalence	Univariate	Theme-adjusted	Fully adjusted
Parental physical activity (self-rated)				
Low	25 %	1.00	1.00	–
Medium	54 %	1.30 [1.07,1.57]	1.27 [1.05,1.54]	–
High	18 %	1.87 [1.51,2.31]	1.81 [1.46,2.23]	–
Parental diet quality (self-rated)				
Low	46 %	1.00	–	–
High	54 %	1.41 [1.21,1.65]	–	–
Has siblings				
No	14 %	1.00	–	–
Yes	86 %	1.00 [1.00,1.00]	–	–
Household income				
$0 to $20,000	8 %	1.00	1.00	
$20,001 to $40,000	18 %	1.02 [0.74,1.39]	1.03 [0.75,1.41]	
$40,001 to $60,000	21 %	0.79 [0.59,1.07]	0.84 [0.62,1.13]	
> $60,000	31 %	0.63 [0.47,0.84]	0.72 [0.53,0.96]	
Parental education				
Secondary school or less	29 %	1.00	–	–
College	36 %	0.85 [0.71,1.02]	–	–
University	22 %	0.63 [0.51,0.78]	–	–
Graduate university	8 %	0.61 [0.45,0.85]	–	–
Neighborhood income				
Lowest tertile		1.00	–	–
Medium tertile		1.03 [0.84,1.27]	–	–
Highest tertile		0.76 [0.61,0.94]	–	–
Neighborhood dwelling value				
Lowest tertile		1.00	1.00	1.00
Medium tertile		0.83 [0.68,1.00]	0.86 [0.71,1.05]	0.84 [0.69,1.02]
Highest tertile		0.62 [0.50,0.75]	0.68 [0.55,0.83]	0.68 [0.55,0.85]

Table 4.1: Prevalences and associations (Odds Ratio and 95% confidence interval) of child, family/environment, and perinatal factors with overweight in Grade 5 students in the 2003 Children's Lifestyle and School Performance Study (n=3351). The prevalences represent population estimates as they were weighted to the Nova Scotia population.

	Fully adjusted model
Maternal pre-pregnancy weight	
$<$ 60 kg	1.00
60 to 70 kg	2.24 [1.62,3.12]
70 to 80 kg	3.01 [2.01,4.51]
$>$ 80 kg	9.54 [6.24,14.58]
Smoking at admission	
None	1.00
$>$ 0 to 0.5 packs per day	1.74 [1.23,2.45]
$>$ 0.5 packs per day	1.94 [1.33,2.82]
Parity	
Para I	1.00
Para II	0.63 [0.49,0.82]
Para III or higher	0.51 [0.36,0.73]
Physically active	
$\leq$ 2x / week	1.00
$>$ 2 to 4x / week	0.93 [0.62,1.40]
$>$ 4 to 7x / week	0.72 [0.52,1.00]
$>$ 7x / week	0.43 [0.28,0.65]
Television/computer/video	
$\leq$ 1 h / day	1.00
$>$ 1 to 3 h / day	2.24 [1.25,4.01]
$>$ 3 to 6 h / day	3.59 [1.92,6.72]
$>$ 6 h / day	4.96 [2.23,11.01]
Weight-for-gestational age	
AGA	1.00
SGA	0.65 [0.41,1.03]
LGA	1.85 [1.29,2.64]
Neighborhood dwelling value	
Lowest tertile	1.00
Medium tertile	0.71 [0.51,0.98]
Highest tertile	0.45 [0.32,0.63]

Table 4.2: Associations of child, family/environment, and perinatal factors with obesity in Grade 5 students in the 2003 Children's Lifestyle and School Performance Study.

5 Prevention potential of risk factors for childhood overweight

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5.1 Introduction

The prevalence of childhood overweight in Canada has doubled since the early 1980s [1, 2]. In Canada, 26% of children and youth are overweight and 8% are obese [3]. Poor nutrition, lack of physical activity, television watching, formula feeding, and parental overweight have been identified as risk factors for childhood overweight [4–8]. However, to better target prevention initiatives, policy makers not only require information about risk factors but also require an understanding of their preventive potential, information that is not provided by relative risks and odds ratios. To assess the preventive potential of a risk factor, the population-attributable risk fraction (PARF) is commonly used. The PARF is the proportion of the total disease burden in a population that is due to a certain cause of that disease. The objective of the current study was to estimate the PARF for childhood overweight risk factors as identified by a population-based study of elementary school children in Nova Scotia.

5.2 Methods

5.2.1 Children's Lifestyle and School Performance Study

The CLASS (Children's Lifestyle and School Performance Study) is a population-based survey of Grade 5 students and their parents in the Canadian province of Nova Scotia in 2003 [5]. The study consisted of a questionnaire that was completed at home by the parents; a Canadianized version of the Harvard Youth/Adolescent Food Frequency Questionnaire (YAQ) [9] administered to the students in the schools by study assistants; and a measurement of the students' height and weight. The home questionnaire collected information on sociodemographic factors, the child's place of birth and residency, as well as household income level, educational attainment, breast-feeding practices, self-rated parental physical activity and diet quality, and questions on the frequency of their child's physical activities and the number of hours of sedentary activities ("screen time": watching television, working on a computer, playing video games). The questions on physical and sedentary activity were taken from the Statistics Canada National Longitudinal Survey of Children and Youth [10]. Standing height was measured to the nearest 0.1 cm after students had removed their shoes; body weight was measured to the nearest 0.1 kg on calibrated digital scales.

In addition to the above information, participating parents were asked to provide their Nova Scotia Health Insurance number and informed consent to allow future linkage with birth and administrative health databases. Of the 291 public schools in Nova Scotia (>97% of students in Nova Scotia attend public schools) with grade 5 classes, 282 (96.9%) participated in the study. The average rate of return of questionnaire and consent form was 51.1% per school. One of the seven provincial school boards did not allow measurements of height and weight. A total of 4298 students participated in the study and had their height and weight measured. Overweight and obesity were defined using the International Obesity Task Force body mass index (BMI) cut-off points established for children and youth [11]. These cut-off points are based on health-related adult definitions of overweight ($\geq$ 25 kg/m^2) and obesity ($\geq$ 30 kg/m^2) but are adjusted to specific age and sex categories for children.

5.2.2 Perinatal Data

The Nova Scotia Atlee Perinatal Database (NSAPD) collects demographics, procedures, interventions, maternal and newborn diagnoses, and morbidity and mortality information for all pregnancies and births occurring in hospitals in Nova Scotia since 1988. Linkage of the CLASS data with the NSAPD was carried out by the Reproductive Care Program of Nova Scotia that administers the database. A combination of deterministic and probabilistic matching was used to link the two datasets. Of the 4298 students in the CLASS study with measured height and weight data, 3426 (79.7%) could be linked with information in the NSAPD. The most common reason for an unsuccessful linkage was that children were born outside the province of Nova Scotia (12.4%); for the remaining children, parents did provide an erroneous or no health insurance number. Seventy-five students (2.2%) were excluded due to missing or improbable data for birth weight and gestational age, leaving a final sample of 3351 children (78.0%).

5.2.3 Data Analysis

As participation rates in residential areas with lower estimates of household income were slightly lower than the average, response weights were calculated to overcome potential non-response bias. On the basis of average household incomes according to postal code data from the 2001 census for both participants and non-participants, response rates per decile of household incomes by postal code were calculated. These response rates were converted into response weights. As all statistical analyses were weighted regarding non-response, they represent provincial population estimates for grade 5 students in Nova Scotia.

A logistic regression model for the outcome overweight was built using Hosmer and Lemeshow's purposeful selection procedure [12]. School was treated as a random factor. The parsimonious model contained the following predictors: Pre-pregnancy weight; smoking status on admission to the delivery ward (as proxy for smoking during pregnancy); parity; physical activity (parent report); sedentary activity (parent report); weight-for-gestational-age (based on birth weight data from the perinatal database; classification as small (SGA), appropriate (AGA) or large for gestational age (LGA) according to Canadian reference values for birth weight [13]; school neighbourhood dwelling value (based on postal code data from the 2001 Census). Details on the model and the CLASS/NSAPD linkage study have been published elsewhere [14].

The PARF of an exposure is the proportional reduction in average disease risk that would be observed if the exposure in question were removed [15]. The unadjusted PARF is calculated as

$$PARF = \frac{100 \times (Pr(Disease) - Pr(Disease\ in\ unexposed))}{Pr(Disease)}$$

To determine the multivariable-adjusted PARF of each risk factor, the probabilities in above formula were predicted from the multiple regression model [16, 17]. We predicted the mean adjusted probability for being overweight using i) the original data (= *Probability (Disease)*) and; ii) after setting the risk factor of interest to zero (= *Probability (Disease in unexposed)*). The PARFs were then calculated using these estimates in above equation as we and others successfully did in the past [18, 19]. The 95% confidence intervals for the PARFs were calculated using 10,000 Monte Carlo replications with random coefficients based on the original parameter estimates and their standard errors. The 2.5^{th} and 97.5^{th} percentile were used as the upper and lower confidence limits. As the parsimonious regression model did not contain interaction terms, the PARFs calculated using above approach are additive. The PARFs for the potentially preventable risk factors (low physical activity, excess screen time, high maternal pre-pregnancy weight and maternal smoking) were added up to calculate the maximum preventive potential. Stata Version 10 (Stata Corp, College Station, TX, USA) was used to perform the statistical analysis.

This study, including data collection, parental informed consent forms, and data linkage with the NSAPD was approved by the Health Sciences Human Research Ethics Board of Dalhousie University, the IWK Health Centre Research Ethics Board and the Joint Data Access Committee of the Reproductive Care Program of Nova Scotia.

5.3 Results

Thirty-three percent of the Grade 5 students in the province of Nova Scotia were overweight. Of the risk factors included in the parsimonious model, physical activity, sedentary activity, maternal smoking during pregnancy, and, with some limitations, maternal pre-pregnancy weight can be considered preventable. There was a gradient for the association of physical activity (negative), sedentary activity and maternal pre-pregnancy weight (positive), respectively, with the risk for overweight. Sedentary activity (15.5%) and maternal pre-pregnancy weight (11.6%) appeared to offer the largest potential for prevention. As PARFs are additive, in total (when considering maternal pre-pregnancy weight preventable) 42.1% (95%CI 31.5; 48.5) of overweight in childhood could potentially be prevented. Odds ratios and PARFs from the multivariable adjusted model are presented in Table 1.

5.4 Discussion

The present study is the first in Canada to investigate the preventive potential of risk factors for childhood overweight. Using population-based data, we were able to show that about 40% of childhood overweight cases could potentially be prevented through promotion of healthy eating and active living, and cessation of smoking during pregnancy. High maternal pre-pregnancy weight and excess sedentary activity emerged as the factor with the greatest potential for prevention.

Excess screen time contributed the largest PARF identified in our study. The observation that screen time remained a strong risk factor after considering physical activity in the analysis underlines the fact that mechanisms other than a decline in energy expenditure [20] are involved in the relationship between screen time and overweight [21, 22]. One may be the influence of commercials on food choices and nutrition. The majority of foods featured in commercials targeted at children are energy-dense, high in fat and/or sugar and commonly do not meet dietary recommendations [23]. Television viewing may also provide an opportunity to consume snack foods [24], resulting in an increased calorie intake [25]. Finally, having meals in front of the TV instead of with the family may reduce the nutritional and psychosocial benefits of family meals [26] and may be associated with higher BMI in children [27].

In keeping with other studies from the US and Canada [8, 28, 29], maternal pre-pregnancy weight was identified as a strong determinant of a child's risk for being overweight at age 11. In order to consider maternal overweight an attributable risk factor for childhood overweight, a causal link between the two needs to be established. The association between maternal weight their child's overweight can potentially be explained through three mechanisms: (i) genetic factors [30], (ii) acquired poor health and lifestyle behaviours [31], and (iii) alterations of the intrauterine environment due to the maternal pre-diabetic state [32], as discussed in a previous publication [14]. While it is not possible at this stage to establish a direct causal mechanism between maternal overweight and their offspring's excess body weight, these data suggest that secondary prevention of overweight in young women may reduce the risk of overweight in their children.

Only a few studies have examined the population attributable risk for childhood overweight [19, 33, 34]. Toschke et al., using German population-based data, reported that 42.5% of overweight cases in Germany are due to potentially preventable risk factors. Parental obesity was considered a non-preventable risk factor and accounted for 15% of overweight cases. Among the preventable risk factors, TV watching > 1 h per day and low meal frequency (< 5 meals per day) contributed a PARF of 13.0 and 14.8% [19]. In the 1990s, population-based study in 10 to 15 year old youth in the US reported that more than 60% of overweight were attributable to excess TV viewing time [34]. However, PARFs were calculated based on non-adjusted prevalences and perhaps confounded by socioeconomic factors. A study in primary school children in Thailand found that the highest PARF was for family history of obesity (34%), followed by those for low exercise level (12%) and an obese or overweight mother (10%) [33].

The strengths of the current study are the use of two population-based data sources, the weighting for non-response, the ability to adjust for a broad range of perinatal, lifestyle and socioeconomic factors, and the use of measured BMI. However, the study also has a few limitations that need to be acknowledged. Part of the data (physical activity, sedentary activity) used in the present study comes from a cross-sectional survey, while calculation of PARFs requires cohort data to establish causality between the exposure and the outcome. Thus, the PARF estimates for the two activity measures must be interpreted with caution. Finally, the use of odds ratios instead of risk ratios may have resulted in an overestimation of the PARF. In the absence of an established definite causal link between maternal pre-pregnancy weight and a child's overweight, the interpretation of the PARF of maternal weight remains somewhat speculative. Further, the use of maternal body weight instead of BMI for the assessment of maternal weight status may have introduced some misclassification bias.

5.5 Conclusion

The present study identified excess screen time and maternal pre-pregnancy weight as potentially preventable risk factors with the largest potential for prevention of childhood overweight at age 11 in Canada.

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5.7 Table

	Prevalence	Multivariable adjusted PARF	Multivariable adjusted OR
Physically active			
$\leq$ 2x / week	22 %	5.5 % [2.8, 8.6]	1.55 [1.25, 1.91]
$>$ 2 to 4x / week	17 %	2.8 % [0.2, 5.4]	1.35 [1.03, 1.77]
$>$ 4 to 7x / week	33 %	2.1 % [-1.8, 5.9]	1.12 [0.91, 1.39]
$>$ 7x / week	25 %	Reference	1.00
Television/computer/video			
$\leq$ 1 h / day	10 %	Reference	1.00
$>$ 1 to 3 h / day	57 %	7.0 % [-0.9, 14.6]	1.26 [0.97, 1.62]
$>$ 3 to 6 h / day	24 %	6.9 % [2.6, 11.4]	1.66 [1.21, 2.27]
$>$ 6 h / day	5 %	1.6 % [0.4, 3.1]	1.79 [1.14, 2.80]
Maternal pre-pregnancy weight			
$<$ 70 kg	66 %	Reference	1.00
70 to $<$ 80 kg	13 %	3.6 % [1.9, 5.5]	1.61 [1.30, 2.00]
$\geq$ 80 kg	10 %	8.0 % [5.7, 10.8]	3.68 [2.82, 4.80]
Smoking at admission			
None	69 %	Reference	1.00
$>$ 0 to 0.5 packs per day	16 %	2.9 % [1.2, 5.0]	1.39 [1.14, 1.70]
$>$ 0.5 packs per day	10 %	1.9 % [0.4, 3.6]	1.41 [1.07, 1.86]
Neighbourhood dwelling value			
Lowest tertile		5.7 % [2.5; 9.1]	1.46 [1.18; 1.81]
Middle tertile		4.0 % [0.4; 7.7]	1.23 [1.02; 1.48]
Highest tertile		Reference	1.00
Weight-for-gestational age			
AGA	77 %	Reference	1.00
SGA	12 %	-2.7 [-4,3; -1.0]	0.66 [0.51; 0.86]
LGA	11 %	1.6 [0.2; 3.2]	1.29 [1.03; 1.62]

Table 5.1: Prevalences, multivariable adjusted population attributable risk fractions and odds ratios for preventable risk factors of childhood overweight.

6 Use and cost of health services among overweight and obese Canadian children

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6.1 Introduction

Overweight and obesity is an acknowledged global public health problem affecting both adults and children. In 2004, 26% of Canadian children and youth aged 2-17 years were found to be overweight or obese [1]. Rates of obesity alone have increased from 2% to 10% for boys and 2% to 9% for girls over the past 15 years, with Atlantic Canadian children and youth at the forefront of this rise, having the highest rates of overweight and obesity in the country [1]. At the same time, obesity-related clinical disorders such as hypertension, obstructive sleep apnea, polycystic ovary syndrome and slipped capital femoral epiphysis are seen with increasing frequency in children [2]. As a consequence, overweight and obese children may use health care services more often than their normal weight peers, which in turn may result in higher direct and indirect health care costs in this population. An understanding of these associations would be highly relevant to policy makers and healthcare delivery organizations who are faced with the question of whether or not to invest into overweight prevention programs among children and adolescents.

Most studies so far on health care utilization in overweight children have been performed in the US whose provider-based health care systems differs considerably from the Canadian health care system. Over and above the limited applicability of US data, the Canadian public health care system provides an ideal setting for studying health care utilization at a population level. Using data from a population-based survey among grade 5 children in the Canadian province of Nova Scotia linked with longitudinal administrative health data, the current study assesses health service utilization across categories of weight status to determine whether overweight or obesity are associated with increased utilization patterns in this population.

6.2 Methods

6.2.1 Study Design

The study design is a prospective cohort study using data from the 2003 Children's Lifestyle and School Performance Study (CLASS) [3] that were linked with Nova Scotia administrative health data.

6.2.2 Children's Lifestyle and School Performance Study

The CLASS is a population-based survey of grade five students (aged 10-11 years at the time of data collection) and their parents in the Canadian province of Nova Scotia. The study consisted of a home questionnaire that was completed by the parents; the Harvard Youth/Adolescent Food Frequency Questionnaire (YAQ) [4] validated for this age group and adapted to reflect Canadian dietary patterns; and a measurement of the students' height and weight. The home questionnaire collected information on sociodemographic factors, the child's place of birth and residency, as well as household income level and highest parental educational attainment. The student surveys were administered to the students in the schools by research assistants. Standing height was measured by a research assistant to the nearest 0.1 cm after students had removed their shoes; body weight was measured to the nearest 0.1 kg on calibrated digital scales. In addition to the above information, participating parents were asked to provide their child's Nova Scotia Health Insurance number and to give consent to allow future linkage of the data with administrative health databases.

More than 97% of students in Nova Scotia attend public schools. Of the 291 public schools in Nova Scotia with grade five classes, 282 (96.9%) participated in the study. The average rate of return of questionnaire and consent form was 51.1% per school. One of the seven provincial school boards did not allow measurements of height and weight. A total of 4412 students took part in the study.

6.2.3 Administrative Health Data

The administrative health datasets consist of the Medical Services Insurance (MSI) database, Canadian Institute for Health Information Discharge Abstract Database (CIHI DAD), and the Nova Scotia Atlee Perinatal Database (NSAPD). Data were available from 1992 (i.e. the child's year of birth) up to 2006 with the exception of hospital cost data, which were only available from 2003 to 2006.

The MSI database is administered by Medavie Blue Cross for the province of Nova Scotia and contains administrative records for each insured health service rendered by a physician (including emergency room visits) and paid for by the Nova Scotia provincial healthcare system. The CIHI DAD contains a comprehensive administrative transcription of each admission to a Nova Scotia hospital facility. Both of these databases contain individual patient-level information including patient demography (age, gender, location, etc), attending physicians, diagnoses and procedures performed, service transfers while in hospital, specialty services received (e.g. physiotherapy, occupational therapy), and case complexity (e.g. resource intensity weight). The NSAPD is managed by the Reproductive Care Program of Nova Scotia and contains demographics, procedures, interventions, maternal and newborn diagnoses, and morbidity and mortality information for all pregnancies and births occurring in hospitals to residents of Nova Scotia since 1988 [5].

Aggregate costs of health care episodes for physician visits and hospitalizations were obtained from the Ontario Case Costing Initiative [6]. For hospitalization costs, data were only available for fiscal years 2003 to 2006. For physician visits, data were available for all years from birth to 2006. Costs were adjusted to 2006 Canadian Dollars using the Canadian Consumer Price Index [7]. A combination of deterministic and probabilistic matching was used to link the administrative health datasets with the CLASS study data. Of the 4412 students in the CLASS study with valid home survey and school information, 4380 (99%) could be linked with information in the administrative datasets. In the remaining children, parents had provided an invalid or no health insurance number.

6.2.4 Outcomes

Primary Outcome. The primary outcome was the total health care costs (in Canadian Dollars) for the three years following the CLASS survey (2003-2006).

Secondary Outcomes. Secondary outcomes are the students' lifetime physician costs (from birth to age 14), the number of family physician visits (2001-2006), and the number of referrals for specialist health care (2001-2006). This time frame was chosen to reflect health utilization patterns around the CLASS data collection period.

6.2.5 Exposures

The main exposure was weight status (normal weight, overweight, obese) in grade five children as defined by the age- and gender-specific body mass index (BMI) cut-off points for children and youth established by the International Obesity Task Force [8] based on health-related adult definitions of overweight ($\geq$ 25 kg/m^2) and obesity ($\geq$ 30 kg/m^2). For 3399 of the 4380 children (78%) included in this study, BMI measurements were available.

Other exposures considered were gender, household income (4 levels: \$0 to \$20,000, \$20,001 to \$40,000, \$40,001 to \$60,000, $>$ \$60,000; 23% missing values), parental education attainment (3 levels: Secondary school or lower, College, University; 7% missing values), and geographic region (urban, rural; based on Canadian postal code data).

6.2.6 Statistical Analysis

Descriptive statistics for the outcomes were calculated by weight status, and socio-demographic factors. Cumulative physician costs were calculated by weight status and year of life. Due to the non-normal distribution of the physician cost data, a permutation test with 5000 Monte Carlo replications was used to test in which year the difference in median cumulative costs for normal weight students vs. overweight and obese students, respectively, became statistically significant. A two-sided p-value < 0.05 was considered statistically significant.

The association between weight status and health care utilization was investigated using a series of multivariable regression models. Regression models were adjusted for gender, income, education, and geographic region. Missing values for weight status (22%), income (23%), and education (7%) were considered as separate covariate categories in the regression models but results are not presented. The health care cost data were skewed to the right and were therefore log-transformed to yield a normal distribution; for students with C$0 health care costs (n=159 for primary cost outcome, n=0 for secondary cost outcome), cost values were replaced with half the observed minimum non-zero health care costs (0.5 x C$27) before log-transformation.

Linear regression was used to examine associations between weight status and log-transformed costs. Regression coefficients and their confidence intervals were back-transformed by taking the anti-log. The exponentiated coefficients represent cost ratios relative to the reference group. After ascertaining homoscedascity, the exponentiated intercept was multiplied by Duan's smearing estimator [9] to correct for the biased estimate of the intercept. The back-transformed intercept corresponds to the adjusted mean costs in the students in the reference group(s). The distribution of the number of family physician visits and specialist referrals showed overdispersion, therefore these outcomes were modelled using negative binomial regression.

As participation rates for the CLASS study in residential areas with lower estimates of household income were slightly lower than the average, response weights were calculated to overcome potential non-response bias [3] and to yield provincial population estimates for children born in 1992 in Nova Scotia. Stata/SE Version 11 (Stata Corp, College Station, TX, USA) was used to perform the statistical analyses.

This study, including data collection, parental informed consent forms, and data linkage with the NSAPD was approved by the Health Sciences Human Research Ethics Board of Dalhousie University, the IWK Health Centre Research Ethics Board, the Reproductive Care Program Joint Data Access Committee and the Dalhousie University Population Health Research Unit Data Access Committee.

6.3 Results

Descriptive statistics showed higher health care costs in overweight and obese children, males, children from lower income and education groups, and children residing in urban areas (Table 1). Regression analysis consistently demonstrated significantly higher health care costs and utilization in obese children compared to normal weight children while costs and utilization did not differ significantly between normal weight and overweight students. There was also a gradient for higher costs and utilization across the three weight groups. These associations did not change after adjusting for socio-demographic factors. Results from the regression analyses are summarized in Table 2.

Based on the results of the regression analysis for the primary outcome, up to 1.3 and 2.1% of total health care costs between age 11 and 14 years in our population-based sample were attributable to overweight and obesity, respectively. When comparing cumulative physician costs and family physician visits over time, overweight and obese children exhibited higher costs and more intense use compared to normal weight children as early as five years of age. The cost differential for the overweight and obesity vs. normal weight appeared to increase with age (Figure 1). For obese students and overweight students, the difference in median costs compared to that of normal weight students was statistically significant at age 3 years and 8 years, respectively.

6.4 Discussion

The present study is the first in Canada to investigate the association between measured weight status and health care utilization in pre-adolescent children. Using administrative health data linked with a population-based survey, we were able to show that obese children had incurred significantly higher health care costs and had undergone physician visits and specialist referrals more often than their normal weight peers. Health care utilization did not differ significantly between normal weight and overweight students.

In the last few years, a number of studies in North America have examined the association between BMI and health care expenditures [10–16]. The majority of papers reported higher costs and higher frequency of care provider visits, while only few [13–15] found no or only negligible differences in costs. Studies in the US were often confined to individuals covered by a certain insurance and therefore are somewhat limited in their generalizability. By contrast, the Canadian publicly funded health care system provides an excellent opportunity to study health care utilization in population-based samples. In the only other Canadian study so far, Janssen et al. linked data from the Canadian Community Health Survey with physician cost data in the province of Ontario for the years 2003 and 2004 [13]. In the adjusted model, overall mean physician costs were comparable in normal-weight adolescents and overweight/obese adolescents. The difference to the present study's findings might be explained by the fact that Janssen et al. compared costs in overweight and obese children combined vs. normal weight children while the strongest effect on health care utilization in the present study was observed at the more extreme end of the BMI spectrum. Other differences to our study were the additional adjustment for smoking status, alcohol consumption and physical activity, as well as the reliance on self-reported information for BMI. The findings of the present study may also apply to other Western countries with a publicly funded health care system. To the best of our knowledge, there is only one European study that assessed health care utilization in overweight/obese children [17]. Using national discharge data from Irish acute hospitals, the authors found a substantial increase in the number of discharges and the length of stay for obesity-related conditions (as per ICD-9 coding) from 1997 to 2004.

Due to the absence of data on the diagnosis and treatment cost by disease, we were not able to investigate the reasons for the higher health care costs in overweight and obese children. Adult obesity-related diseases such as type 2 diabetes mellitus and cardiovascular disease are seen with increasing frequency in children [18] but are still relatively rare and unlikely to account for the observed differences. Rather, common pediatric diseases such as asthma or obstructive sleep apnea that are seen more frequently in overweight children are likely responsible. An US study recently reported that overweight children were significantly more likely to be admitted for an asthma exacerbation than normal weight children [19]. On a similar token, another study found that obese children undergoing tonsillectomy incurred $1000 higher costs than their normal weight peers [20]. Besides a number of physical diseases that are more prevalent in obese children, several studies have also reported a higher frequency of mental disorders in obese children [21, 22]. A study in the US examining health care utilization in 3 to 17 year old children in an integrated health care system showed that mental health-related visits were more common in obese children [10]. Finally, Wang and Dietz investigated data from the US National Hospital Discharge Survey [23] and found that asthma and some mental disorders were the most common principal diagnoses when obesity was listed as a secondary diagnosis.

The additional cumulative physician costs associated with overweight and obesity (relative to normal weight children) up until 14 years of age as found in the present study only amount to a raw value of C$156 and C$349 (see Figure 1), respectively, per year. However, when assessing the public health significance of this finding, one needs to consider the high prevalence of overweight/obesity and, more importantly, the fact that physician costs only represent 13% of total health care costs (adults and children combined) in Canada [24]. Other direct costs, such as hospital costs or drug expenditures, add further to the magnitude of these figures. It can be expected that, since overweight and obesity track into adulthood, the long exposure to overweight since childhood will result in earlier occurrence of complications with associated increased costs. In Nova Scotia, the health budget consumed 48% of the provincial budget in 2005-6, compared to 36% in 1995-96 and is projected to increase to 66% by 2013 [25]. Based on Canadian national data [26], it has been estimated that about 6.8% of the provincial health budget are costs incurred as a result of obesity [27]. These expenditures are unsustainable in the long run and highlight the need for significant investment in prevention programs to lessen the growing prevalence of obesity in children. While it has been argued that obesity prevention is not a cure for increasing health expenditures [28], these data were modelled from age 20 years, where our data suggests that additional costs are incurred from as early as age 5 years.

The strengths of the current study are the use of two population-based data sources, the adjustment for non-response to obtain population estimates, the use of measured BMI as opposed to self-report, the availability of individual-level health care costs, and the ability to adjust for socio-demographic factors in the analysis. The study was limited by the lack of hospital data for the years before 2003, and the non-availability of drug prescription costs. Based on these findings, one would expect the cost differential between obese and normal weight children to be much higher had all health care costs been available. Adjustment for socioeconomic factors was based on self-reported data with approximately 23% missing values for household income. Thus, we cannot exclude misclassification of a family's socioeconomic status. As a result, residual confounding may have occurred and the associations found may rather reflect underlying socioeconomic differences in health care use and disease susceptibility than being a result of the student's overweight itself. Finally, the measurement of height and weight was done at age 10-11 years and it was assumed that a child's weight status remained the same for the years before and after the study. There is the possibility of reverse causation with some health conditions and prescription drugs influencing weight status, which may bias the association between body weight and health care costs. However, there is no clear evidence in the literature that supports this hypothesis.

To conclude, obese children in Nova Scotia have significantly higher health care costs and more physician visits and specialist referrals than their normal weight peers. The health care cost trajectories of normal weight and obese children drift apart as early as 3 years of age. These findings highlight the need for investments in obesity prevention programs. Future research should focus on a better understanding of the reasons for the higher health care costs in obese children.

6.5 References

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6.6 Tables

	Prevalence [%]	Total health care cost 2003-2006 [C$]	Lifetime physician cost 1992-2006 [C$]	# of GP visits 2001-2006	# of specialist referrals 2001-2006
Population	100 %	295(133; 629)	2201 (1449; 3370)	10 (6; 17)	15 (8;24)
Weight Status					
Normal weight	67 %	275 (128; 598)	2147 (1428; 3297)	10 (5; 16.5)	14 (8; 24)
Overweight	23 %	298 (136; 600)	2309 (1463; 3315)	11 (6; 18)	15 (9; 25)
Obese	10 %	356 (140; 721)	2504 (1694; 3725)	13 (5; 17)	17 (10; 29)
Gender					
Male	48 %	316 (135; 670)	2367 (1578; 3627)	10 (5; 17)	15 (8; 25)
Female	52 %	272 (130; 584)	2058 (1341; 3198)	10 (6; 17)	14 (8; 24)
Household income					
$0 to $20,000	12 %	368 (181; 761)	2323 (1560; 3677)	12 (7; 20)	18 (11; 28)
$20,001 to $40,000	23 %	283 (116; 626)	2086 (1411; 3348)	11 (5; 17)	15 (8; 25)
$40,001 to $60,000	26 %	299 (136; 607)	2345 (1503; 3470)	11 (6; 18)	15 (8; 25)
> $60,000	38 %	267 (124; 589)	2135 (1409; 3219)	9 (5; 15)	14 (7; 22)
Household education					
Secondary school or less	31 %	317 (137; 693)	2274 (1480; 3511)	11 (6; 18)	16 (8; 26)
College	38 %	297 (132; 616)	2323 (1514; 3518)	11 (6; 17)	15 (8; 24)
University	31 %	271 (132; 590)	2096 (1386; 3075)	9 (5; 16)	13 (7; 23)
Region					
Urban	67 %	308 (136; 656)	2240 (1475; 3474)	10 (5; 17)	15 (8; 25)
Rural	33 %	264 (120; 589)	2127 (1410; 3221)	10 (6; 17)	14 (8; 24)

Table 6.1: Health care cost and utilization in grade five students from the Canadian province of Nova Scotia by weight status and sociodemographic factors. Data are presented as median (25^{th} and 75^{th} percentile).

	Total health care cost 2003-2006 [C$]		Lifetime physician cost 1992-2006 [C$]		# of GP visits 2001-2006		# of specialist referrals 2001-2006	
	Univariate	Multivariable	Univariate	Multivariable	Univariate	Multivariable	Univariate	Multivariable
Weight Status								
Normal weight	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Overweight	1.06 (0.95;1.18)	1.06 (0.95;1.18)	1.03 (0.97;1.08)	1.03 (0.98;1.08)	1.12 (1.04;1.20)	1.10 (1.03;1.19)	1.07 (1.00;1.14)	1.07 (1.00;1.14)
Obese	1.22 (1.03;1.44)	1.21 (1.02;1.43)	1.14 (1.07;1.23)	1.14 (1.06;1.22)	1.26 (1.15;1.37)	1.22 (1.12;1.33)	1.18 (1.08;1.28)	1.17 (1.07;1.28)
Gender								
Male	–	1.00	–	1.00	–	1.00	–	1.00
Female	–	0.91 (0.83;0.99)	–	0.87 (0.84;0.90)	–	1.02 (0.97;1.07)	–	0.96 (0.92;1.01)
Household income								
$0 to $20,000	–	1.28 (1.08;1.51)	–	1.04 (0.96;1.12)	–	1.31 (1.18;1.45)	–	1.24 (1.12;1.36)
$20,001 - $40,000	–	1.01 (0.88;1.16)	–	0.99 (0.93;1.05)	–	1.12 (1.03;1.21)	–	1.09 (1.00;1.18)
$40,001 - $60,000	–	1.05 (0.93;1.18)	–	1.06 (1.01;1.12)	–	1.13 (1.05;1.21)	–	1.09 (1.01;1.17)
> $60,000	–	1.00	–	1.00	–	1.00	–	1.00
Household education								
Secondary school or less	–	1.12 (0.99;1.27)	–	1.09 (1.03;1.15)	–	1.10 (1.02;1.18)	–	1.09 (1.02;1.17)
College	–	1.04 (0.93;1.16)	–	1.12 (1.06;1.17)	–	1.09 (1.02;1.16)	–	1.09 (1.03;1.16)
University	–	1.00	–	1.00	–	1.00	–	1.00
Region								
Urban	–	1.16 (1.07;1.27)	–	1.10 (1.06;1.15)	–	1.03 (0.97;1.08)	–	1.15 (1.09;1.21)
Rural	–	1.00	–	1.00	–	1.00	–	1.00
Constant term *	845.63	816.25	2687.10	2862.54	-	-	-	-

Table 6.2: Exponentiated linear regression coefficients (Total health care cost and lifetime physician cost) and incidence rate ratios (# of family physician visits and # of specialist referrals) and their 95% confidence intervals (CI) for the association between weight status, gender, household income, household education, geographic region with health service utilization.
* The bias-corrected [9] exponentiated value of the constant term represents the average cost in Canadian Dollar (C$) for a normal weight child (univariate) or a normal weight male child, household income > $60,000, household education University from a rural region (multivariable), respectively. The exponentiated coefficients of the natural logarithm of health care costs are multiplicative relative to the constant term (e.g. in the univariate analysis, an obese child has 22% higher total health care costs [$845.63 $\times$ 1.22] than a normal weight child).

6.7 Figures

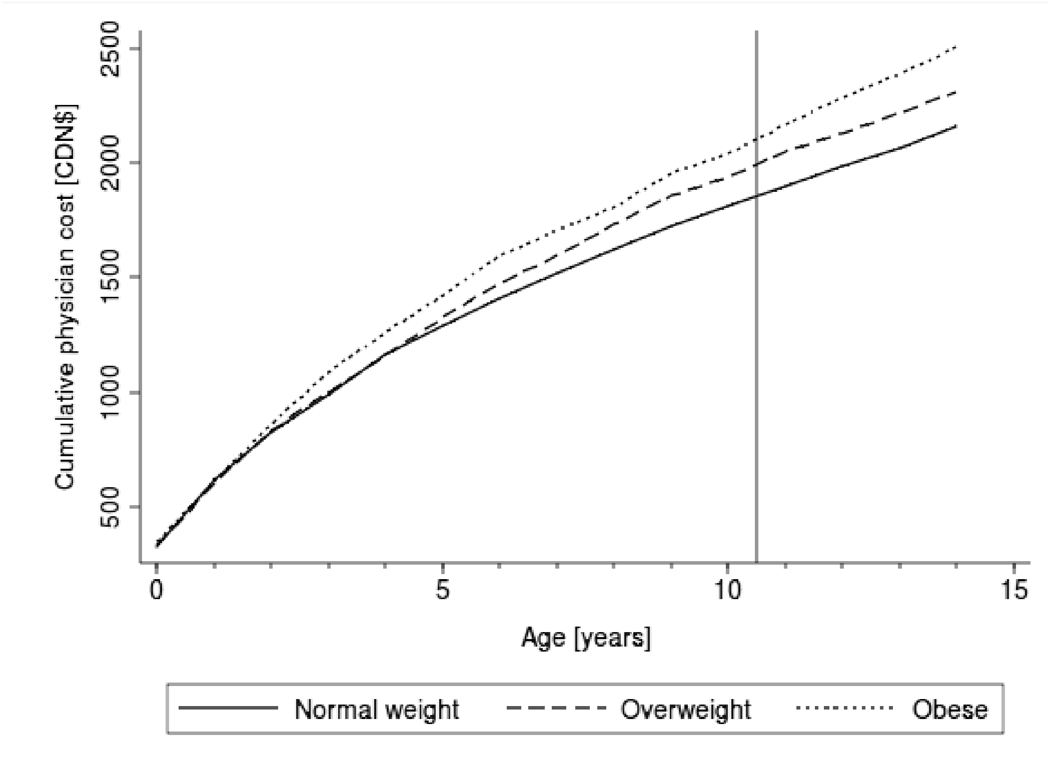

Figure 6.1: Cumulative physician costs from birth (1991/1992) to age 14 by weight status in Canadian children in the province of Nova Scotia.
The vertical line indicates the date of the 2003 Children's Lifestyle and School Performance Study (CLASS).

7 Medication use in normal weight and overweight children in a nationally representative sample of Canadian children

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7.1 Introduction

Childhood obesity has increased considerably over the past few decades and is now a major public health concern worldwide [1]. In Canada, rates of childhood obesity have tripled, with an estimated 26% of children aged 2 to 17 year being overweight and 8% being obese [2]. Overweight often persists into adulthood and is associated with a spectrum of chronic conditions later in life, including cardiovascular disease, osteoarthritis and certain types of cancer [3, 4]. Moreover, childhood obesity is a further cause for concern given the emergence of adult onset diseases, such as type 2 diabetes and the metabolic syndrome, among overweight children [5, 6].

Not only does excess body weight among children result in diminished quality of life for the individual [7, 8], but the growing obesity epidemic and its related morbidities place considerable financial burden on healthcare systems, with total direct costs estimated to be up to $6.0 billion in Canada [9]. More importantly, however, is that overweight children, like adults, are at an increased risk of developing serious medical conditions and psychosocial complications compared to their normal weight counterparts [10, 11]. Specifically, children who are overweight are at an increased risk of developing musculoskeletal problems [12], asthma [13, 14], cardiovascular disease [15], depression [16], and sleep apnea [17]. As a result, health care costs and utilization in overweight and obese children is already higher than in their normal weight peers [18–22].

We have previously shown that obese children between 11 and 14 years of age have 21% higher physician and hospital costs than normal weight children [21]. The second largest cost share behind hospital costs in the Canadian health care system is medication use. Prescription drug costs account for 17% of health care spendings in Canada and their share has doubled over the last two decades [23]. Thus, the differential between the health care costs for obese and normal weight children may be even larger if medication costs are considered. In the presence of ever rising health care expenditures, characterizing these disparities in prescription drug use will provide a more complete picture on the burden of the current childhood obesity epidemic and can aid with health care planning and resource allocation. To the best of our knowledge, no study so far has compared medication use between weight status groups in children in a publicly funded health care system. Therefore, the objective of our study was to compare medication use between normal weight and overweight children in a nationally representative sample from Canada.

7.2 Methods

7.2.1 Study design

The current study used data from the Canadian Health Measures Survey (CHMS). The CMHS is a representative, cross-sectional survey assessing indicators of health and wellness in Canadians between 6 and 79 years [24]. The survey consisted of a household interview to obtain sociodemographic and health information, and a visit to mobile examination centre to perform a number of physical measure tests (including blood and urine samples and a fitness test). The sampling frame of the Canadian Labour Force Survey was used to identify 15 collection sites for the mobile examination centres. Within each collection site, households were selected using the 2006 Census as the sampling frame. A detailed description of the sampling strategy is available elsewhere [24]. Interviews and examinations for the CHMS were performed between 2007 and 2009. The overall response rate was 51.7%. A total of 5604 persons participated in physical examination part of the survey. The present analysis uses data from 2087 children and adolescents between 6 and 19 years of age. Information for the household interview for children 6 and 11 years was provided by an adult with assistance from the child; children 12 years and older answered the questions on their own where possible.

7.2.2 Primary outcome and main exposure of interest

The primary outcome was the number of medications taken by the respondent in the past month. Information on medication use was collected during the household interview. Respondents were asked to name all prescription drugs, over the counter (OTC) drugs, and natural health products they had been taking in the last month. Each medication was classified according to the Anatomical Therapeutic Chemical (ATC) classification system. The ATC is a classification of pharmaceutical products by target organ system [25]. The main exposure of interest was the body mass index (BMI) status based on the cutoffs proposed by the International Obesity Task Force [26].

7.2.3 Covariates

Gender, household education, household income adequacy, and province of residence were used as covariates in the analyses. Household education was used as a 3-level categorical covariate representing the highest level of educational attainment in the household (secondary school or less; some post-secondary education or college; university). Household income adequacy was considered as a 3-level categorical variable that takes into account both the number of people in the household and the total household income from all sources in the 12 months before the interview. Province of residence of the respondents was New Brunswick, Quebec, Ontario, Alberta, or British Columbia.

7.2.4 Statistical analysis

Descriptive data on sociodemographic factors and medication intake by weight status were reported as median or relative frequency as applicable. Associations between weight status and the number of medications taken in the last month were examined using Poisson or, in the presence of overdispersion, negative binomial regression. Separate models were built for number of prescription medications, and number of any medication in each of the ATC level 1 classes A (*Alimentary tract and metabolism*), M (*Musculo-skeletal system*), N (*Nervous system*), and R (*Respiratory system*), respectively. Medications in the remaining ATC domains were infrequently used and were thus not analyzed further. Due to the relatively small number of respondents, propensity scores were used to adjust for potential confounders. A propensity score represents the probability that an individual had a certain exposure status given their set of covariates [27]. Propensity scores for the current study were determined using predictions from a logistic regression model that included gender, household education, household income adequacy, and province of residence of a respondent. All analyses were stratified by age group (6-11 and 12-19 years). Missing values for categorical variables used in the analysis were considered as separate categories but results are not presented. Estimates were obtained using sampling weights provided by Statistics Canada to account for design effect and non-response bias. Standard errors were estimated using a bootstrapping procedure with 11 degrees of freedom as recommended by Statistics Canada for this survey [24]. Statistics Canada recommendations for sampling variability [24] as determined by the coefficient of variation (CV) were followed: Data with a moderate CV (16.6% - 33.3%) must be interpreted with caution and data with a CV of >33.3% were suppressed due to extreme sampling variability. Information based on the information of less than 10 individuals was omitted as per Statistics Canada guidelines. Stata Version 11 (Stata Corp, College Station, TX, USA) was used to perform the statistical analyses.

7.3 Results

A total of 2087 children and adolescents between 6 and 19 years participated in the survey and had valid information on measured BMI. Twenty-three percent of the 6 to 11 year-olds and 28% of the 12 to 19 year-olds were overweight or obese. Demographic information and medication use by weight status is summarized in Table 1. Prescription medication, OTC medication, and natural health product use in the last month was reported by 17, 51, and 25%, respectively, of 6 to 11 year-old children, and 33, 70, and 22%, respectively, of 12 to 19 year-old children. In the younger age group, 69% of children took any type of medication in the past month, whereas this number was 83% in the 12 to 19 years group. Prescription medication use for the most part followed a social gradient with children from socioeconomically disadvantaged households or living in less affluent provinces reporting more frequent drug use (Table 2).

The frequency of medication use did not differ between normal weight and overweight children in the 6 to 11 years age group. For the 12 to 19 year olds, overweight and obese children used prescription medications significantly more frequently in the past month than their normal weight peers whereas for natural health products the opposite was the case (Table 3).

Normal weight children used of medications for the alimentary tract and metabolism more frequently than overweight and obese children in both age groups. In the 12 to 19 years age group, overweight and obese children had a significantly higher rate of usage of nervous system and respiratory medications. Patterns of usage of medications within each of the four ATC top level domains did not differ between normal weight and overweight children with the notable exception of respiratory medications, which saw drugs for the treatment of obstructive airways disease as the most common ATC subclass in overweight and obese children (Table 4).

7.4 Discussion

Our study demonstrates that prescription medication usage was higher among overweight/obese children relative to normal weight children, particularly among older children. Use of OTC medications did not differ by weight status whereas natural health product use was more common in normal weight children. In older children, overweight and obese children were more frequent users of nervous system and respiratory medications. Within the respiratory medication class, drugs for the treatment of obstructive airways disease were more often used by overweight and obese children than by their normal weight peers.

Prescription drug use was fairly common in the 12 to 19 year old group, with one third reporting to have used one or more prescription medications in the past month. There is limited data in the literature on the use of prescription medications in children. Three studies in the US and one study in the Netherlands using prescription expenditure data consistently reported prescription drug use in about 60% of the participating children over the course of a year [28–31]. The seemingly low 1-year prevalence relative to the 1-month prevalence found in our study is readily explained by the fact that only drugs that were covered by the insurance plan were included in the US and Dutch studies. By contrast, our current study assessed all prescription drugs including those not covered by the provincial insurance plan and paid for by the families. Another study using a 15-day recall of prescription drug use in Brazil found a prevalence of 20% in a birth cohort of 11-year old children [32].

The results from our study confirm our hypothesis that the higher health care use observed in overweight and obese children [18–22] is paralleled by a more frequent use of prescription drugs. While there was no significant difference between the two weight status groups in younger children, in the 12 to 19 years age group, overweight and obese children and youth took 59% more prescription drugs than those in the normal weight group. Assuming equal costs for the medications, this finding would translate in 59% higher medication costs. That is the cost differential for prescription medications may even be higher than the 21% difference for hospital and physician costs between obese and normal weight children as previously reported by us [21]. With an overweight/obesity prevalence of 28% in the sample and 59% higher medication costs, approximately 17% (0.28×0.59) of drug expenditures in this age group can be attributed to overweight and obesity. Only two other studies have compared medication use between obese and normal weight children: A study from a regional pediatric health care centre in Israel found about 60% more prescriptions in obese children between 12 and 18 years compared to normal weight children [33]. Data from a follow-up of the PIAMA birth cohort at age 11 years in Brazil showed that obesity is associated with 20% higher intake of medications (both prescription and OTC) [32]. By contrast to the latter two studies, the present analysis was further able to examine which drug classes accounted for the differential between overweight and normal weight children. Most importantly, respiratory medications (ATC class R) were used twice as often by overweight children than by their normal weight counterparts. Among the most common medications in this group we found antihistamines and drugs for the treatment of obstructive airways diseases (Table 4). These latter two findings reflect the higher rate of respiratory disorders, in particular asthma, in overweight and obese children as reported by ourselves (Kirk et al. 2011, unpublished) and others [13].

Two other medication groups that were examined in the current study are OTC medications and natural health products. The former can be an indicator for barriers in access to care [34, 35], overuse/misuse of drugs [36], and concern with health matters [37]. The use of OTC medications was slightly more common in overweight children and youth in the 12 to 19 years age group. However, the limited sample size and the lack of variables relating to the reasons for the medication use did not allow us to further investigate this finding. A striking contrast to the higher prescription drugs use by overweight children was the significantly lower intake of natural health products in the same group. Use of natural health products is motivated by the belief that natural health products are better than conventional drugs, personal health concerns and the desire to maintain and promote personal health [38]. Conversely, non-use of natural health products is driven by the perceived lack of need, lack of knowledge, or a general feeling of "being healthy" [38]. In keeping with this finding, reported use of medications in the ATC class A (Alimentary tract & metabolism) was 50% lower in obese older children and youth than in their normal weight peers. The most common medication (about 90%) in this class taken by normal weight children were vitamin preparations (Table 4). These findings indicate a greater concern with personal health and prevention in the families of normal weight children.

Strengths of the current study include its nationally representative sample of Canadians and objective measurements of height and weight. Moreover, data collected from the CHMS, unlike administrative databases, includes individuals who may not have sought medical attention or treatment for their condition. A limitation of the study is the relatively small sample size, which required the analysis of overweight and obese children in one group and may have diluted existing differences between obese and normal weight children. The smaller sample size also did not allow for an in-depth investigation into the contribution of sociodemographic factors. However, the use of propensity scores to adjust the regression models has helped to minimize confounding by socioeconomic status. The use of self- and proxy-reported data may suffer from recall problems or differences in reporting medication between the children and their parents. We feel that the potentially lower data quality through limited recall is offset by the inclusion of all medications used, irrespective of their being covered by the insurance. Further, it has been previously shown that there is a good agreement between children and parent report of medication use [39].

To conclude, overweight and obese children use prescription drugs more frequently than their normal weight peers. In older children, overweight and obese children were more frequent users of nervous system and respiratory medications. Within the respiratory medication class, drugs for the treatment of obstructive airways disease were more often used by overweight and obese children than by their normal weight peers.

7.5 References

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7.6 Tables

	6-11 years (n=1074)		**12-19 years** (n=1013)	
	Normal weight (77%)	**Overweight/ Obese** (23%)	**Normal weight** (72%)	**Overweight/ Obese** (28%)
Gender				
Male	50 %	53 %	50 %	56 %
Female	50 %	47 %	50 %	44 %
Household education				
Secondary school or less	12 %[1]	16 %[1]	13 %	21 %[1]
College	46 %	58 %	47 %	53 %
University	42 %	26 %	40 %	27 %[1]
Household income adequacy				
Low	26 %	31 %[1]	23 %	21 %[1]
Middle	26 %	29 %	25 %	40 %
High	42 %	40 %[1]	52 %	39 %[1]
Province of residence				
New Brunswick	7 %[2]	5 %[2]	6 %[2]	8 %[2]
Quebec	23 %[1]	16 %[2]	26 %[1]	15 %[1]
Ontario	39 %	48 %	37 %	49 %
Alberta	19 %	16 %	19 %	15 %[2]
British Columbia	11 %	16 %[1]	13 %	13 %[1]
Number of prescription medications				
None	83 %	82 %	70 %	59 %
One	11 %[1]	11 %[1]	22 %	22 %[1]
More than one	6 %[1]	7 %[1]	8 %[1]	20 %[1]
Number of OTC medications				
None	48 %	54 %	30 %	30 %
One	34 %	31 %[1]	42 %	36 %[1]
More than one	19 %	15 %	28 %	33 %
Number of natural health products				
None	75 %	79 %	75 %	84 %
One	20 %	Suppr.[1]	16 %[1]	14 %[1]
More than one	5 %[1]	Suppr.[2]	9 %[1]	2 %[2]
Took any medication				
All ATC domains	70 %	65 %	83 %	83 %
Alimentary tract & metabolism (A)	33 %	22 %[1]	30 %	18 %
Musculo-skeletal system (M)	15 %	16 %[1]	34 %	39 %
Nervous system (N)	26 %	20 %	40 %	50 %
Respiratory system (R)	18 %	18 %	15 %[1]	26 %

Table 7.1: Demographics and medication use by weight status.
[1] $16.6\% \leq CV \leq 33.3\%$; [2] $CV > 33.3\%$
Abbreviations: *CV* Coefficient of Variation; *Suppr.* Suppressed due to extreme sampling variability (CV >33.3%)

	6-11 years (n=1074)		12-19 years (n=1013)	
	Took prescription medication	**Mean # of prescription medications***	**Took prescription medication**	**Mean # of prescription medications***
Gender				
Male	18 %	1.63	29 %	1.41
Female	17 %	1.92	38 %	1.51
Household education				
Secondary school or less	19 %[1]	1.39	37 %[1]	1.47[1]
College	14 %	1.80[1]	35 %	1.48
University	20 %[1]	1.82	28 %[1]	1.54
Household income adequacy				
Low	20 %[1]	1.89 %[1]	27 %[1]	1.61 %[1]
Middle	16 %[1]	1.84 %[1]	39 %	1.50 %
High	17 %	1.67 %	32 %	1.48 %
Province of residence				
New Brunswick	26 %[2]	3.03[1]	32 %[2]	1.31[2]
Quebec	16 %[1]	1.67	36 %[1]	1.34
Ontario	19 %	1.71	33 %	1.57
Alberta	15 %[1]	1.59	32 %	1.46[1]
British Columbia	11 %[2]	1.20	29 %[2]	1.48[1]

Table 7.2: Prescription drug use by sociodemographic factors.
[1] $16.6\% \leq CV \leq 33.3\%$; [2] $CV > 33.3\%$
* in those who reported prescription medication use
Abbreviations: *CV* Coefficient of Variation

	6-11 years		12-19 years	
	Univariate IRR (95% CI)	**Adjusted** IRR (95% CI)	**Univariate** IRR (95% CI)	**Adjusted** IRR (95% CI)
Took prescription medication				
Normal weight	1.00	1.00	1.00	1.00
Overweight/obese	1.05 (0.71; 1.54)	1.23 (0.82; 1.86)	1.62 (1.14; 2.30)	1.59 (1.19; 2.14)
Took over-the-counter medication				
Normal weight	1.00	1.00	1.00	1.00
Overweight/obese	0.82 (0.62; 1.07)	0.81 (0.60; 1.08)	1.15 (0.93; 1.42)	1.14 (0.95; 1.38)
Took natural health product				
Normal weight	1.00	1.00	1.00	1.00
Overweight/obese	0.74 (0.51; 1.09)	0.79 (0.53; 1.17)	0.50 (0.31; 0.80)	0.52 (0.32; 0.82)
Took any alimentary tract medication (A)				
Normal weight	1.00	1.00	1.00	1.00
Overweight/obese	0.65 (0.45; 0.93)	0.69 (0.47; 1.00)	0.49 (0.33; 0.71)	0.50 (0.34; 0.72)
Took any musculo-skeletal medication (M)				
Normal weight	1.00	1.00	1.00	1.00
Overweight/obese	1.14 (0.67; 1.94)	1.13 (0.65; 1.96)	1.29 (0.94; 1.79)	1.29 (0.96; 1.73)
Took any nervous system medication (N)				
Normal weight	1.00	1.00	1.00	1.00
Overweight/obese	0.83 (0.60; 1.15)	0.81 (0.59; 1.10)	1.39 (1.15; 1.69)	1.34 (1.08; 1.66)
Took any respiratory medication (R)				
Normal weight	1.00	1.00	1.00	1.00
Overweight/obese	1.08 (0.70; 1.66)	1.19 (0.78; 1.82)	2.14 (1.56; 2.92)	2.08 (1.38; 3.13)

Table 7.3: Incidence rate ratios for taking medications in the last month.
Abbreviations: *IRR* Incidence Rate Ratio; *CI* Confidence Interval

	6-11 years		12-19 years	
	Normal weight	**Overweight/Obese**	**Normal weight**	**Overweight/Obese**
Alimentary tract & metabolism (A)	- Vitamins (88 %)	- Vitamins (91 %)	- Vitamins (78 %)	- Vitamins (69 %) - Drugs for acid related disorders (11 %)
Musculo-skeletal system (M)	- Anti-inflammatory products (>85 %)	- Anti-inflammatory products (>85 %)	- Anti-inflammatory products (>85 %)	- Anti-inflammatory products (>85 %)
Nervous system (N)	- Analgesics (80 %) - Psychoanaleptics (17 %)	- Analgesics (82 %) - Psychoanaleptics (14 %)	- Analgesics (87 %) - Psychoanaleptics (10 %)	- Analgesics (84 %) - Psychoanaleptics (12 %)
Respiratory system (R)	- Drugs for obstructive airways disease (35 %) - Antihistamines (28 %) - Cough and cold preparations (24 %) - Nasal preparations (11 %)	- Drugs for obstructive airways disease (50 %) - Antihistamines (29 %) - Nasal preparations (Suppr.)	- Antihistamines (31 %) - Drugs for obstructive airways disease (25 %) - Nasal preparations (21 %) - Cough and cold preparations (21 %)	- Antihistamines (46 %) - Drugs for obstructive airways disease (30 %) - Nasal preparations (Suppr.) - Cough and cold preparations (Suppr.)

Table 7.4: The most commonly used medication types ($>$ 10%) within each ATC domain in normal weight and overweight/obese children in descending order of frequency.

8 Health care utilization from prevalent medical conditions in normal weight, overweight and obese children

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8.1 Introduction

Obesity is a considerable threat to public health, and prevalence rates in children have increased at an alarming rate over the last few decades [1]. This trend has important consequences for population health status and health care utilization. A number of studies have shown that obese children have higher health care costs than normal weight children, although the reasons for this are, as yet, not clearly defined [2–6]. In most cases, investigators were not able to examine the reasons for these higher health care costs due to a lack of data on diagnoses and procedures, or because data came from single center or provider studies with limited generalizability. Apart from a number of physical conditions (such as type II diabetes, hypertension and other cardiovascular risk factors) that are increasingly associated with childhood obesity [7], several studies have reported a higher frequency of mental disorders [4, 5], mental health-related physician visits [8] and hospital stays [9] in obese children. Also, obese children may experience more severe and complicated courses of other relatively common disorders: A recent study reported that overweight children presenting to the emergency room with an asthma exacerbation were more likely than normal weight children to be admitted to the hospital [2]. Another study in a US tertiary hospital showed that obese children undergoing tonsillectomy accrued higher health care costs than their normal weight peers [3]. Similarly, data from Canada found that 40% of obese children undergoing appendectomy had a Length of Stay of five days or greater, more than double the rate in non-obese children, along with increased rates of wound infections and slower general recovery [10]. In order to fully understand these trends, this study sought to explore which disorders or groups of disorders may explain the higher health care utilization in overweight and obese children compared to their normal-weight peers.

8.2 Methods

The study design was a prospective cohort study, linking data from the 2003 Children's Lifestyle and School Performance Study (CLASS) with Nova Scotia administrative health data [6]. Given that administrative data does not always accurately reflect diagnosis of disease, this analysis cannot accurately compare differences in disease prevalence across categories of weight status, but can elucidate differences in health care utilization. CLASS is a population-based survey of Grade 5 students (age 10/11 years at the time of data collection) and their parents, conducted in the Canadian province of Nova Scotia in 2003. The study consisted of a questionnaire that was completed at home by the parents; a Canadian version of the Harvard Youth/Adolescent Food Frequency Questionnaire (YAQ) [11], administered to the students in the schools by study assistants; and a measurement of the students' height and weight. The parental questionnaire collected information on socio-demographic factors, the child's place of birth and residency, as well as household income level, educational attainment, breast-feeding practices, self-rated parental physical activity and diet quality, and questions on the frequency of their child's physical activities and the number of hours of sedentary activities (watching television, working on a computer, playing video games). Standing height was measured to the nearest 0.1 cm after students had removed their shoes; body weight was measured to the nearest 0.1 kg on calibrated digital scales. In addition to the above information, participating parents were asked to provide their Nova Scotia Health Insurance number and informed consent to allow linkage with birth and administrative health databases. Of the 291 public schools in Nova Scotia (>97% of students in Nova Scotia attend public schools) with grade 5 classes, 282 (96.9%) participated in the study. The average rate of return of questionnaire and consent form was 51.1% per school. One of the seven provincial school boards did not allow measurements of height and weight.

The administrative health datasets consist of the Medical Services Insurance (MSI) database and the Canadian Institute for Health Information Discharge Abstract Database (CIHI DAD). The MSI database contains administrative records for each insured health service rendered by a physician (including emergency room visits) and paid for by the Nova Scotia provincial healthcare system. The CIHI DAD contains a comprehensive administrative transcription of each admission to a Nova Scotia hospital facility. Aggregate costs of health care episodes for physician visits and hospitalizations were obtained from the Ontario Case Costing Initiative [12]. For hospitalization costs, data were only available for fiscal years 2003 to 2006. This timeline was chosen to reflect health care utilization around the CLASS data collection period.

For physician visits, data were available for all years from 1992 (i.e. the children's birth) to 2006. Costs were adjusted to 2006 Canadian Dollars using the Canadian Consumer Price Index [13]. A combination of deterministic and probabilistic matching was used to link the administrative health datasets with the CLASS study data. Of the 4412 students in the CLASS study with completed valid home survey and school information, 4380 (99%) could be linked with information in the administrative datasets. In the remaining children, parents had provided an invalid or no health insurance number. When comparing the original CLASS sample with the linked sample, there were no statistically significant differences for socio-demographic factors or weight status between the two groups. More detailed information on the CLASS study, the administrative datasets and the data linkage can be found elsewhere [6].

The outcome was health care utilization between 2001 and 2006 for the following conditions (ICD-9 codes in brackets): Infectious diseases (001-139); Internalizing Disorders (296, 300, 308, 309, 311, 313); Conduct Disorder (312); Other Mental Disorders (all other mental disorders [ICD-9 chapter IV]); Asthma (493); Other Respiratory Disorders (all other respiratory disorders [ICD-9 chapter VIII]); Injury (800-999); Obesity (278); Miscellaneous Obesity-related Disorders (256, 401, 402, 575, 576, 715, 716, 732, 734); Otitis Media (382); Chronic Adenoid/Tonsil Disorder (474). A description of the ICD-9 codes for each diagnosis group is shown in Table 1.

For privacy protection reasons, we were not able to access all diagnostic codes in the sample. We therefore selected a number of diagnoses/diagnosis groups based on a priori hypotheses. Infectious disease, respiratory disorders, and injury were chosen as they are among the most common childhood disorders while the remainder of disorders were considered because they have previously been associated with overweight/obesity in the literature [4, 5, 7, 8]. Only primary diagnoses were used for the current analysis. For the vast majority of visits ($>$ 95%) only one diagnosis was assigned. Health care utilization was assessed as:

1. Ever having had a physician visit for a condition
2. Per capita number of physician visits for a condition
3. Mean number of physician visits for a condition (in those with at least one visit for the condition)
4. Per capita physician costs for a condition
5. Mean physician costs per visit for a condition (in those with at least one visit for the condition)
6. Relative contribution of physician costs for a condition to total physician costs

The main exposure was weight status (normal weight, overweight, obese) in grade five children as defined by the age- and gender-specific body mass index (BMI) cut-off points for children and youth established by the International Obesity Task Force [14] based on health-related adult definitions of overweight ($\geq$ 25 kg/m^2) and obesity ($\geq$ 30 kg/m^2). For 3399 of the 4380 children (78%) included in this study, BMI measurements were available. Other covariates considered were gender, household income (4 levels: \$0 to \$20,000, \$20,001 to \$40,000, \$40,001 to \$60,000, $>$ \$60,000), parental education attainment (three levels: Secondary school or lower, College, University), and geographic region (urban, rural; based on Canadian postal code data).

Descriptive statistics for the outcomes were calculated by weight status. Chi-Square test and Kruskal-Wallis test were used to test for differences in health care utilization between the three weight status groups. P values were adjusted for multiple testing using the Benjamini-Hochberg method [15]. The association between weight status and 'ever having had a physician diagnosis for one of the selected conditions' was investigated using logistic regression. Multivariable regression models were adjusted for gender, household income, parental educational attainment, and geographic region. Missing values for categorical data were considered as separate covariate categories. As participation rates for the CLASS study in residential areas with lower estimates of household income were slightly lower than the average, response weights were used to overcome potential non-response bias [16] and to yield provincial population estimates for children born in 1992 in Nova Scotia. Stata/SE Version 11 (Stata Corp, College Station, Texas, USA) was used to perform the statistical analyses.

This study, including data collection, parental informed consent forms and data linkage was approved by the Health Sciences Human Research Ethics Board of Dalhousie University, the IWK Health Centre Research Ethics Board, the IWK/Reproductive Care Program Joint Data Access Committee and the Dalhousie University Population Health Research Unit Data Access Committee.

8.3 Results

Table 2 shows the frequency of physician visits for the eleven pre-selected conditions by weight status. Overweight and obese children were more likely to have had one or more physician visits for internalizing disorders, asthma, other respiratory disorders, obesity, otitis media and chronic adenoid/tonsil disorder. Conversely, a diagnosis of conduct disorder, or other mental disease was more frequently seen in normal weight than in overweight or obese children. Similar results were seen for the per capita number of physician visits. Obese children had twice as many physician visits for otitis media and chronic adenoid/tonsil disorder. With the exception of otitis media, there was no statistically significant difference in the number of visits in those with a certain condition between overweight and normal weight children.

The per capita physician costs per visit for asthma, other respiratory disorders, obesity, miscellaneous obesity-related disorders, otitis media and chronic adenoid/tonsil disorder was significantly higher in obese than in normal weight children. The average physician cost per visit in those with at least one visit for a condition was not statistically significantly different across weight groups for any of the conditions. Non-asthma respiratory disorders accounted for the highest rel-

ative contribution to total physician costs in all three groups. The most notable differences between groups were seen for asthma, other respiratory disorders, otitis media, and chronic adenoid and tonsil disorder, all of which had a larger share in the total costs for obese children compared to normal weight children. Further details on the physician cost differentials can be found in Table 3.
Regression analysis showed higher odds for having at least one physician diagnosis of internalizing disorder, asthma, other respiratory disorder, obesity, otitis media, and chronic adenoid/tonsil disorder associated with being overweight or obese (Table 4). Odds ratios displayed little variation between univariate and fully adjusted models.

8.4 Discussion

This study has found that overweight and obese children were more likely to have physician visits for a range of diagnoses, most notably internalizing disorder, asthma, other respiratory disorders, otitis media, and chronic adenoid/tonsil disorder than normal weight children. As a result, per capita physician costs and number of visits for these conditions were significantly higher in overweight and obese children.

Our previous analysis on health care costs in the same sample of children found that obese children use health care more often and incur higher health care costs than normal weight children [6]. The cumulative physician cost trajectories of normal weight and obese children drifted apart as early as three years of age. By the age of 14, obese children already had $200 (10%) higher per capita physician cost (not including hospital cost) than normal weight children. The current study had set out to identify disorders that account for the higher health care utilization in obese children. However, based on our findings it is difficult to pinpoint one disorder or disease category as being responsible for the higher health care costs. In particular, adult obesity-related disorders, such as hypertension, that have been reported with increasing frequency in children [7], did not contribute to the difference in health care costs. This is likely to be because prevalence of these conditions was low, given that the children were pre-adolescent at the time that weight status was assessed, and therefore relatively early in the trajectory for development of these more chronic conditions. We were not able to assess Type 2 Diabetes as there is no unambiguous ICD-9 code for this condition. However, a preliminary analysis had shown that the incidence of physician visits with the ICD-9 code for Diabetes (250.x) was not higher than what would have been expected for Type 1 diabetes alone (data not shown).

For the more common childhood disorders, asthma and other respiratory disorders incurred significantly higher costs in overweight and obese children, while there was no difference in health care utilization for infectious diseases and injuries. Another common childhood disorder that accounted for a substantially larger number of physician visits in obese children compared to normal weight children is otitis media. Acute otitis media is the second most common reason for visits to a family physician, accounting for 10% to 15% of all childhood visits [17]. A relationship between overweight and obesity and a higher prevalence of otitis media [18] has recently been reported in a clinical sample [19], but the exact mechanism of this relationship has yet to be fully elucidated. Our findings in this population-based sample further support the notion that obesity and overweight may be an important risk factor for this common childhood condition. The economic consequences of otitis media in Canada in 1994 were estimated at $611.0 million, with over 70% of these costs (or $428.4 million) attributable to childhood [20]. Taken together, during the six-year study period, an obese child incurred on average C$50 more in physician costs for non-asthma respiratory disorders and otitis media than a normal weight child. This amount would further increase if hospital and drug costs had been considered. Additionally, obesity as a diagnosis accounted for an average of $14 of physician costs per obese child during the study period.

Another remarkable finding was that, contrary to current opinion in the literature [4, 5], mental disorders were not generally more common in overweight/obese children; we found only internalizing disorders to be more common (i.e. those that include common symptoms of depression and anxiety). It is possible that underweight children in the "normal weight" group accounted for the higher costs for "other mental health disorders" (i.e. mostly Attention-Deficit Disorder). Due to the lack of an established definition for childhood underweight in the literature [14] and with the focus of the current analysis being overweight children, we decided to forego a separate analysis of the underweight group.

The strengths of this study include the availability of individual-level health care costs, including diagnostic codes and the use of measured as opposed to self-reported BMI, within a population-based study. The use of population-based data provides a more complete and less biased picture of weight status differentials in health services use, as Canada's publicly funded health care system reduces financial barriers to seeking health services. Limitations are the validity of administrative data diagnoses, which may not have been accurately recorded, and the use of a cross-sectional weight measurement (2003) applied to longitudinal data. It was assumed that a child's weight status remained the same for the years before and after the study. Given the six-year time frame assigned to assess health care utilization, we believe this is a valid assumption as weight status is the result of long term lifestyle habits and is not expected to change over a relatively short time period [21].

8.5 Conclusion

This analysis has further confirmed that health care utilization patterns of overweight and obese children differ from their normal weight peers, with internalizing disorders, asthma, other respiratory disorders, obesity, otitis media and chronic adenoid/tonsil disorder incurring higher costs and use in overweight and obese children. These findings indicate that greater attention to the relationship between more common childhood conditions and overweight and obesity is needed, given their frequency of occurrence and the fact that some of the more established obesity-related conditions are likely to be seen less frequently, particularly in younger children.

8.6 References

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8.7 Tables

Diagnosis group	ICD-9 codes	Conditions
Infectious Diseases	001-139	Infectious and parasitic diseases
Internalizing Disorders	296	Episodic mood disorders
	300	Neurotic disorders
	308	Acute reaction to stress
	309	Adjustment reaction
	311	Depressive disorder, not elsewhere classified
	313	Disturbance of emotions specific to childhood and adolescence
Conduct Disorder	312	Disturbance of conduct, not elsewhere classified
Other Mental Disorders	290-319 (excl. 296, 300, 308, 309, 311-313)	Mental disorders
Asthma	493	Asthma
Other Respiratory Disorders	460-519 (excl. 493)	Diseases of the respiratory system
Injury	800-999	Injury and poisoning
Obesity	278	Obesity and other hyperalimentation
Miscellaneous Obesity-related Disorders	256	Ovarian dysfunction
	401	Essential hypertension
	402	Hypertensive heart disease
	574	Cholelithiasis
	575	Other disorders of gallbladder
	576	Other disorders of biliary tract
	715	Osteoarthrosis and allied disorders
	716	Other and unspecified arthropathies
	732	Osteochondropathies
	734	Flat foot
Otitis Media	382	Suppurative and unspecified otitis media
Chronic Adenoid/Tonsil Disorder	474	Chronic disease of tonsils and adenoids

Table 8.1: Diagnosis groups used in the analysis and the corresponding ICD-9 codes and descriptions.

	% with one or more physician visit between 2001 and 2006 for the condition				Per capita # of physician visits 2001-2006 for the condition				Mean # of physician visits 2001-2006 in those with at least one visit for the condition			
	Normal weight	Over-weight	Obesity	B-H adj. p-value*	Normal weight	Over-weight	Obesity	B-H adj. p-value†	Normal weight	Over-weight	Obesity	B-H adj. p-value†
Infectious disease	47	47	46	n.s.	1.37	1.21	1.53	n.s.	2.9	2.6	3.2	n.s.
Internalizing disorder	10	13	15	< 0.05	0.21	0.27	0.24	n.s.	2.0	2.2	1.6	n.s.
Conduct disorder	4	3	3	< 0.05	0.09	0.07	0.07	n.s.	2.3	2.5	2.4	n.s.
Other mental disease	16	13	11	< 0.05	1.07	0.67	0.67	< 0.05	6.8	5.2	5.9	n.s.
Asthma	22	25	30	< 0.01	0.90	0.93	1.18	< 0.001	4.2	3.7	3.9	n.s.
Other respiratory disorder	74	79	80	< 0.01	2.92	3.32	3.63	< 0.01	3.9	4.2	4.6	n.s.
Injury	64	65	69	n.s.	1.88	1.95	2.00	n.s.	3.0	3.0	2.9	n.s.
Obesity	0	4	14	< 0.01	0.00	0.07	0.26	< 0.001	1	1.9	1.9	n.s.
Misc obesity-related disorders	3	5	5	n.s.	0.07	0.09	0.11	< 0.05	2.2	1.7	2.4	n.s.
Otitis media	30	36	46	< 0.001	0.74	0.98	1.47	< 0.001	2.4	2.8	3.2	< 0.01
Chronic adenoid/tonsil disorder	3	5	8	< 0.01	0.05	0.08	0.13	< 0.001	1.7	1.8	1.7	n.s.

Table 8.2: Physician visits between 2001 and 2006 for selected conditions in a cohort of Nova Scotia elementary school children (n=3361).
* Chi-Square test; † Kruskal-Wallis test
Abbreviations: *B-H adj.* Benjamini-Hochberg adjusted; *n.s.* Not significant

	Per capita physician costs 2001-2006 for the condition [C$]				Mean physician costs per visit 2001-2006 in those with at least one visit for the condition [C$]				Relative contribution of the condition to total physician costs 2001-2006 [%]			
	Normal weight	Over-weight	Obesity	B-H adj. p-value*	Normal weight	Over-weight	Obesity	B-H adj. p-value†	Normal weight	Over-weight	Obesity	B-H adj. p-value†
Infectious disease	42.9	39.0	47.2	n.s.	31.4	30.8	32.5	n.s.	7.5	6.3	6.6	n.s.
Internalizing disorder	10.7	12.8	9.5	n.s.	41.0	40.8	42.9	n.s.	1.3	1.4	1.6	n.s.
Conduct disorder	6.6	5.1	5.4	n.s.	73.5	86.8	49.6	n.s.	0.6	0.4	0.5	n.s.
Other mental disease	78.1	51.2	49.6	< 0.05	68.3	72.6	63.8	n.s.	5.5	4.0	3.4	< 0.05
Asthma	30.6	27.4	37.8	< 0.01	29.9	27.3	28.6	n.s.	3.6	3.6	4.6	< 0.01
Other respiratory disorder	91.7	103.7	122.2	< 0.001	30.8	30.9	31.1	n.s.	16.5	17.9	17.9	< 0.05
Injury	64.6	68.4	68.1	n.s.	33.1	33.0	33.6	n.s.	12.2	12.1	11.5	n.s.
Obesity	0.0	2.9	13.6	< 0.01	25.8	45.7	50.7	n.s.	0	0.3	1.7	< 0.01
Misc obesity-related disorders	4.4	4.7	8.9	< 0.05	51.0	47.8	59.6	n.s.	0.4	0.8	0.6	n.s.
Otitis media	24.7	32.0	47.9	< 0.001	30.1	31.1	30.4	n.s.	4.1	4.9	6.6	< 0.001
Chronic A&T disorder	4.0	6.4	13.2	< 0.001	66.4	81.7	88.4	n.s.	0.5	0.7	1.2	< 0.01

Table 8.3: Physician costs between 2001 and 2006 for selected conditions in a cohort of Nova Scotia elementary school children (n=3361).

* Chi-Square test; † Kruskal-Wallis test

Abbreviations: *B-H adj.* Benjamini-Hochberg adjusted; *n.s.* Not significant

	Univariate	Multivariate
Infectious disease		
Normal weight	1.00	1.00
Overweight	0.98 (0.85;1.19)	0.99 (0.78;1.25)
Obese	0.87 (0.74;1.01)	0.84 (0.71;0.98)
Internalizing disorder		
Normal weight	1.00	1.00
Overweight	1.25 (0.97;1.62)	1.26 (0.98;1.63)
Obese	1.46 (1.05;2.04)	1.47 (1.05;2.06)
Conduct disorder		
Normal weight	1.00	1.00
Overweight	0.79 (0.48;1.30)	0.80 (0.49;1.32)
Obese	0.42 (0.23;0.73)	0.80 (0.41;1.57)
Other mental disease		
Normal weight	1.00	1.00
Overweight	0.82 (0.64;1.05)	0.81 (0.63;1.04)
Obese	0.70 (0.49;0.99)	0.64 (0.45;0.93)
Asthma		
Normal weight	1.00	1.00
Overweight	1.22 (1.00;1.49)	1.24 (1.02;1.50)
Obese	1.59 (1.23;2.06)	1.60 (1.24;2.08)
Other respiratory disorder		
Normal weight	1.00	1.00
Overweight	1.36 (1.11;1.66)	1.34 (1.09;1.64)
Obese	1.40 (1.05;1.85)	1.38 (1.03;1.82)
Injury		
Normal weight	1.00	1.00
Overweight	1.09 (0.91;1.29)	1.07 (0.90;1.27)
Obese	1.28 (1.00;1.64)	1.19 (0.92;1.53)
Obesity		
Normal weight	1.00	1.00
Overweight	33.8 (10.2;112.3)	32.7 (9.8;108.8)
Obese	136.1 (41.6;445.4)	123.3 (37.8;402.7)
Misc obesity-related disorders		
Normal weight	1.00	1.00
Overweight	1.71 (1.15;2.54)	1.69 (1.13;2.52)
Obese	1.48 (0.84;2.60)	1.40 (0.80;2.47)
Otitis media		
Normal weight	1.00	1.00
Overweight	1.28 (1.08;1.53)	1.27 (1.06;1.51)
Obese	2.00 (1.58;2.53)	1.96 (1.55;2.48)
Chronic A&T disorder		
Normal weight	1.00	1.00
Overweight	1.55 (1.02;2.36)	1.58 (1.03;2.41)
Obese	2.72 (1.68;4.39)	2.76 (1.70;4.48)

Table 8.4: Odds Ratios and 95% confidence intervals for having one or more diagnosis of a selected health condition by weight status.

* adjusted for sex, income, education, urban residence

9 The association between childhood obesity and otitis media

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9.1 Introduction

Childhood obesity has been associated with a number of health problems in childhood such as asthma, sleep apnea, slipped femoral capital epiphysis and gallstones [1, 2]. Recently, two case-control studies from Korea reported an association between otitis media with effusion and increased body weight: Children treated with ventilation tube insertion for otitis media with effusion had a higher body mass index (BMI) than children undergoing surgery for conditions other than ear disorders [3, 4]. As otitis media poses a significant burden to the health care system [5] and may result in long-term morbidity [6], these findings would have substantial public health relevance in light of the current obesity epidemic. The investigators suggested that gastroesophageal reflux or accumulation of fatty tissue around the Eustachian tube in obese patients may result in chronic middle ear infection and effusion, respectively [7]. An alternative explanation for the observed association may be confounding by socioeconomic status as the latter is associated with both obesity [8] and otitis media [9–11]. The two hospital-based studies by Kim et al. [3, 4] were not able to adjust for socioeconomic factors and the found association may therefore be due to confounding. Accordingly, we sought to re-examine the relationship between otitis media and childhood obesity, adjusting for socioeconomic factors, in a population-based sample of Canadian school children.

9.2 Methods

The data used in this study come from a population-based cross-sectional survey in elementary school children in the Canadian province of Nova Scotia linked with administrative health data.

9.2.1 Children's Lifestyle and School Performance Study (CLASS)

CLASS was a population-based survey of Grade 5 students and their parents in Nova Scotia in 2003 [12]. The study consisted of a questionnaire that was completed at home by the parents; a Canadianized version of the Harvard Youth/Adolescent Food Frequency Questionnaire administered to the students in the schools by study assistants; and a measurement of the students' height and weight. The home questionnaire collected information on sociodemographic factors, the child's place of birth and residency, as well as household income level, educational attainment, breast-feeding practices, self-rated parental physical activity and diet quality, and questions on the frequency of their child's physical activities and the number of hours of sedentary activities (watching television, working on a computer, playing video games). Standing height was measured by a research assistant to the nearest 0.1 cm after students had removed their shoes; body weight was measured to the nearest 0.1 kg on calibrated digital scales. In addition to the above information, participating parents were asked to provide their Nova Scotia Health Insurance number and informed consent to allow future linkage with birth and administrative health databases. Of the 291 public schools in Nova Scotia ($>$97% of students in Nova Scotia attend public schools) with grade 5 classes, 282 (96.9%) participated in the study. The average rate of return of questionnaire and consent form was 51.1% per school. One of the seven provincial school boards did not allow measurements of height and weight. Students in the survey were between 10 and 13 years old; mean age was 11.1 years (SD 0.4). The male-to-female ratio was 0.97.

9.2.2 Administrative Health Data

The administrative health datasets used in the linkage consist of the Medical Services Insurance database and the Canadian Institute for Health Information Discharge Abstract Database. The Medical Services Insurance database contains administrative records for each insured health service rendered by a physician (including emergency room visits) and paid for by the Nova Scotia provincial universal health care system. The Canadian Institute for Health Information Discharge Abstract Database contains a comprehensive administrative transcription of each admission to a Nova Scotia hospital facility. For the majority of physician visits and hospital stays in the dataset ($> 95\%$), only one diagnosis was assigned.

Aggregate costs of health care episodes for physician visits and hospitalizations were obtained from the Ontario Case Costing Initiative [13]. For hospitalization costs, data were only available for fiscal years 2003 to 2006. For physician visits, data were available for all years from 1992 (i.e. the children's birth) to 2006. Costs were adjusted to 2006 Canadian Dollars using the Canadian Consumer Price Index [14].

The administrative health datasets were linked with the CLASS study data through the health card numbers provided by the students' parents. Where no direct match was found, a probabilistic matching algorithm was used. Of the 4412 students in the CLASS study with valid home survey and school information, 4380 (99%) could be linked with information in the administrative datasets. In the remaining children, parents had provided an invalid or no health insurance number.

More detailed information on the administrative datasets and the data linkage can be found elsewhere [15].

9.2.3 Outcomes

The primary outcome was an ICD diagnosis of *suppurative otitis media* (ICD9: 382; ICD10: H65-66) made during a physician visit or hospital stay, with no ICD diagnosis of otitis media in the preceeding 30 days. Secondary outcomes were health care utilization for otitis media (number of physician visits, physician costs) and repeated otitis media (defined as having 3 or more provider contacts for otitis media during the study period). The outcomes were assessed for the period from 2001 to 2006 (i.e. around the CLASS data collection).

9.2.4 Exposure and Covariates

The main exposure was weight status (normal weight, overweight, obese) in grade five children as defined by the age- and gender-specific BMI cut-off points for children and youth established by the International Obesity Task Force [16] based on health-related adult definitions of overweight ($\geq$ 25 kg/m^2) and obesity ($\geq$ 30 kg/m^2). BMI measurements were available for 3399 of the 4380 children (78%) included in this study. Other covariates considered were gender, household income (4 levels: \$0 to \$20,000, \$20,001 to \$40,000, \$40,001 to \$60,000, $>$ \$60,000), parental education attainment (3 levels: Secondary school or lower, College, University), geographic region (urban, rural; based on Canadian postal code data), breast-feeding (parental report, 4 levels: Not breast-fed or $<$ 1 week; 1 week to $<$ 3 months; 3 to 6 months; $>$ 6 months); ever having had a chronic adenoid/tonsil disorder (from administrative health data: ICD-9: 474 or ICD-10: J35 between 1992 and 2006); and allergic disorder (from administrative health data: a diagnosis of allergic rhinitis [ICD-9: 477] or atopic dermatitis [ICD-9: 691] between 1992 and 2006).

9.2.5 Statistical Analysis

Descriptive statistics for the outcomes were calculated by weight status. Negative binomial regression (due to the presence of overdispersion) was used to model the relationship between weight status and the number of physician visits for otitis media. The association between weight status and repeated otitis media was investigated using logistic regression. All multivariable regression models were adjusted for gender, income, education, and geographic region. Missing values for categorical data were considered as separate covariate categories. As participation rates for the CLASS study in residential areas with lower estimates of household income were slightly lower than the average, response weights were used to overcome potential non-response bias [12] and to yield provincial population estimates for children born in 1992/1993 in Nova Scotia. Stata/SE Version 11 (Stata Corp, College Station, TX, USA) was used to perform the statistical analyses.

This study, including data collection, parental informed consent forms, and data linkage was approved by the Health Sciences Human Research Ethics Board of Dalhousie University, the IWK Health Centre Research Ethics Board, the Reproductive Care Program Joint Data Access Committee and the Dalhousie University Population Health Research Unit Data Access Committee.

9.3 Results

Table 1 summarizes the sociodemographic characteristics and health care utilization of the sample. Twenty-three percent of children in the sample were overweight and 10% were obese. More than 30% of children had at least one diagnosis of otitis media between 2001 and 2006. For more than 95% of the otitis media-related provider contacts, otitis media was the only diagnosis assigned. There was a clear gradient for the association between weight status and otitis media with overweight and obese children having a higher incidence of health care provider contacts for otitis media. Overweight and obese children were also more likely to have repeated episodes of otitis media compared to normal weight children. Detailed results from the regression analysis are shown in Table 2. Neither a history of breast-feeding or of an allergic disorder was a confounder in the association between weight status and otitis media. Having had an allergic disorder was an independent risk factor for otitis media in the multiple regression model. Children with a previous diagnosis of chronic adenoid/tonsil disorder had twice the incidence of provider visits for otitis media than those without the condition. Adjusting the multiple regression model for chronic adenoid/tonsil disorder changed the association between weight status and otitis media only slightly (Table 3).

9.4 Discussion

We were able to show in our population-based sample of elementary school children that otitis media is more frequently seen in overweight and obese children. Overweight and obese children also incur more costs per otitis media-related visit and have higher odds to have repeated otitis media. Socioeconomic factors, a history of breast-feeding, presence of an allergic disorder or chronic adenoid/tonsil disorder did not change the association between obesity and otitis media.

To the best of our knowledge, the current study is the first to describe the association between childhood obesity and otitis media in a large, population-based sample. An association between chronic otitis media and increased BMI had been described previously in two hospital-based case-control studies from the same centre in South Korea [3, 4]. The generalizability of the results from these studies was limited owing to the selection of severe cases of chronic otitis media with effusion requiring surgery at a university hospital. A number of studies have examined associations between obesity and health care use for a variety of conditions but no study identified otitis media to be associated with obesity [17–20]. Shibli et al. in their study of admissions to a pediatric hospital in Israel [21] reported that the number of cases of acute otitis media were less than expected for children above the 85th percentile of weight. The latter finding may be explained by the young age ($\leq$ 24 months) of the children in Shibli's study compared to our sample: The mechanism that drives the association between obesity and otitis media may not be operative early in life.

A number of pathophysiological mechanisms have been suggested to explain the association between obesity and otitis media [7]: E.g. obesity has been linked with low-grade systemic inflammation [22] which may produce a milieu that increases the risk of otitis media or lead to chronic otitis media. Alternatively, gastroesophageal reflux, which is seen more frequently in individuals with higher BMI [23] may enter the middle ear through the Eustachian tube and cause otitis media [24]. Finally, in obese individuals fatty tissue may accumulate around the Eustachian tube [25] thereby compromising ventilation of the middle ear. Given the cross-sectional study design, there is also the possibility of reverse causality (i.e. otitis media leading to overweight or obesity). However, there is no plausible pathophysiological mechanism that would explain this directionality of the association. While our health services utilization study was not able to explain the etiology of the association, we were able to show that the presence of an allergic disorder or chronic adenoid/tonsil disorder were not confounders in the association between obesity and otitis media (Table 3). A previously described protective effect of breast-feeding on the occurrence of otitis media [26] could not be confirmed in the present study.

The association between childhood obesity and otitis media is of considerable public health significance. By contrast to most other obesity-related disorders, otitis media is a very common childhood disorder. Acute otitis media is the second most common reason for visits to a family physician, accounting for 10% to 15% of all childhood visits [27]. Recurrent otitis media may result in long-term sequelae such as learning disability [6], impaired linguistic development or hearing disorder [28, 29], or sleep apnea due to the development of chronic adenoid/tonsil disorder [30]. We were able to show that the per capita physician costs for otitis media between 2001 and 2006 were 92% higher ($47 vs. $24) in obese children compared to normal weight children. This cost differential is second only to that of chronic adenoid/tonsil disorder (230%) out of the 10 childhood disorders examined (S Kirk, unpubl. data, 2010). Given the increase in childhood obesity prevalence over the last two decades [31], one may expect to see an associated increase in the incidence of otitis media. However, recent reports indicate that the prevalence of otitis media is on the decline [32]. It appears that long-term trends for the prevalence of otitis media are confounded by the changing prevalence of allergic disorders [32] and the recent introduction of the pneumococcal conjugate vaccine [33].

The strengths of the present study are the linkage of longitudinal population-based administrative health data with a province-wide survey, and the use of measured (as opposed to self-reported) BMI. As Canada's publicly funded universal single provider health care system poses no financial barriers to seeking health services, the data provide a more complete and less biased picture of weight status differentials in health services use than that of many other Western countries. Our study is limited by the relatively low response rate, which may have introduced selection bias. As the non-response was higher in socioeconomically disadvantaged areas (where children can be presumed to be more likely to be obese and to develop otitis media), our findings may actually underestimate the true magnitude of the association. Another limitation of the study is the lack of availability of clinical data. Diagnoses from administrative health data are primarily collected for billing purposes and may not always accurately reflect the clinical picture. However, a misclassification of disease status would be expected to be non-differential with regard to weight status and would likely result in an underestimation of the true association between obesity and otitis media (bias towards the Null). For privacy protection reasons, we had no access to data beyond the top level ICD code (i.e. the first three digits) and were therefore not able to distinguish between acute and chronic suppurative otitis media. We were also unable to explore factors such as sharing of rooms, nursery attendance, hygiene, or family history of otitis media all of which have been identified as risk factors for otitis media [34]. If obesity in our dataset were positively associated with these factors, the reported magnitude of the association between obesity and otitis might be an overestimate. However, adjustment for both parental education and household income should have largely removed the effect of these potential confounders. Finally, the extrapolation of the cross-sectional weight measurement in 2003 to the period from 2001 to 2006 may have resulted in misclassification of the exposure. As a child's weight status is the result of long term lifestyle habits and is not expected to change over a relatively short time period, we feel that the assumption that the children's weight status remained the same for the two years before and after the study is valid.

In summary, this study has reported for the first time in a population-based setting that obese children are more likely to experience otitis media than normal weight children, have higher costs per otitis media-related visit and have higher odds to have repeated otitis media. The exact underlying mechanism by which obesity predisposes to otitis media needs to be elucidated in clinical studies.

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9.6 Tables

	Total (n=3399)	Normal weight (n=2264)	Overweight (n=788)	Obese (n=347)	p-value*
Gender					-
Male	48.1 %	48.1 %	47.6 %	52.4 %	
Female	51.9 %	51.9 %	52.4 %	47.6 %	
Household income					-
\$0 to \$20,000	12.1 %	9.9 %	11.1 %	15.4 %	
\$20,001 to \$40,000	23.4 %	21.2 %	24.7 %	33.2 %	
\$40,001 to \$60,000	26.5 %	26.8 %	26.7 %	26.7 %	
> \$60,000	38.1 %	42.1 %	37.5 %	24.6 %	
Household education					-
Secondary school or less	31.1 %	29.0 %	33.4 %	40.1 %	
College	38.1 %	37.3 %	38.9 %	39.0 %	
University	30.9 %	33.8 %	27.7 %	21.0 %	
Region					-
Urban	33.2 %	36.9 %	42.8 %	51.1 %	
Rural	66.8 %	63.1 %	57.2 %	48.9 %	
One or more health care provider contact for otitis media 2001-2006	31.1 %	28.2 %	33.8 %	44.2 %	<0.0001
Repeated ($\geq$ 3x) otitis media 2001-2006 †	24.9 %	20.5 %	28.1 %	37.6 %	<0.0001
Mean # of physician visits for otitis media 2001-2006 †	2.59	2.42	2.74	3.19	0.0001
Mean per capita physician costs for otitis media 2001-2006 [C$]	28	24	32	47	0.0001

Table 9.1: Sociodemographic characteristics and health care utilization for otitis media in a sample of 3399 grade 5 students in the Canadian province of Nova Scotia.
* Chi-Square test (categorical data) or Kruskal-Wallis test (continuous data) for differences between weight status groups
† In children with at least one otitis media-related physician visit

	Health care provider contacts for Otitis Media 2001-2006		Repeated ($\geq$ 3x) Otitis Media 2001-2006	
	Univariate	**Multivariable**	**Univariate**	**Multivariable**
Weight Status				
Normal weight	1.00	1.00	1.00	1.00
Overweight	1.30 (1.10;1.54)	1.28 (1.08;1.51)	1.51 (1.08;2.11)	1.49 (1.06;2.09)
Obese	2.10 (1.72;2.58)	2.03 (1.66;2.49)	2.33 (1.58;3.43)	2.27 (1.54;3.35)
Gender				
Male	-	1.00	-	1.00
Female	-	1.01 (0.88;1.15)	-	0.89 (0.69;1.15)
Household income				
$0 to $20,000	-	0.86 (0.67;1.12)	-	0.72 (0.42;1.23)
$20,001 to $40,000	-	0.92 (0.75;1.14)	-	1.09 (0.72;1.63)
$40,001 to $60,000	-	1.08 (0.90;1.31)	-	1.10 (0.76;1.58)
> $60,000	-	1.00	-	1.00
Household education				
Secondary school or less	-	1.16 (0.97;1.40)	-	1.34 (0.92;1.95)
College	-	1.26 (1.06;1.50)	-	1.53 (1.09;2.15)
University	-	1.00	-	1.00
Region				
Urban	-	1.00	-	1.00
Rural	-	0.84 (0.73;0.96)	-	0.90 (0.68;1.17)

Table 9.2: Incidence rate ratios (health care provider contacts for otitis media) and odds ratios (repeated otitis media) and their 95% confidence intervals (CI) for the association between weight status and health care utilization for otitis media. Multivariable models are adjusted for gender, household income, household education, and geographic region.

Incidence Rate Ratios for health care provider contacts for otitis media 2001-2006	
Multivariable*	
Weight Status	
Normal weight	1.00
Overweight	1.28 (1.08;1.51)
Obesity	2.03 (1.66;2.49)
Multivariable* + Breastfeeding	
Weight Status	
Normal weight	1.00
Overweight	1.29 (1.09;1.51)
Obese	2.03 (1.66;2.48)
Breastfeeding	
Not breast-fed / $<$ 1 week	1.00
1 week to $<$ 3 months	0.92 (0.75;1.12)
3 to 6 months	1.01 (0.84;1.21)
$>$ 6 months	0.95 (0.79;1.14)
Multivariable* + Chronic adenoid/tonsil disorder	
Weight Status	
Normal weight	1.00
Overweight	1.24 (1.05;1.46)
Obese	1.83 (1.50;2.23)
Chronic Adenoid/Tonsil Disorder	
No	1.00
Yes	2.01 (1.71;2.37)
Multivariable* + Allergic disorder	
Weight Status	
Normal weight	1.00
Overweight	1.28 (1.09;1.51)
Obese	2.03 (1.66;2.49)
Allergic Disorder	
No	1.00
Yes	1.16 (1.02;1.33)

Table 9.3: Incidence rate ratios (health care provider contacts for otitis media) and odds ratios (repeated otitis media) and their 95% confidence intervals (CI) for the association between weight status and health care utilization for otitis media. Multivariable models are adjusted for gender, household income, household education, and geographic region.

10 Comparison of ICD code-based diagnosis of obesity with measured obesity in children and the implications for health care cost estimates

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10.1 Introduction

The prevalence of childhood overweight and obesity has reached epidemic proportions in Western countries [1]. One of the emerging and costly consequences of this epidemic is the increase in health care utilization by obese children for a number of conditions [2–5]. Documenting these disparities in health care use can help to better target prevention efforts and resource allocation. Administrative databases provide an invaluable tool in this respect as they capture information on physician-diagnosed conditions for a large sample of the population. However, a significant shortcoming of these databases for their use in obesity research is the lack of weight data. Previous studies have often linked utilization data with anthropometric data from surveillance systems, hospital charts, or surveys to identify overweight and obese children [2–4, 6]. Such linkage may not always be feasible and other investigators have used an ICD-9/10 diagnosis of obesity from the administrative database to identify obese children [7–11]. Woo et al. [12] using data from a tertiary care hospital in the US showed that using an ICD-9 code-based diagnosis underestimated the true prevalence of obesity in children. However, children in a tertiary care hospital represent a rather selected population and any weight problem in these children may have been considered minor compared to the health problem that led to the admission. A weight problem is more likely to come to the attention of a pediatrician or general practitioner who commonly has a closer relationship with the family and sees most children on a regular basis. Hence, the former findings may not apply to population-based administrative databases that include data on physician visits and diagnoses such as Canadian provincial administrative health databases. Canada's publicly funded universal single provider health care system poses no financial barriers to seeking health services and tracks use and costs of hospital and physician services in each province. The objective of the current paper was twofold: i) to investigate the diagnostic properties of an ICD code-based diagnosis of obesity from administrative health data relative to the gold standard measured BMI in Canadian children; and ii) to compare health care costs in obese children identified by either method.

10.2 Methods

The data used in the present study come from a linkage of a population-based survey in elementary school children with administrative health data.

10.2.1 Children's Lifestyle and School Performance Study

The CLASS (Children's Lifestyle and School Performance Study) is a population-based survey of Grade 5 students and their parents in the Canadian province of Nova Scotia in 2003. The study consisted of a questionnaire that was completed at home by the parents; a student questionnaire and a Canadianized version of the Harvard Youth/Adolescent Food Frequency Questionnaire (YAQ) [13] administered to the students in the schools by study assistants; and a measurement of the students' height and weight. Standing height was measured to the nearest 0.1 cm after students had removed their shoes; body weight was measured to the nearest 0.1 kg on calibrated digital scales. In addition to the above information, participating parents were asked to provide their Nova Scotia Health Insurance number and informed consent to allow future linkage with birth and administrative health databases.

Of the 291 public schools in Nova Scotia (>97% of students attend public schools) with grade 5 classes, 282 (96.9%) participated in the study. The average rate of return of questionnaire and consent form was 51.1% per school. One of the seven provincial school boards did not allow measurements of height and weight. A total of 4298 students participated in the study and had their height and weight measured.

10.2.2 Administrative Health data

The CLASS data were linked with Nova Scotia administrative health data consisting of the Medical Services Insurance (MSI) database, Canadian Institute for Health Information Discharge Abstract Database (CIHI DAD), and the Nova Scotia Atlee Perinatal Database (NSAPD). ICD diagnosis data were available from 1992 (i.e. the child's year of birth) up to 2006. The MSI database is administered by Medavie Blue Cross for the province of Nova Scotia and contains administrative records for each insured health service rendered by a physician (including emergency room visits) and paid for by the Nova Scotia provincial healthcare system. The CIHI DAD contains a comprehensive administrative transcription of each admission to a Nova Scotia hospital facility. Both of these databases contain individual patient-level information including patient demography (age, gender, location, etc), attending physicians, diagnoses and procedures performed, service transfers while in hospital, specialty services received (e.g. physiotherapy, occupational therapy), and case complexity (e.g. resource intensity weight). Aggregate costs of health care episodes for physician visits and hospitalizations were obtained from the Ontario Case Costing Initiative [14]. Costs were adjusted to 2006 Canadian Dollars using the Canadian Consumer Price Index [15]. A combination of deterministic and probabilistic matching was used to link the administrative health datasets with the CLASS study data. Of the 4412 students in the CLASS study with valid home survey and school information, 4380 could be linked with information in the administrative datasets. In the remaining children, parents had provided an invalid or no health insurance number. A total of 3399 out of the 4380 children had a measured BMI.

10.2.3 Obesity Definitions

Measured obesity was defined using the body mass index (BMI) cut-off points based on the CDC growth charts [16], which were used by physicians in Canada until 2010 to identify overweight and obese children. At the time of BMI measurement, children were 10 to 11 years old. To enable comparability with an ICD code-based obesity diagnosis, which does not have an 'overweight' category, overweight children were considered 'normal weight' for the purposes of this analysis. An ICD code-based diagnosis of obesity was made when the child had one or more ICD-9 code of 278 or one or more ICD-10 code of E66-E68 as a primary or secondary diagnosis from either a physician visit or a hospital stay.

10.2.4 Statistical Analysis

Point estimates and 95% confidence intervals for Cohen's Kappa, sensitivity, and specificity were calculated for ICD code-based obesity diagnosis vs. obesity diagnosis based on measured BMI at age 10/11 years (gold standard). To assess the impact of misclassification resulting from using an ICD code-based diagnosis of obesity, the association between obesity and total health care costs incurred between 2003 to 2006 was examined in a series of regression models. Results from the models based on measured and ICD code-based obesity were compared qualitatively. Details on the cost model methodology have been published elsewhere [6]. The BMI and the number of physician visits of obese (as per measured BMI) children with an ICD code of obesity was compared to obese children with no ICD code of obesity using a t-test. Finally, a logistic regression model for ICD code-based obesity diagnosis adjusting for BMI, gender, parental education, parental income, and area of residence was used to identify factors that may predict having an ICD code of obesity.

10.3 Results

The prevalence of measured overweight (excl. obesity) and obesity in the sample based on the CDC BMI cut-offs [16] were 17.7 and 16.3%, respectively. There were 326,951 physician diagnoses from 319,072 physician visits and 13,839 hospital discharge diagnoses from 8325 hospital stays. Between 1992 and 2006, 216 out of 3399 children (6%) received one or more ICD codes for obesity. Twenty-seven percent (n=59) of the 216 children received the diagnosis during the first or second year of life. The remainder of obesity ICD diagnoses were equally distributed between the 3rd and 14th year of life.

In the majority of cases (85%), the diagnosis of obesity was made by a general practitioner, while most of the remaining diagnoses came from a pediatrician. Only very few obesity diagnoses were made during a hospital stay. Two-thirds of children received only one diagnosis of obesity during the 15-year time span, approximately 15% had two diagnoses, 5% had 5 or more (up to 14) obesity diagnosis codes. Ninety-five percent of ICD diagnoses of obesity were primary diagnoses.

The diagnostic properties of an ICD code-based diagnosis of obesity relative to the gold standard measured obesity are shown in Table 1. Sensitivity and agreement increased with a longer observation period but still remained poor overall. Modelling the association between obesity and total health care costs using different definitions of obesity showed that an ICD code-based diagnosis of obesity overestimated the true costs by a wide margin (Table 1).

Children who were correctly diagnosed as obese between 2002 and 2004 differ from those who were obese but not diagnosed through an ICD code in that they have a significantly larger BMI (29.9 vs. 27.0 kg/m2, p¡0.0001). Twenty-five percent of obese children who did not have an ICD code of obesity had an BMI of 28.5 kg/m^2 or higher (up to a maximum of 44.0 kg/m^2). The average number of physician visits between 2002 and 2004 in those correctly identified as obese was significantly higher than in those who were obese but not diagnosed (15.5 vs. 9.7, $p = 0.0003$).

A logistic regression model to identify factors that may predict having an ICD code of obesity between 1992 and 2006 found BMI (OR 1.26; 95%CI 1.22-1.31) and residence in a rural area (OR 1.53; 95%CI 1.06-2.21) as statistically significant predictors.

10.4 Discussion

This study examined for the first time how well an ICD code of obesity for identifies obese children in Canadian administrative health data. The sensitivity of an ICD code-based obesity diagnosis for detecting measured obesity was low: Depending on the length of the observation period, only about 7 to 16% of obese children were correctly identified. Those correctly identified had higher health care utilization than those without an ICD diagnosis of obesity.

An ICD diagnosis of obesity has been used previously to identify obese children in administrative databases [7–11]. A recent study showed that the majority of children (>90%) with measured obesity did not receive an ICD diagnosis of obesity during their inpatient stay at a tertiary care hospital in Ohio [12]. We had speculated that the sensitivity of an ICD diagnosis might be higher if both physician visits and hospital stays are used since children see their general practitioner or pediatrician far more often than being admitted to a hospital, and a weight problem may be more likely to be picked up during a well child visit or a consultation for a minor ailment. All but one child (out of 216) received the ICD diagnosis of obesity during a physician visit, which is far beyond what one would have expected based on the ratio of physician visits to hospital stays (319,072/8,325). However, an ICD diagnosis of obesity from one year before to one year after the BMI measurement still only had a sensitivity of 7.1% for detecting children with true obesity. Interestingly, when using all ICD codes from 0 to 14 years, the sensitivity for identifying obesity at age 10/11 years increased to 17% while specificity remained high. The area under the ROC curve (AUC) was maximized (but still poor) when all ICD codes assigned up to age 14 years were considered (AUC: 0.57).

The consequence of the poor diagnostic properties of the ICD code for obesity is that administrative data will grossly underestimate the true population prevalence of obesity. We were also interested in examining whether this misclassification is differential with regard to health care utilization. When comparing the costs in obese children and normal weight children, costs were 16% higher in children with measured obesity. This cost differential increased to 108% when the analysis was based on an ICD diagnosis of obesity between 2002 and 2004. That is, using an ICD diagnosis compare health care utilization between obese and non-obese children severely overestimated health care costs for obese children. A possible explanation is that physicians are more likely to diagnose obesity in a child if multiple, potentially obesity-related, co-morbidities are present. This argument is further supported by the finding that the number of physician visits was significantly higher in those correctly identified as obese. Hampl et al. [4] examining inpatient utilization in a pediatric primary care centre in the US reported higher health care costs for children with diagnosed obesity compared to those with undiagnosed obesity. By contrast, Woo et al. [12] found that children with diagnosed obesity had shorter hospital stays and fewer hospital discharges than both non-obese and undiagnosed obese patients. The apparent discrepancy may be explained by the fact that the study was done in a tertiary care hospital while some health conditions that are more common in obese children are primarily treated on an outpatient basis (e.g. asthma, type 2 diabetes). Children with diagnosed obesity in Woo's study were more likely to have primary diagnoses of mental health, endocrine, and musculo-skeletal disorders compared to children with undiagnosed obesity. This finding may indicate that the presence of a 'typical' obesity-related disorder increases the likelihood of receiving a diagnosis of obesity [12].

Besides the methodological aspects, our findings raise some concern about identification of obesity in the primary care system. General practitioners and pediatricians have a critical role in the diagnosis, education and management of overweight and obesity as they constitute the first point of contact within the health care system. An obese child that is not diagnosed (and not counselled) is a lost opportunity for secondary prevention. As shown in our analysis, less than 10% of obese children are diagnosed as obese by an ICD code. Even more concerning is that a quarter of children with undiagnosed obesity had a BMI between 29 and 44 kg/m^2which is well beyond the age-specific obesity cut-off of approximately 23 kg/m^2 [16] and clearly associated with health risks. The marked discrepancy between the ICD-based prevalence between 2002 and 2004 (1.5%) and that of measured obesity (16.3%) suggests that obesity was frequently overlooked or the issue was avoided by the physicians. On the other hand, ICD codes in administrative health data are primarily collected for billing purposes and the lack of an ICD code of obesity for an obese child may not necessarily indicate that a physician did not address the problem in the consultation. One may also argue that the Canadian health care system does not have the capacity to manage childhood overweight and obesity, and that the problem is best tackled by primary prevention measures.

The strengths of the current paper are the use of longitudinal administrative data from a universal single provider health care system linked with a population-based survey, and the coverage of both physician visits and hospital stays. Our findings are limited by the single BMI measurement at age 10/11 years and the lack of synchronicity between the BMI measurement and the physician visit/hospital stay. However, obesity is the result of long-term lifestyle habits and not expected to change within a relatively short time frame.

To conclude, an ICD diagnosis of obesity grossly underestimates the true prevalence of childhood obesity in Canadian administrative health data. Children with diagnosed obesity have higher health care costs than obese children without an ICD diagnosis or normal weight children.

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10.6 Table

Obesity assessment	Observation period	Obesity prevalence	Sensitivity	Specificity	Kappa	Health care cost ratio and 95%CI for obese vs. non-obese children
Measured	2003	16.3 %	-	-	-	1.16 (1.01; 1.32)
ICD-based	2002-2004	1.5 %	7.1 %	99.7 %	0.11	2.08 (1.47; 2.93)
ICD-based	2000-2006	2.8 %	11.6 %	99.2 %	0.16	2.23 (1.73; 2.87)
ICD-based	1992-2006	5.0 %	16.6 %	97.5 %	0.20	1.64 (1.34; 2.02)

Table 10.1: Properties of an ICD code-based diagnosis of obesity relative to the gold standard measured obesity (as per CDC growth charts [16]).
Abbreviations: *CI* Confidence Interval

11 Discussion

The key findings from this thesis highlight a number of issues related to the childhood obesity epidemic in Canada. In less than 20 years, if the prevalence of overweight continues to rise at the current speed, what is known today as "normal weight" will no longer be "normal". Instead, overweight will become the most prevalent weight status as shown by my projections. At that stage (but probably earlier), the epidemic may reach a "point of no return". If the majority of Canadians has adopted an unhealthy lifestyle and most adults are overweight and obese as a result, chances that that generation will induce change are slim. After a critical mass is reached, overweight and obesity may receive a further growth spurt through social networks [1]: With most peers being overweight or obese, there will now be "pressure" on non-obese individuals to embrace an unhealthy lifestyle. Policy changes that will lead affect the lifestyles of the overweight majority of voters will not become tenable. As a consequence, there will be little advocacy or incentive to invest in primary prevention. Society will then turn to secondary and tertiary prevention to ameliorate the worst health consequences with the aid of pharmacology and surgery.

Even if the current prevalence rates remain stable over the next 20 years, the long term consequences for the health of Canadians, for the health care system, and for the economy will be dramatic. Overweight and obesity are associated with a number of chronic health problems, such as type 2 diabetes, cardiovascular disease, arthritis and others [2]. The earlier onset of these diseases will result in a longer burden of illness and earlier and more severe complications. The peak of the health care costs has not been reached yet as the first obese generation is still relatively young. The already very high 21% health care cost differential between obese and normal weight children at age 11 years as described in this thesis (Objective 5) indicates that the future costs the obesity in adulthood will be even higher. Another concern is that besides the adult obesity-related diseases that are now seen in children, there is also an increase in the number of certain childhood disorders associated with obesity, such as asthma, internalizing disorders, sleep apnea or otitis media (Objectives 7 and 8). These conditions may become chronic or lead to long-term morbidity beyond childhood, which will further increase the burden to the health care system.

There is general agreement that primary prevention efforts are best directed at children as healthy behaviors learned early on may lead to a future in wellness

[3]. However, results from my analysis on risk factors for childhood obesity and their preventive potential (Objectives 3 and 4) have shown that one of the most important risk factors for childhood overweight with the largest single preventive potential is the body weight of the mother. Irrespective of whether this finding is truly indicative of an adverse effect *in utero* or whether it is simply a proxy for a unhealthy environment at home, it illustrates a conundrum with obesity prevention: To battle the epidemic, children should be targeted. But children can only be reached if the parents join the struggle. However, parents that never learnt a healthy and active lifestyle when they were kids make poor allies and role models. Such an environment will perpetuate the obesity epidemic.

From the above it is evident that action against the rising obesity tide is warranted. The obesity epidemic threatens the physical, mental and economic wellbeing of the Canadian people. While obesity can be reduced to the simple formula "energy intake exceeding energy expenditure", it is ultimately the environment that determines a person's choices. A joint, post-partisanship effort from all stakeholders is necessary to change create an environment that allows people to live healthy [4, 5]. While some have suggested that primary prevention has failed [6] and that we should focus on secondary and tertiary prevention, I believe that with a health care budget where 97% are spent on treatment and only 3% on prevention [7], the options of primary prevention have not been fully used yet. Moreover, even in the unlikely case that the health care system in Canada were to "cure" all obese individuals through pharmacologic or surgical treatment at once, the environment that has produced the epidemic continues to exist and relapse rates will be high. Hence it is my belief that given the complexity of the problem, only a fundamental environmental change, a systems approach, will be effective [4]. Initiatives focussing on isolated risk factors will reap little benefits as long as the obesogenic environment continues to exist. For children, a school-based approach appears to be the most promising as children are easy to reach in schools. A number of school-based obesity prevention program have been developed in Canada [8–10], some with promising results in terms of health behaviors and weight change [11] (Fung 2011, unpublished).

In addition, the government must take the lead in creating policies that help shape a healthy environment. Policy can be implemented at various levels: At the school level, healthy eating could be promoted by a ban of junk food. Keeping nutritional standards could become mandatory for school lunch programs. Physical education should be part of the curriculum at every public school. At the community level, the use of elevators, escalators, and walkways in worksites, apartment buildings and public buildings should be discouraged. City planners should ensure the provision of play facilities for children and easy access to parks to enable children and adults to be physically active in a safe environment. Walking and cycling to work should be supported by creating safe bicycle and walking trails. Finally, at the government and regulatory agencies level, legislation may be passed to ban advertisement for fast food geared at children. Prevention strategies proposed at the school level could be enforced by provincial legislation. Incentives for schools who initiate healthy food programs and physical activity education should be provided. Provinces or the federal government could sponsor celebrity advertising for healthy food and/or physical activity. Non-nutritious foods may be taxed or nutritious foods may be subsidized. That way, the food industry could be encouraged to produce healthy foods.

Public Health legislation in Canada may be passed at the federal, provincial and municipal level. However, it is not clear as to who should take the lead in fighting the obesity epidemic and this has hampered coordinated efforts in battling the epidemic. In addition to these challenges, policy makers face another general problem with the obesity epidemic. Comparisons are often drawn between the public health problem smoking and the obesity epidemic. Public health legislation and regulation has been quite successful in the past in promoting health of Canadians, the best example being the reduced rates of smoking following strict anti-tobacco legislation and regulation [12]. However, the obesity epidemic is quite different from smoking: While people can abstain from smoking, they cannot do so from eating. Some unhealthy food may be part of everyone's diet and drawing the line between what is acceptable and what should be banned is difficult if not impossible. Second-hand smoke poses a health risk to non-smokers, which increased the social disapproval towards smoking and facilitated anti-tobacco legislation. However, an unhealthy lifestyle has no direct adverse effects on people other than the individual (increased health care costs aside). Also, government interventions affecting the lifestyle choices of many may be received as an impingement of civil liberties or paternalism [13]. On the other hand, it has been argued that the victims of the epidemic are children who do not have the ability to critically judge food advertising and marketing [14]. On the same token, it is well possible that anti-obesity regulations may be better perceived if they focus on children as the most vulnerable members of our society. Alternatively, instead of attempting to impose restrictions on food advertising to children, counter-advertising campaigns alerting the children and youth to the consequences of unhealthy eating may prove equally successful as seen before with anti-tobacco advertisements [15].

One of the major strengths of the current thesis is the use of population-based data sources for all objectives. Statistics Canada data are generally of a very high quality due to their multistage sampling design and correction for non-response bias. Unfortunately, the high quality of Statistics Canada data will likely suffer in the future owing to the omission of the mandatory long-form census as of 2011 [16]. This thesis used Statistics Canada data to evaluate the past and current burden of obesity (Objective 1), to forecast the prevalence and cost of obesity in Canada, and to assess medication use in normal weight and overweight children (Objective 6). The second dataset used in my research linked a population-based survey in school children with a perinatal database and administrative health data from the province of Nova Scotia. The dataset can be considered unique in Canada due to the availability of measured BMI, the correction for non-response [11], the good response rate for school-based research, and the bringing together of clinical, economic, and population-based data in one dataset. Another strength is the application of a broad range of methodologies including systematic review, Markov modeling, regression modeling, adjusted population attributable risk analysis, Monte Carlo methods, cost analysis, and diagnostic method comparison. Students in the CLASS data were clustered in schools and some correlation of student data within a school can be expected. For some analyses I therefore used random effects modeling to consider this effect. However, some of the effects (e.g. weight-for-gestational age) were measured before or after the children attended the same school, and using school as a random effect in the model may therefore be over conservative. The chief limitation of the current thesis is the fact that the CLASS data was collected at the provincial level but the objective was to make inferences about the whole Canadian population. Nova Scotia is among the provinces with the highest rates of overweight and obesity in the country and there is no large metropolitan centre. Further, the ethnic composition of Nova Scotia is different from e.g. Ontario or British Columbia. Therefore, associations found in the analyses presented in this thesis may not apply to Canada as a whole.

To conclude, the results from the current thesis have a number of policy implications:

1. The systematic review (Objective 1) and my prediction model (Objective 2) suggest that the burden of childhood overweight and obesity in Canada is substantial and will continue to grow. Swift policy action is necessary to prevent the epidemic from reaching a "point of no return" where an unhealthy lifestyle becomes the societal norm.

2. Prevention efforts should target future mothers to break the vicious cycle of overweight mothers having overweight children (Objectives 3 and 4).

3. Obesity incurs excess health care costs as early as during the first decade of life (Objectives 5 and 6). Policy makers need to be prepared for a steep rise in health care costs when the first generation of children of the obesity epidemic reaches their 30s and 40s and the first complications of obesity-associated diseases will set in.

4. The prevalence of a number of childhood disorders (e.g. asthma, otitis media, internalizing disorders) will increase in the future because of its association with overweight and obesity (Objective 7 and 8). Some of these disorders or their sequelae will carry over into adulthood, adding further to the increased health care expenditures.

The present work also suggests a number of avenues for future research:

1. An ongoing surveillance study that uses Statistics Canada data sources on

childhood and adult overweight and obesity should be established to monitor national and regional trends of the epidemic. Such a surveillance database would help policy makers in assessing the effectiveness of policy changes at all levels and in all social groups. The use of primary data (as opposed to the secondary sources used in Objective 1) and a unified approach to the assessment and classification of overweight and obesity will greatly enhance the usability of the data.

2. The prevalence projection for overweight and obesity in Canada should be further supplemented by cost projections to aid in resource allocation planning. In a next step, the long-term health care costs saved by preventing a case of childhood obesity could be assessed. The ultimate goal would be an economic model-based cost-effectiveness analysis comparing the cost for prevention with the long-term savings in health care expenditures. These calculations will likely lend further support to school-based programs to promote healthy eating and active living.

3. The relationship between maternal pre-pregnancy weight and overweight in the offspring should be further explored. Specifically, data on maternal BMI and pregnancy weight gain are now available in the Nova Scotia Atlee Perinatal Database and will allow for more specifc analyses of this issue.

4. The reasons for the higher health care use in obese children deserve further investigation. The costs attributable to major disease entities like e.g. asthma, otitis media, and internalizing disorders in normal weight, overweight and obese children should be determined to get a better understanding of the contribution of individual disorders to the overall health care costs. Another approach would be to compare needs-based resource use in normal weight and obese children using different needs indicators to identify factors driving the higher health care utilization .

5. The newly found association between childhood obesity and otitis media should be further examined i) using detailed clinical data in a hospital setting, and ii) with a more comprehensive and detailed set of ICD codes on otitis media and associated disorders in administrative health data. Linkage with the recently completed CLASS II study in Nova Scotia will provide measured BMI data.

11.1 References

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