The Relationship between Lifestyle Behaviours and Mental Health in Canadian Children

by

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Abstract

Mental health disorders are an issue of epidemic proportions, affecting children and adolescents worldwide. Recent studies have suggested a link between lifestyle behaviours of diet, physical activity, screen time, and sleep with mental health in adolescence. However, a combined lifestyle behaviour measurement in relationship with mental health in young people has not been thoroughly studied. This thesis examines the association between lifestyle behaviours and mental health among a population-based sample of Canadian children and adolescents.

My first objective of this thesis was to examine the prospective relationship between adhering to lifestyle recommendations in childhood and mental health disorders in the subsequent four years. The second objective was to determine the correlates of meeting lifestyle recommendations in early adolescence with the incidence of Attention-Deficit/Hyperactivity Disorder until age fourteen. These objectives were addressed using population-based data collected in 2011 with the Children's Lifestyle and School Performance study (CLASS), in Nova Scotia Canada and was linked with administrative health care data. In the first study I found that children meeting more recommendations had significantly fewer mental health visits in the following years than children who met fewer lifestyle recommendations, with greater benefits for mental health as more recommendations were met. In the second study I found that children meeting recommendations for physical activity and dietary recommendations had lower incidence of ADHD, with even lower incidence of ADHD among those who met more lifestyle recommendations.

The present findings suggest that meeting lifestyle recommendations may be beneficial for adolescent mental health, with further benefits as more recommendations are met. These findings have important implications due to the modifiable nature of lifestyle behaviours and encourage a broad focus of psychosocial wellbeing initiatives for adolescents. Experimental and longitudinal studies are needed to expand on the present findings.

Preface

This thesis is an original work by Olivia K. Loewen. Chapter 2 and 3 of this thesis were written in collaboration with K. Maximova, J.P. Ekwaru, E.L. Faught, M. Asbridge, A. Ohinmaa, and P.J. Veugelers. P.J. Veugelers conceived and designed the study. P.J.Veugelers, E.L. Faught, and J.P. Ekwaru, and Olivia K. Loewen conceived and designed the analysis. Olivia K. Loewen conducted the analysis and drafted the manuscripts.

The CLASS study received research ethics approval from University of Alberta Research Ethics Board, "Assessing the Impact of Healthy Eating and Physical Activity Policies on School-Based Practices and Health Behaviours of Children in Nova Scotia," No. Pro00007488 (renewed March 2, 2018). The research project, Return on Investment for Kids (ROI4Kids), of which this thesis is a part, received research ethics approval from the University of Alberta Research Ethics Board, "CRIO 2.2: School-based health promotion and children healthcare utilization," No. Pro00049900 (renewed May 18, 2018). The data used in this thesis were made available by Health Data Nova Scotia of Dalhousie University. Although this research is based on data obtained from the Nova Scotia Department of Health and Wellness, the observations and opinions expressed are those of O.K. Loewen and do not represent those of their Health Data Nova Scotia or the Department of Health and Wellness.

No part of this thesis has been previously published.

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List of Abbreviations

ADHD	Attention Deficit/Hyperactivity Disorder
DALY	Disability-Adjusted Life-Years
MSI	Medical Services Insurance
CIHI DAD	Canadian Institute for Health Information Discharge Abstract Database
PA	Physical Activity
FFQ	Food Frequency Questionnaire
PAQ-C	Physical Activity Questionnaire for Children
YAQ	Harvard Food Frequency Questionnaire for Children and Youth
BMI	Body Mass Index
SES	Socioeconomic Status
CLASS	Children's Lifestyle And School Performance Study
ICD-9/10	International Classification of Diseases 9^{th}/10^{th} Revision
NBM	Negative Binomial Regression Model
CRC	Composite Recommendation Compliance

Chapter 1: Introduction

1.1 Introduction to Mental Health

Mental health disorders constitute a global epidemic affecting 10-20% of children and adolescents worldwide,[1] yet only recently they have been considered a priority on the global stage. The World Health Organization released a comprehensive Mental Health Action Plan in 2013 to call for change and focus international attention on the long-neglected problem.[2] The action plan was unveiled the same year the Global Burden of Disease study found major depression was the second most important cause of years lived with disability globally; anxiety was seventh, and overall, five mental disorders were among the top twenty causes.[3] Thus, the action plan is urgently needed.

Mental health disorders are behavioural or mental patterns that cause subjective distress or disability associated with impairment of an individual's normal cognitive, emotional, or behavioural functioning.[4] Approximately half of all mental illnesses have their onset before age 14.[5] Mental health disorders that encompass anxiety, depressive mood disorders, adjustment reaction, and acute reaction to stress are referred to as internalizing disorders, and attention deficit/hyperactivity (ADHD) and conduct disorder, are referred to as externalizing disorders. Other mental health disorders include schizophrenia, psychosis, paranoia, and eating disorders among others. Mental health disorders in childhood are linked to many short and long-term consequences. These disorders negatively affect social development, educational performance, and increase the risk of substance abuse and suicide.[6,7] In addition to negative effects on an individual's wellbeing, those with mental health disorders utilize added healthcare services, incurring substantial healthcare costs.[5,8,9] In young people, these neuropsychiatric conditions are the leading cause of health-related burden, accounting for 15-30% of the disability-adjusted life-years (DALY's) lost in the first 30 years of life.[10] Therefore, mental health disorders in childhood and early adolescence amount to substantial personal and societal costs both within Canada and worldwide.

1.1.1 Epidemiology of Mental Health Disorders

In any given year in Canada, one in five will have a mental health disorder, with mental health disorders accounting for 28% of the total number of years of life lost to illness, disability, or premature death.[4] Mental health disorders are common across all ages, ethnic groups, and genders. Externalizing disorders including ADHD and conduct disorder have an onset as early as age 3 with the average age of diagnosis at age 7.[11] Boys are three times as likely to be diagnosed with ADHD.[12] Internalizing disorders manifest slightly later, with most diagnoses after age 10 and continuing through adolescence and early adulthood.[12] From early adolescence through to adulthood the prevalence of internalizing disorders is higher in girls.[12]

Studies from the United States and Australia found the prevalence of mental health disorders among adolescents to be between 3% and 14%, with other population-based studies finding 24% of a large adolescent sample had an internalizing diagnosis.[12–14] Adolescence represents a critical period of biological change, rapid growth, and developmental potential, and there is evidence adolescent mental health disorders are important predictors for future mental illness.[15,16] Mental health disorders that develop in adolescence also tend to track into adulthood.[17] Thus, childhood and adolescent mental health should be a high priority not only to improve quality of life, but also to help prevent future disability from mental illness.

There are conflicting impressions of trends in the prevalence of mental health disorders. In popular media, the prevalence of mental health disorders is depicted as increasing at an alarming rate. However, a recent analysis of time trends in symptoms of mental illness in Canadian children found (with the exception of hyperactivity) the prevalence of other mental illnesses has remained relatively stable in this population.[18] It is possible that increased mental health literacy, treatment-seeking behaviour, or changes in practices or diagnostic criteria could be responsible for the conflicting reports of escalating rates. Regardless of the relatively stable prevalence of mental health disorders in Canadian children and adolescents, the rates are high and severity of mental health issues is increasing.[19,20] Recent reports

indicate a 56% increase in emergency hospital visits and 46% increase in hospitalizations for youth mental health disorders between 2006 and 2016,[19] with Canada's youth suicide rate the third highest in the industrialized world.[20] Therefore despite the stable prevalence of mental health disorders, it is clear their burden in Canadian youth is increasing.

1.1.2 Measuring Mental Health Disorders in Children

Developments in mental health literacy have led to the realization that children are capable of providing reliable information about their own mental wellbeing, and that internalizing and externalizing mental symptoms constitute disorders deserving of medical attention. Self-report and screening questionnaires exist; however, physician diagnosis of mental health disorders provides a more objective and clinically meaningful assessment. Diagnosis by a physician still requires children to report their symptoms, however the physician uses specific prompts and can clarify questions for the child. Within Canada, the public healthcare system provides an opportunity for studying medical health outcomes at the population level. Canada's healthcare system is publicly funded and it provides universal access to all medically necessary hospital and physician services, which reduces financial barriers to seeking health services. In each province the use and cost of hospital and physician services are tracked in administrative health databases.[21] The Medical Services Insurance (MSI) database contains records for each insured health service rendered by a physician (including emergency room visits) and paid for by the provincial healthcare system. The Canadian Institute for Health Information Discharge Abstract Database (CIHI DAD) contains administrative transcription of each admission to a Nova Scotia hospital facility. The database contains patient-level information on patient demographic characteristics, attending physicians, diagnoses, and procedures received. Thus, the databases can be used to efficiently extract medical diagnoses for research purposes. Case validation of using medical diagnostic codes for case definition of mental health disorders has shown a reasonable sensitivity of 81.1%, specificity of 94.8%, positive predictive value of 79.6% and negative predictive value of 95.2%.[22]

1.2 Healthy lifestyle Recommendations and Canadian children

In the past three decades children and adolescents' lifestyle habits have been deteriorating as evidenced through the childhood obesity epidemic.[23,24] Children are opting for larger food portion sizes, decreased physical activity (PA), increased screen time, and are sleeping less.[25–27] Educational tools and guidelines have been designed to set Canadian standards for children to prevent lifestyle-related chronic diseases. These healthy lifestyle recommendations have been established specifically for children's physical health to guide healthy choices for proper development and health across the lifespan. *Eating Well with Canada's Food Guide* from Health Canada outlines the number of servings of vegetables and fruit, grain products, milk and alternatives, and meat and alternatives recommended to consume daily.[28] The Guide also provides examples of foods and portion sizes in a bright and visually appealing brochure for parents and children alike to guide their daily dietary intake. Canada's Food Guide has undergone many revisions, with the most recent recommendation changes in 2007 and additional updates are anticipated. However, many children are not meeting these requirements. The majority of Canadian children and adolescents do not receive adequate nutrition with only 30% of children aged 4 to 8 consuming the recommended number of servings of vegetables and fruits.[29]

The Canadian Society for Exercise Physiology recently announced a 24-hour movement guideline for children and youth age 5 to 17. It encapsulates guidelines for sweat (60 minutes of moderate to vigorous physical activity), step (several hours of light and unstructured physical activities), sleep (9 to 11 hours of uninterrupted sleep for children age 5 to 13), and sit (no more than 2 hours per day of recreational screen time). These recommendations echo the National Sleep Foundation's recommendation of 9 to 11 hours of uninterrupted sleep, and the recommended limit of 2 hours of screen time (recreational computer and television) per day in the Canadian Sedentary Behaviour Guidelines. However, Canadian children are receiving a failing grade for many of these recommendations as well. According to the 2016 ParticipAction Report Card On Physical Activity for Children and Youth, only 9% of Canadian children

five to 17 years of age are meeting the recommended 60 minutes a day of moderate to vigorous activity.[30] Additionally, only 24% of five to 17 year olds meet the screen time recommendations of no more than two hours of recreational television and computer time per day. Lastly, since the 1990's children's nightly sleep duration has decreased by about 30 to 60 minutes.[30] Shorter sleep duration has been associated with childhood obesity.[27] The decrease in children's sleep duration and quality has been linked to the use of electronic entertainment devices in the hour before bed.[27] It is clear there has been an unfavourable shift in Canadian children's lifestyle behaviours.

1.2.1 Nutritional & Lifestyle Behaviour Assessment

Nutritional epidemiology emerged based on the premise that certain characteristics of diet or dietary habits may influence disease.[31] Although the initial focus of nutritional epidemiology was to evaluate the relationship between diet and major chronic diseases such as heart disease and various cancers, the same tools can be used to assess relationships between diet and mental health disorders. Information on food consumption can be converted to intakes of specific nutrients by analyzing foods consumed directly or using food composition tables and nutrient databases.[32] Since epidemiological studies often involve the participation of large populations, food composition tables or nutrient databases are deemed more feasible than direct analysis of food consumed.[32] Food frequency questionnaires (FFQ) are most commonly used to assess usual dietary intake and eating habits over a period of time. FFQs vary in length and the number of nutrients or foods assessed, but are a useful tool as they are consistent, inexpensive, and can be administered in large populations with ease.[31] Information from FFQs can be transformed into specific nutrient, energy, and food serving information using the Canadian Nutrient File.

Other lifestyle behaviours can be assessed through the use of questionnaires as well. The Physical Activity Questionnaire for Children (PAQ-C) instrument is a self-administered, 10-item PA recall, validated tool that measures general levels of moderate-to-vigorous PA in children ages 8-14.[33] Similarly,

a questionnaire for parents can be used to assess the number of hours their children spend in front of a screen and on average how many hours their children sleep per day.

1.3 Link between Lifestyle Behaviours and Mental Health

Studies have demonstrated the association between healthy lifestyles and mental health disorders.[34–36] In particular, previous research has examined the associations between individual lifestyle behaviours of diet,[37–39] physical activity,[40–42] sleep,[43] and screen time[44] with assorted measures of mental health. Mental health research is difficult to conduct in a controlled experimental design due to ethical considerations regarding human research and challenges in measuring mental health. Further, it can be difficult to assign and ensure accuracy in measuring lifestyle behaviours. Due to the high cost of randomized control trials, those that have been conducted have been restricted to small sample sizes.[45] However, some experimental studies are beginning to contribute important insights into causality, prevention and treatment.[45,46] As such, observational studies currently provide much of the evidence between the aforementioned lifestyle behaviours and mental health.

Of the lifestyle behaviours, diet and its relation to mental health has been the most thoroughly studied.[34,38,47] A meta-analysis of thirteen methodologically rigorous studies on diet and mental health among adults suggested that higher intakes of healthy foods (vegetables and fruits, fish, and whole grains) were associated with reduced likelihood of depression.[47] Moreover, a recent systematic review confirmed the association between unhealthy diets and increased risk of mental health disorders for children and adolescents.[34] Poor nutritional quality has also been found to be associated with specifically externalizing disorders (particularly hyperactivity).[48] As Attention-Deficit/Hyperactivity-Disorder (ADHD) is one of the most common mental disorders, it's associations with diet have been comparably more researched than those of diet and internalizing disorders. In general, however, findings remain inconsistent between mental health and diet in adolescents. For example, some studies have observed a dose-response

relationship between diet quality and mental health,[37] other studies have found no significant relationship.[39]

A recent review reported physical activity has been shown to have beneficial links to mental health, but the evidence base is limited.[49] The benefits of physical activity for mental health among children and adolescents has been primarily documented in cross sectional studies.[49] An Australian study of over 8000 adolescents, meeting physical activity recommendations was found to be cross-sectionally associated with significantly reduced odds of depressive symptoms.[50] The prospective studies on the effect of physical activity on mental health in adolescents have been less consistent. In a longitudinal study among German adolescents, physical activity was significantly associated with a lower incidence of mental health disorders after a four-year period.[41] Similar trends have been observed in slightly older age groups as well. In a recent longitudinal study from Denmark, girls with low leisure time physical activity at age 16 had poorer mental health outcomes in early adulthood compared to those who were more active in adolescence.[51] In contrast, several other prospective studies have found no association between physical activity and later mental illness symptoms.[52,53]

There are various international observational studies examining the relationship between sedentary behaviour and mental health during adolescence. Findings indicate a small, but consistent relationship between increased computer/internet, mobile phone, and TV viewing and depressive symptomology.[36] However much of the evidence is cross-sectional. In a large sample of Canadian youth screen time was cross-sectionally associated with severe depression and anxiety, and specifically computer use was associated with more severe depressive symptomology.[54] In a prospective analysis from Norway, high levels of sedentary activity in boys alone predicted higher levels of depressive symptoms one year later.[55]

The associations between sleep and mental health in adolescence have not been as thoroughly investigated as the other lifestyle behaviours. However, in a large Australian cross-sectional study, students aged 14 to 19 who had more sleep were less likely to experience depressive symptoms. For every additional hour of sleep per night, there was a 22% and 26% reduction in the probability of depressive

symptomology for males and females, respectively.[43] Previous research has characterized the strong association between ADHD and poor sleep.[56] This association may be due in part to stimulant medication use, but the effects between ADHD and sleep may be bidirectional.[57,58]

While many studies have examined the diet-mental health and physical activity/sedentary behaviour-mental health relationships, very few have done so simultaneously in the same analysis. One study in Australia cross-sectionally investigated an assessment of physical activity, sedentary behaviour, and weekly food intake with depressive symptomology. However, effect sizes were generally small and only gender specific associations between unhealthy dietary patterns and physical activity with depressive symptoms in males, and screen time and depressive symptoms in females were found. A recent case-control study examined the number of health behaviours in children with ADHD compared to their healthy control counterparts.[57] Holton & Nigg found children with ADHD were almost twice as likely to have fewer healthy behaviours after adjusting for a wide array of confounders.[57] This study called for increased attention to the aggregate effects of multiple health behaviours, as an overall heathy lifestyle may be much more impactful than the contribution of singular health behaviours to mental health development.

1.4 Gaps in Research

Research in the area of lifestyle behaviours and mental health is scant, particularly in young people. The majority of existing research has focused on the associations between individual lifestyle behaviours and patient reported symptoms. Very little research has considered multiple health behaviours and mental health simultaneously. As lifestyle behaviours do not occur in isolation of one another, it is applicable to investigate them simultaneously. This thesis will elaborate on the limited amount of research assessing the aggregate effect of multiple lifestyle behaviours on mental health. Further, this thesis will create novel Composite Recommendation Compliance scores to assess the impact of meeting multiple health recommendations on mental health. Lifestyle recommendations for children are widely used and

primarily intended to promote healthy physical development and prevent chronic diseases later in life. However, the potential benefits for mental health when recommendations are met have not been studied. This thesis is the first to examine mental health outcomes by children's adherence to established health behaviour recommendations to provide information for public health professionals and health policy decision makers. Lastly, while other research in this area has relied primarily on self-report measures of mental health, this thesis will utilize physician diagnosis of mental health disorders to provide reliable outcome measures. The use of clinical mental health outcomes will also elaborate on the paucity of mental health-related health care utilization.

1.5 Public Health & Clinical implications

The relationship between lifestyle behaviours and mental health has important public health and clinical implications. A knowledge gap in the broader benefits to a child's short-term mental health when he or she meets healthy lifestyle recommendations exists. Examining the effect of meeting established health recommendations will improve interpretability and applicability of results for policy and public health decision makers. As lifestyle behaviours of diet, physical activity, sleep, and screen time are modifiable, potential for intervention exists. Greater understanding of the benefits of complying with healthy lifestyle recommendations for children will justify programs that support adherence to the recommendations. The inclusion of improved mental health as an additional benefit for the promotion of a healthy diet and active lifestyle in childhood will further bolster support of public health policies and programs for Canadian children. It is also important for the relationship between health lifestyle behaviours and mental health to be emphasized in primary care. The potential to improve adolescent mental health and reduce the primary care utilization burden associated with mental health disorders has benefits not only for the individual, but for society as well. This thesis aims to provide additional evidence to support the clear need of improving mental health for young Canadians.

1.6 Research Objectives

The objective of this thesis is to investigate the relationship between lifestyle recommendation adherence and mental health in childhood and adolescence by:

- Examining the association of adherence to each lifestyle behaviour recommendation singularly, and in combination, with the number of health care contacts for mental health in the four subsequent years.
- Examining the correlates of adherence to each lifestyle behaviour recommendation singularly, and in combination, in adolescence and the time to incident ADHD diagnosis from birth to age fourteen.

1.6.1 Research Questions

Question 1: Is the rate of diagnosis of mental health disorders lesser among students who meet lifestyle recommendations, relative to students who do not meet lifestyle recommendations, in the subsequent four years?

Question 2: Is the incidence of ADHD through childhood lower among students who meet lifestyle recommendations in adolescence, relative to students who do not meet lifestyle recommendations in adolescence?

1.7 Structure of this thesis

The structure of this thesis is as follows: This first chapter provided a general introduction and description of study objectives. The second chapter includes the first study of this thesis, which involved a prospective population-based study using survey data from the 2011 Children's Lifestyle and School Performance Study (CLASS) and linked administrative health care data from the subsequent four years.

The third chapter includes the second study, which also used survey data from the 2011 Children's Lifestyle and School Performance Study and was linked with administrative health care data from birth until each child's 14th birthday. The first study examined the prospective associations between adherence to lifestyle recommendations and health care contacts for mental health disorders. In the second study, the correlates of adherence to lifestyle recommendations in early adolescence with the incidence of ADHD from birth to adolescence were examined. The fourth chapter provides an overview of the main findings and general implications of the research with a conclusion and recommendations.

1.8 My Contributions

The CLASS Study was conceived and designed by P.J. Veugelers. I travelled to Nova Scotia to access the health-linked 2011 CLASS survey data. A. Ohinmaa conceptualized the link between lifestyle behaviours and mental health. I translated this concept, and adapted E.L. Faught's idea to analyze the associations between adherence to combined lifestyle behaviour recommendations[59] and mental health. J.P. Ekwaru provided statistical advice for the analysis. I detailed the existing research on lifestyle behaviours and mental health in a literature review, conducted all analyses, and drafted the manuscripts.

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Chapter 2: Adherence to lifestyle behaviour recommendations and mental health in early adolescence: A population-based prospective study

2.1 Introduction

Mental health disorders are a problem of epidemic proportions, affecting one in five Canadians in any given year.[1] Studies have shown approximately half of all lifetime cases of poor mental health emerge before age 14.[2] In addition to the negative effects on patients' well-being, mental health disorders place a high burden on primary care resources.[3] Innovative strategies to promote mental health and reduce illness early in the lifecourse are urgently needed.[4] A trend in the evidence has emerged suggesting lifestyle behaviours such as diet, physical activity, sedentary behaviours, and sleep are associated with mental health[5–9] and could provide novel targets to reduce the burden of mental illness.

The association between diet and mental health across age groups has been synthesized in a series of systematic reviews. A meta-analysis on diet and mental health among adults suggested higher intakes of healthy foods (vegetables and fruits, fish, and whole grains) were associated with reduced likelihood of depression (OR:0.84; 95%CI 0.76, 0.92).[5] More recently, a systematic review confirmed the association between unhealthy diets (processed, high saturated fat, refined carbohydrates) and increased risk of mental health disorders for adolescents.[10] The majority of extant evidence linking physical activity[11] and sedentary behaviour[8] with mental health in adolescents is cross-sectional, derived from small studies, and employs self-reported measures of mental health.[8,10,11]

Recommendations for the aforementioned lifestyle behaviours exist, however recommendation adherence has not been investigated in relation to mental health. Aside from our previous work, no other prospective studies in adolescents have utilized physician diagnosis of mental health disorders.[9,12] Further, a recent meta-analysis on diet quality and depression risk underscored the need for larger prospective studies controlling for relevant confounders while avoiding overcorrection of baseline mental health symptoms.[13] Additionally, healthy lifestyle behaviours are increasingly acknowledged to be interrelated.[14]

While previous studies have examined health behaviours with mental health, few have assessed the independent effects by considering several lifestyle behaviours together,[9] none have considered the cumulative effect of meeting several lifestyle behaviour recommendations simultaneously. Given lifestyle behaviours do not occur in isolation, a pertinent research objective is to concurrently examine the effect of meeting recommendations for these behaviours on reducing primary care utilization for mental health disorders.[15] The present study examined the associations of adherence to lifestyle behaviour recommendations considered (1) singularly and (2) simultaneously with the number of physician visits for mental health disorders during adolescence.

2.2 Methods

2.2.1 Study Design

The present study linked health behaviour survey data from 5th grade students participating in the 2011 Children's Lifestyle and School Performance Study (CLASS) with administrative health data to obtain information on physician diagnosis of mental health disorders in subsequent years. CLASS is a population-based health survey among fifth grade students (10-11 years old) in Nova Scotia, Canada. All grade five students, their parent(s)/guardian(s), and school administrators were invited to participate in the study. Of all 286 provincial public schools with grade five students, 269 schools participated in the study. Parental consent to participate in the survey was given for 6,591 of the 8,736 students, resulting in a mean response rate of 75.4% per school. Of these, 1,481 (22.5%) did not complete the survey, were absent the day of the survey, or had unrealistic caloric intakes (<500 or >5,000kcal)[16] and were excluded from analysis, leaving 5,110 eligible students.

The study consisted of a student survey with questions on physical activity (PA), sedentary activities, and a Canadian version of the Harvard Youth/Adolescent Food Frequency Questionnaire[17] administered at the school by research assistants. Research assistants measured students' height and weight. Parent(s)/guardian(s) also completed a home survey on the adolescent's sleep habits, screen time

usage, place of residency, household income, and highest level of parent education. Of the 5,110 students who completed the CLASS survey, 3,436 (67.2%) provided valid health card numbers that could be linked with their administrative health data. There were no significant differences in sociodemographic factors or bodyweight status between the linked and unlinked sample.

2.2.2 Exposure of Interest: Adherence to Lifestyle Behaviour Recommendations

We examined adherence to nine established lifestyle recommendations. Eating Well with Canada's Food Guide was used to evaluate students' consumption of age-specific recommendations for daily servings of vegetables and fruit, grain products, milk and alternatives, and meat and alternatives.[18] The World Health Organization's Guideline: Sugar Intake for Adults and Children was used to determine meeting added sugar recommendations[19] and Dietary Guidelines for Americans were to assess saturated fat intake.[20] Meeting PA recommendations was determined by questionnaire cut-offs and Canadian 24-Hour Movement Guidelines for Children and Youth determined sleep and screen time recommendations. (These recommendations are detailed in Appendix A).

2.2.3 Outcome of Interest: Health-care Provider Contacts for Mental Health Disorders

The outcome of interest was the number of health-care provider contacts related to an internalizing, externalizing, or other mental health disorder given between the survey, in the spring of 2011, and December 31st 2014. A participant's mental health visit with a physician was counted if they received a primary internalizing, externalizing, or other mental health disorder diagnosis, according to the International Classification of Diseases, 9th Revision [ICD-9] or 10th revision [ICD-10-CA] in the approximate four-year follow-up period (see Table 1 for diagnoses and ICD-9/10 codes used). The administrative health data for the present study were derived from the Medical Services Insurance (MSI) database and Canadian Institute for Health Information Discharge Abstract Database (CIHI DAD).

2.2.4 Statistical Analysis

Associations of meeting recommendations for diet, PA, sedentary behaviour, and sleep with mental health visits were examined using mixed-effects regression models to accommodate clustering of students within schools. As the distribution of the number of physician visits with a mental health diagnosis (i.e., mental health visits) showed overdispersion, we employed Negative Binomial Regression Models (NBM). Univariate NBM was used to assess the associations between each of the health behaviours and the number of mental health visits. Multivariable NBMs (Model 1) were used to adjust for potential confounders. We adjusted for adolescent's gender, bodyweight status (normal weight, overweight, or obese using age and gender specific cut-offs)[21], parental educational attainment (secondary or lower, post-secondary/college, or university), household income (<$20,000, $20,001-40,000, $40,001-60,000, or >$60,000) as assessed by categorical questions in the home survey, and region of residence (rural or urban) determined by postal code. As recommended, analysis including YAQ data was adjusted for energy intake.[16] A full model (Model 2) simultaneously considered all lifestyle behaviours and confounders to analyze the independent associations between meeting each lifestyle behaviour recommendation and number of mental health visits. To assess the cumulative effects of meeting multiple recommendations, a Composite Recommendation Compliance (CRC) score was generated. The CRC was considered continuously and according to categories: low (meeting 1-3 recommendations), medium (meeting 4-6 recommendations), and high (meeting 7-9 recommendations). Missing values for confounding variables were considered as separate covariate categories in the regression analysis, but their estimates are not presented. Response rates for CLASS in residential areas with lower household income were slightly lower than average. To minimize potential non-response bias, analyses were weighted for non-response to represent provincial estimates of the grade five student population.[22] The above analyses were repeated with the exclusion of all students with a mental health diagnosis before the date of the survey (*N*=330). Additionally, all modes were stratified by gender. The STATA/SE 15

statistical software package (Stata Corp., College Station, TX, USA) was used for all data analysis. The Human Research Ethics Boards of Dalhousie University and the University of Alberta approved the data collection and parental informed consent forms of CLASS. Linkage of the CLASS survey data with administrative health care data was approved by Human Research Ethics Boards at the University of Alberta, Dalhousie University, and by Health Data Nova Scotia.

2.3 Results

Of 3,436 participants that were included in analyses, 14.6% had at least one physician visit with a mental health diagnosis between the date of completing the survey in 2011 and December 31th, 2014. A greater proportion of participants diagnosed with mental health disorders were from lower socioeconomic backgrounds, had parents with secondary education or less, and resided in urban areas (Table 2.2). The proportion of participants diagnosed with a mental health disorder was lower among those who met the recommendations for vegetables and fruit, grain products, milk and alternatives, saturated fat, added sugars, PA, sleep, screen time, and who were of normal weight (Table 2.2).

Participants met, on average, 5.3 out of 9 recommendations with the following percentage of adherence to each recommendation: 31% for vegetables and fruit, 22% for grain products, 57% for milk and alternatives, 86% for meat and alternatives, 54% for saturated fat, 63% for added sugars, 77% for PA, 93% for sleep, and 44% for screen time (Table 2.2). Meeting recommendations for milk and alternatives, added sugars, and PA were associated with lowering the Rate Ratio (RR) of mental health visits, before adjusting for potential confounders (Table 2.3). Having higher bodyweight status, levels of parental education, household income, and being female reduced the likelihood of having mental health visits.

After adjusting for potential confounders, meeting recommendations for milk and alternatives, screen time, and PA reduced the number of mental health visits by 20%, 25%, and 47%, respectively (Table 2.3, Model 1). When considering lifestyle behaviours simultaneously (Model 2), meeting screen time and PA recommendations appeared to be the only behaviours with significant independent

associations with mental health visits during follow-up, respectively, (RR:0.76 [95%CI: 0.60, 0.96]) and (RR:0.54 [95%CI: 0.42, 0.68]). Gender-stratified analysis revealed the independent protective effects of meeting milk and alternative recommendations for boys when considering all other variables (RR:0.65 [95%CI: 0.48, 0.88]).

For each additional recommendation met, the RR of mental health visits during follow-up declined by 15% (RR:0.85 [95%CI: 0.79, 0.91]). In the categorical CRC model, 12%, 67%, and 21% of adolescents were in the low, medium, and high categories, respectively (Table 2.2). Compared to meeting 1-3 recommendations, adolescents who met 4-6 and 7-9 lifestyle recommendations had respectively 39% (RR:0.61 [95%CI: 0.44, 0.84]) and 56% (RR:0.44 [95%CI: 0.31, 0.62]) fewer mental health visits in the subsequent four years.

Exclusion of adolescents with a mental health diagnosis prior to the survey revealed similar RRs of mental health visits to those in Table 2.3. Compared to being normal weight, participants who were overweight or obese had substantially fewer mental health visits (RR:0.63 [95%CI: 0.47, 0.85]). Analyses without considering bodyweight revealed similar finding as those in Table 2.3.

2.4 Interpretation

Our finding of low adherence to lifestyle recommendations is not surprising, as substantial proportions of Canadian children do not meet healthy lifestyle recommendations.[23] We demonstrated meeting recommendations for milk and alternatives and PA in adolescence had significant protective effects on mental health, reducing the number of healthcare encounters for mental health disorders. This study also revealed meeting multiple lifestyle recommendations accumulates to a protective effect on mental health in adolescence.

Our finding that adherence to PA recommendations in early adolescence is associated with 47% fewer mental health visits in the subsequent years is corroborated by some,[9,24,25] but not all prospective studies.[26,27] Ströhle et al. found in a sample of older adolescents and young adults that PA was

significantly associated with a lower incidence of mental health disorders after a four-year period.[25] In a sample of grade five students surveyed in 2003, we also demonstrated low PA predicted future development of internalizing and externalizing disorders in adolescence.[9] In the present study, the protective effect of PA was more pronounced in boys, reducing the number of mental health visits by 53% (RR:0.47 [95%CI: 0.34, 0.64]). An Australian population-based study of 14-19 year olds found associations with mental health outcomes also differed by gender, with each day (per week) of PA guideline attainment associated with a 9% decrease in likelihood of depressive symptoms in boys.[28] In the present study, we revealed further gender differences with boys having 84% more mental health visits in the follow-up period compared to girls. Considering our study captured more externalizing than internalizing disorders, as they often have an earlier onset, and externalizing disorders are more prevalent in boys, these gender differences are consistent across studies in this age group.[9,29] Although the associations between dietary behaviours and mental health in adolescents has been supported by previous literature,[7,10,12,28] no earlier study has examined mental health in combination with dietary and other lifestyle recommendations.

Our finding that adherence to screen time recommendations is associated with 25% fewer mental health visits is substantiated by other population-based studies. In a large sample of Canadian youth screen time was cross-sectionally associated with severe depression and anxiety, and specifically computer use was associated with more severe depressive symptomology.[30] In a sample of grade five students surveyed in 2003, we also found that children who used computers and video games more frequently were more likely to develop mental health disorders.[31] In the present study television and computer time were co-investigated as per the recommendation for combined recreational screen time. Thus, we cannot comment on the separate effects of television and computer use on adolescent mental health disorders.

The effect of adherence to individual lifestyle behaviours with health care utilization for mental health is valuable, but more compelling is the cumulative effect of adherence to multiple recommendations. We observed a 15% reduction in the number of mental health visits for every

additional lifestyle recommendation met and a 39% and 56% reduction in mental health visits among those meeting 4-6 and 7-9 recommendations when compared to those meeting 1-3 recommendations. This accumulation of effects supports the absence of a "magic bullet" notion for avoiding poor mental health.[32] Rather, concurrent adherence to recommendations for diet, PA, sleep, and screen time has the potential to reduce the burden of health care utilization for mental health disorders in adolescents.

Other literature has reported that obesity in adolescence increases the risk of depression and other mental health symptoms.[33] We found overweight and obesity relative to normal weight reduced the number of mental health visits. This could be explained by the higher incidence of hyperactivity disorders in normal weight children at this age.[9]

The interplay between lifestyle behaviours and mental health disorders remains to be fully disentangled, and reverse causality cannot yet be refuted.[28] As suggested by Molendijk et al., correcting for baseline depression symptoms in the cohort may cancel out the effects lifestyle behaviours such as diet, had in the years before the study.[13] Concordant with this concern, we analyzed the cohort with and without correction for baseline mental health diagnosis and present the latter analyses.

Findings from the study should be interpreted considering several limitations. Assessment of diet, sedentary behaviours, and PA were based on self-report and can be prone to error, though the Harvard YAQ and PAQ-C measures have been validated for children. Only children who were seen and diagnosed by a physician were considered as cases. This may have underestimated the number mental health visits as children avoiding treatment or with barriers to accessing healthcare could have been missed. Despite adjusting for a broad set of potential confounders, the possibility of residual confounding related to unmeasured potential cofounders exists. Mental health was investigated as a single outcome; further investigation of the relationships between healthy lifestyle behaviours and individual mental health disorders is merited.

This study contributes to the evidence of potential causal relationships between lifestyle behaviours and mental health disorders among adolescents. Lifestyle recommendations are widely used and primarily intended to promote healthy physical development in children and prevent chronic diseases

later in life. Findings from this study show recommendation compliance has significant short-term benefits for mental health in addition to long-term benefits for physical health. Emphasizing the importance of adherence to lifestyle behaviours during well-visits has the potential improve adolescent mental health and reduce the primary care utilization burden associated with mental health disorders. Promotion of multiple health behaviours in childhood may have a more pronounced effect on reducing the primary care utilization associated with mental health disorders than targeting a single behaviour.

Table 2.1 ICD 9/10 diagnostic codes for mental health disorders

Disorder	ICD-9 code	ICD-10 code
Internalizing disorders (depressive episode, recurrent depressive disorder, mood disorder, neurotic disorder, general anxiety disorder, reaction to stress, adjustment reaction, emotional disorders)	296, 300, 308, 309, 311, 313	F30-34, F38-F43, F45, F48, or F92-F93
Externalizing disorders (hyperkinetic syndrome, hyperkinetic conduct disorder, attention deficit hyperactivity disorder)	312, 314	F70 or F90
Other mental health disorders	290-219 not aforementioned	F00-F99 not aforementioned

Table 2.2 Characteristics of grade 5 students and percentage (%) with a subsequent mental health diagnosis, 2011 Children's Lifestyle and School Performance Study

Characteristics	Total population (%) *N=3436*	With a Mental Health Disorder (14.56%)
Vegetables and Fruit - avg. # of servings (SD)	4.85 (3.24)	
6+ servings	31.4%	12.8%
<6 servings	68.6%	15.4%
Grain Products - avg. # of servings (SD)	4.63 (2.27)	
6+ servings	21.5%	14.4%
<6 servings	78.5%	14.6%
Milk and Alternatives - avg. # of servings (SD)	3.33 (1.98)	
3+ servings	57.4%	14.1%
<3 servings	42.6%	15.3%
Meat and Alternatives - avg. # of servings (SD)	1.47 (0.81)	
2+ servings	86.0%	14.9%
<2 servings	14.0%	12.8%
Saturated Fat - avg. intake (SD)	20.9 (10.1)	
<10% of energy intake	53.9%	13.5%
>10% of energy intake	46.1%	15.8%
Added Sugars - avg. intake (SD)	45.0 (35.7)	
<10% of energy intake	63.4%	13.7%
>10% of energy intake	36.6%	16.0%
PAQ-C - avg. score (SD)	3.27 (0.67)	
Sufficiently active	76.7%	13.8%
Not sufficiently active	23.3%	17.0%
Sleep - avg. duration (SD)	10.1 (0.50)	
9-11 hours	93.1%	14.4%
<9, >11 hours	6.89%	17.2%
Screen (TV & Computer daily hours (SD)	3.00 (1.57)	
<2hours	43.9%	13.4%
>2 hours	59.1%	15.5%
Percentage of Children Meeting Multiple Healthy Lifestyle Recommendations (9)	5.27 (1.47)	
Low (1-3)	11.9%	18.1%
Med (4-6)	67.4%	14.7%
High (7-9)	20.7%	12.1%
Body weight status – avg. BMI (SD)	19.8 (4.19)	
Normal Weight	57.7%	13.9%
Overweight	22.7%	15.4%
Obese	12.5%	15.7%
Gender		
Girl	51.0%	14.7%
Boy	49.0%	14.4%
Parental Education		
Secondary or Less (reference)	17.3%	15.3%
College Diploma	38.1%	14.9%
University or Graduate Degree	39.1%	12.9%
Missing/Prefer not to answer	5.51%	22.2%
Household Income (CAN$)		
<= 20,000	20.7%	20.1%
20,000-40,001	14.1%	16.0%
40,001-60,000	25.3%	12.5%
>= 60,001	21.8%	11.4%
Missing/Prefer not to answer	18.2%	14.0%
Region of Residence		
Urban	69.7%	15.1%
Rural	30.3%	13.5%

Table 2.3 Associations of meeting healthy lifestyle recommendations with physician visits for mental health disorders in subsequent 4-year follow-up

	Univariate RR (95%CI)	*p-value*	Model 1[a] RR (95%CI)	*p-value*	Model 2[b] RR (95%CI)	*p-value*
Vegetables and Fruit						
No (reference)	1	-	1	-	1	-
Yes	0.77 (0.59, 1.00)	0.052	0.85 (0.67, 1.07)	0.162	0.98 (0.75, 1.27)	0.850
Grain Products						
No (reference)	1	-	1	-	1	-
Yes	1.09 (0.84, 1.41)	0.508	1.10 (0.86, 1.42)	0.451	1.16 (0.89, 1.50)	0.269
Milk and Alternatives						
No (reference)	1	-	1	-	1	-
Yes	**0.78 (0.62, 0.98)**	**0.029**	**0.79 (0.63, 0.99)**	**0.037**	0.83 (0.66, 1.05)	0.099
Meat and Alternatives						
No (reference)	1	-	1	-	1	-
Yes	0.85 (0.62, 1.17)	0.324	0.89 (0.66, 1.20)	0.439	0.82 (0.60, 1.10)	0.181
Saturated Fat						
No (reference)	1	-	1	-	1	-
Yes	0.87 (0.68, 1.12)	0.277	0.90 (0.71, 1.15)	0.399	0.84 (0.64, 1.09)	0.196
Added Sugars						
No (reference)	1	-	1	-	1	-
Yes	**0.70 (0.56, 0.87)**	**0.002**	0.82 (0.65, 1.03)	0.093	0.93 (0.73, 1.20)	0.585
PAQ-C						
No (reference)	1	-	1	-	1	-
Yes	**0.51 (0.39, 0.66)**	**<0.001**	**0.53 (0.41, 0.68)**	**<0.001**	**0.53 (0.42, 0.68)**	**<0.001**
Sleep						
No (reference)	1	-	1	-	1	-
Yes	0.98 (0.63, 1.52)	0.914	1.23 (0.78, 1.95)	0.369	1.24 (0.81, 1.89)	0.330
Screen (TV & Comp.)						
No (reference)	1	-	1	-	1	-
Yes	**0.64 (0.51, 0.79)**	**<0.001**	**0.75 (0.59, 0.94)**	**0.013**	**0.76 (0.60, 0.96)**	**0.021**
Body weight status						
Normal Weight (reference)	1	-	1	-	1	-
Overweight	**0.74 (0.55, 0.98)**	**0.032**	**0.75 (0.57, 0.98)**	**0.038**	0.84 (0.65, 1.10)	0.213
Obese	**0.73 (0.54, 0.98)**	**0.038**	**0.63 (0.47, 0.85)**	**0.002**	**0.61 (0.46, 0.82)**	**0.001**
Gender						
Girl (reference)	1	-	1	-	1	-
Boy	**1.91 (1.53, 2.38)**	**<0.001**	**2.11 (1.70, 2.60)**	**<0.001**	**1.84 (1.48, 2.27)**	**<0.001**
Parental Education						
Secondary or Less (reference)	1	-	1	-	1	-
College Diploma	**0.68 (0.50, 0.93)**	**0.017**	0.74 (0.54, 1.03)	0.072	0.74 (0.48, 1.07)	0.060
University or Graduate Degree	**0.47 (0.33, 0.66)**	**<0.001**	**0.58 (0.40, 0.85)**	**0.005**	**0.60 (0.41, 0.89)**	**0.012**
Household Income (CAN$)						
<= 20,000	1	-	1	-	1	-
20,000-40,001	0.74 (0.50, 1.09)	0.126	0.72 (0.48, 1.07)	0.108	0.72 (0.48, 1.07)	0.103
40,001-60,000	**0.50 (0.36, 0.69)**	**<0.001**	**0.51 (0.36, 0.72)**	**<0.001**	**0.51 (0.36, 0.73)**	**<0.001**
>= 60,001	**0.39 (0.27, 0.57)**	**<0.001**	**0.44 (0.29, 0.65)**	**<0.001**	**0.46 (0.30, 0.69)**	**<0.001**
Region of Residence						
Urban	1	-	1	-	1	-
Rural	**0.71 (0.55, 0.93)**	**0.011**	**0.69 (0.54, 0.86)**	**0.001**	**0.64 (0.51, 0.81)**	**<0.001**

RR: Rate ratio; 95% CI; 95% confidence interval; [a]Adjusted for gender, bodyweight status, parental education, parental income, region of residence, and energy intake. [b]Mutually adjusted for all variables in the table. Estimates are weighted to represent grade five students in Nova Scotia.

Results in bold are statistically significant ($p<0.05$)

Table 2.4 Associations of Composite Recommendation Compliance scores with physician visits for mental health disorders in subsequent 4-year follow-up

	Univariate		Multivariable[a]	
	RR (95%CI)	*p-value*	RR (95%CI)	*p-value*
Per recommendation met[b]				
	0.80 (0.74, 0.87)	**<0.001**	**0.85 (0.79, 0.91)**	**<0.001**
No. of recommendations met[b]				
3 or less	1	-	1	-
4 to 6	**0.54 (0.39, 0.73)**	**<0.001**	**0.61 (0.44, 0.84)**	**0.002**
7 to 9	**0.33 (0.22, 0.49)**	**<0.001**	**0.44 (0.31, 0.62)**	**0.004**

RR: Rate ratio; 95% CI; 95% confidence interval; [a]Adjusted for gender, bodyweight status, parental education, parental income, region of residence, and energy intake; [b]Includes meeting the recommendations for vegetables and fruit, grains, milk and alternatives, meat and alternatives, added sugar, saturated fat, physical activity, and screen time. Estimates are weighted to represent grade five students in Nova Scotia.
Results in bold are statistically significant ($p<0.05$)

2.5 References

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Chapter 3: Lifestyle behaviour recommendations and Attention-Deficit/Hyperactivity Disorder: A population-based study of Canadian adolescents

3.1 Introduction

Attention deficit/hyper activity disorder (ADHD) is one of the most common mental health disorders in childhood and adolescence both in Canada, and around the globe.[1] Recent Canadian time trend analyses have reported ADHD prevalence is increasing,[2] despite other adolescent mental health disorder rates stabilizing.[3] About 5% of Canadian school age children are affected by ADHD, and experience difficulties in interpersonal relationships, poor school performance,[4] and increased risk of substance abuse and suicidal ideation.[5] ADHD is marked by an ongoing pattern of inattention and/or hyperactivity-impulsivity that interferes with functioning or development.[6] Symptoms of ADHD usually surface between the ages of three and five but become more apparent in elementary school-aged children and often endure throughout adulthood[6] incurring further personal difficulties, and health care costs.[7] Given the broad range of negative outcomes for affected individuals and the large financial burden for families and society, ADHD constitutes a major public health problem.

ADHD is one of the most thoroughly researched disorders in medicine, and clues about the genetic, neuro-biologic, and neurochemical basis have been uncovered.[8] However, the underlying causes of ADHD remain to be fully elucidated. Studies have focused on genetic[9] and environmental factors such as prenatal cigarette exposure, alcohol and drugs, and exposure to other environmental toxins at a young age. Recent literature has shifted to focus on the associations of lifestyle behaviours such as diet, physical activity, screen time and sleep with ADHD.[10,11]

Large cross-sectional surveys have found associations between increased TV usage, low participation in sports, and low diet quality in children with ADHD.[12,10] However, these associations need to be confirmed in longitudinal studies. Furthermore, recommendations for the aforementioned lifestyle behaviours exist, however recommendation adherence and ADHD have not been investigated. As

suggested by Holton & Nigg, health behaviours need to be investigated in aggregate, as an overall healthy lifestyle has the potential to be more impactful on ADHD than the contribution of only one or two individual health behaviours.[13] Aside from our previous work, no other population-based studies in adolescents have utilized physician diagnosis of ADHD. Given the evidence for the potential of multiple lifestyle behaviours to affect ADHD in children, the effect of adherence to lifestyle recommendations on ADHD is urgently needed to inform prevention strategies and public health policy.

The objective of the present study was two-fold. First; to examine the correlates of meeting health behaviours with ADHD diagnosis in childhood and early adolescence. The second; to investigate the cumulative effects of meeting multiple health behaviour recommendations on ADHD diagnosis through to early adolescence.

3.2 Methods

3.2.1 Study Design

The present study used survey data on diet, lifestyle behaviours, and socioeconomic background from 5th grade students participating in the Children's Lifestyle and School Performance study (CLASS), in Nova Scotia Canada. The information was linked with administrative health data to ascertain physician diagnosis of ADHD from birth until age 14. All grade five students, their parent(s)/guardian(s), and school administrators were invited to participate in the study. Of all 286 provincial public schools with grade five students, 269 schools participated in the study. Parental consent to participate in the survey was given for 6,591 of the 8,736 students, resulting in a mean response rate of 75.4% per school. Of these, 1,481 (22.5%) did not complete the survey, were absent the day of the survey, or had unrealistic caloric intakes (<500 or >5000kcal)[14] and were excluded from analysis, leaving 5,110 eligible students.

The CLASS Study consisted of a student survey on physical activity (PA), sedentary activities, a Canadian version of the Harvard Youth/Adolescent Food Frequency Questionnaire,[15] and height and weight measurements by research assistants. Parent(s)/guardian(s) completed a home survey on the

adolescents' sleep habits, screen time usage, place of residency, gender, household income, and highest level of parent education. Of the 5,110 students who completed the CLASS survey, 3,436 (67.2%) provided valid health card numbers that could be linked with their administrative health data. There were no significant differences in socioeconomic factors or bodyweight status between the linked and unlinked sample.

3.2.2 Exposure of Interest: Healthy Lifestyle Behaviours

We examined adherence to nine established lifestyle recommendations. Eating Well with Canada's Food Guide was used to evaluate students' consumption of age-specific recommendations for daily servings of vegetables and fruit, grain products, milk and alternatives, and meat and alternatives.[16] The World Health Organization's Guideline: Sugar Intake for Adults and Children was used to determine meeting added sugar recommendations[17] and Dietary Guidelines for Americans were to assess saturated fat intake.[18] Meeting PA recommendations was determined by questionnaire cut-offs and Canadian 24-Hour Movement Guidelines for Children and Youth determined sleep and screen time recommendations.[19] All 9 recommendations are detailed in Appendix A.

3.2.3 Outcome of Interest: Attention-Deficit/Hyperactivity Disorder

The first outcome of interest was time to incident ADHD diagnosis. The second outcome of interest was the number of health-care provider contacts related to ADHD between the survey and December 31st 2014. A participant's ADHD physician visit was counted if they received Attention Deficit Hyperactivity Disorder diagnosis, according to the International Classification of Diseases, 9th Revision [ICD-9; code 314.xx] or 10th revision [ICD-10-CA; code F90.xx]. The administrative health data for the

present study were derived from the Medical Services Insurance (MSI) database and Canadian Institute for Health Information Discharge Abstract Database (CIHI DAD).

3.2.4 Statistical Analysis

Correlates of meeting recommendations for diet, PA, sedentary behaviour, and sleep with physician visits for ADHD were examined using mixed-effects regression models to accommodate clustering of students within schools. To investigate incidence of ADHD by lifestyle recommendation adherence, cumulative incidence curves were generated. Complimentary unadjusted and adjusted Cox Regression Models were used. Univariate regression was employed to assess the associations between each of the dichotomized health behaviours and ADHD incidence. Multivariable regression models (Model 1) were used to adjust for potential confounders. We adjusted for child's gender, bodyweight status (normal weight, overweight, or obese using age and gender specific cut-offs[20]), parental educational attainment (secondary or lower, post-secondary/college, or university), household income (<$20 000, $20 001-40 000, $40 001-60 000, or >$60 000) as assessed by categorical questions in the home survey, and region of residence (rural or urban) determined by postal code. As recommended, analysis including YAQ data was adjusted for energy intake.[14] A full model (Model 2) simultaneously considered all lifestyle behaviours and confounders to analyze the independent associations between meeting each lifestyle behaviour recommendation and ADHD incidence. To assess the cumulative effects of meeting multiple recommendations, a Composite Recommendation Compliance (CRC) score was generated. The CRC was considered continuously and according to categories: low (meeting 1-3 recommendations), medium (meeting 4-6 recommendations), and high (meeting 7-9 recommendations). Similar to assessing independent associations, univariable and multivariable regression models were employed to assess the cumulative impact of meeting lifestyle recommendations on ADHD incidence.

We tested the proportional hazards assumption using Schoenfeld residuals. Analysis was repeated with Negative Binomial Regression Models (NBM) to capture all ADHD health care contacts between the date of the survey and age 14 to quantify the associations between lifestyle behaviours and health care

utilization for ADHD while allowing for temporality. NBM analysis was repeated with ADHD health care contacts between birth and age 14 to match the same time period used in the first objective. The distribution of the number of health-care provider contacts with a primary ADHD diagnosis showed overdispersion, thus Negative Binomial Regression Models (NBM) were used instead of Poisson Regression. Missing values for confounding variables were considered as separate covariate categories in the regression analysis, but their estimates were not presented. Response rates for CLASS in residential areas with lower household income were slightly lower than average. To minimize potential non-response bias analyses were weighted for non-response to better represent provincial estimates of the grade five student population.[21] All modes were stratified by gender. The STATA/SE 15 statistical software package (Stata Corp., College Station, TX, USA) was used for all data analysis. The Human Research Ethics Boards of Dalhousie University and the University of Alberta approved the data collection and parental informed consent forms of CLASS. Linkage of the CLASS survey data with administrative health care data was approved by Human Research Ethics Boards at the University of Alberta, Dalhousie University, and by Health Data Nova Scotia.

3.3 Results

Of the 3,436 participants, 10.8% had at least one primary care contact for ADHD before their 14th birthday. A greater proportion of students diagnosed with ADHD were from lower socioeconomic backgrounds, had parents with secondary education or less, and resided in urban areas (Table 3.1). The proportion of students diagnosed with ADHD was lower among those who met recommendations for vegetables and fruit, milk and alternatives, meat and alternatives, added sugar, saturated fat, physical activity, recreational screen time, and sleep. Children on average met 5.3 recommendations with the following sample percentage of adherence to each recommendation: 31% for vegetables and fruit, 22% for grain products, 57% for milk and alternatives, 86% for meat and alternatives, 54% for saturated fat, 63% for added sugars, 77% for PA, 93% for sleep, and 44% for screen time (Table 3.1).

The cumulative incidence of ADHD by recommendation adherence for vegetables and fruit, meat and alternatives, added sugar, saturated fat, screen time, and physical activity and covariates of parental income and education are presented in Figure 3.1. The likelihood of being diagnosed with ADHD was higher among those not meeting each of the nine aforementioned recommendations and from lower socioeconomic backgrounds. The majority of the cumulative incidence curves show a distinct divergence at ages 3 and 4.

Table 3.2 presents results on the average time from birth to ADHD diagnosis for different recommendation adherence. The proportional hazards assumption of the Cox regression models was not violated ($p>0.05$). After adjusting for potential confounders, the incidence of ADHD was reduced by meeting the following recommendations (the reduction in probability of a new ADHD diagnosis for meeting each recommendation in brackets): vegetables & fruit (28%), meat and alternatives (31%), saturated fat (31%), added sugar (25%), and physical activity (39%), (Table 3.2, Model 1). When considering lifestyle behaviours simultaneously (Table 3.2, Model 2), meeting saturated fat, meat and alternatives, and physical activity recommendations had significant independent associations in reducing the probability of a new ADHD diagnosis. When adjusting for all lifestyle behaviours and confounders, boys had 2.77 times higher likelihood of having ADHD compared to girls (HR:2.77 [95%CI: 2.19, 3.50]).

For each additional recommendation met, the probability of developing ADHD during follow up declined by 18% (HR:0.82 [95%CI: 0.76, 0.88]). In the categorical model, 12%, 67%, and 21% of adolescents were in the low, medium, and high adherence categories, respectively (Table 3.1). Compared to meeting 1-3 recommendations, adolescents who met 4-6 recommendations and 7-9 recommendations had respectively 35% (HR:0.65 [95%CI: 0.50, 0.84]) and 58% (RR:0.42 [95%CI: 0.28, 0.61]) lower probability of being diagnosed with ADHD until age 14.

Table 3.4 presents the differences in the number of health care contacts (from the date of the survey until age 14) for ADHD when multiple recommendations are met. For each additional recommendation met, the rate of ADHD visits during follow-up declined by 19% (RR:0.81 [95%CI: 0.73, 0.90]). Compared to meeting 1-3 recommendations, adolescents who met 4-6 and 7-9 lifestyle

recommendations had respectively 40% (RR:0.60 [95%CI: 0.40, 0.90]) and 55% (RR:0.45 [95%CI: 0.27, 0.75]) fewer mental health visits in the follow up period until age 14. A second analysis was performed to analyze the relationship between lifestyle behaviours and health care contacts for ADHD, considering health care contacts from birth to age 14 (Table 3.5). All RR's remained significant, with higher recommendation compliance reducing the RR of health care contacts for ADHD (see Table 3.5).

3.4 Discussion

We observed meeting recommendations for meat and alternatives, saturated fat, and physical activity independently reduced the probability of a new ADHD diagnosis throughout childhood and early adolescence. Meeting multiple lifestyle recommendations in early adolescence had strong correlations with decreased incidence of ADHD until age 14. Greater reductions in health care utilization for ADHD were observed as more recommendations were met.

To our knowledge, this is the first population-based study among children and adolescents that reveals an association between multiple lifestyle recommendation adherence and clinical diagnoses of ADHD in children and adolescents. Other large cross-sectional studies have shown an association between ADHD with diet,[22] physical activity,[12] sleep,[23] and screen time,[10] however none of the assessed combined effects from multiple lifestyle behaviours. Multiple lifestyle behaviours and ADHD were investigated in a recent case control study.[13] Holton & Nigg found that children with ADHD were almost twice as likely to have fewer healthy behaviours (OR:1.95 [95%CI: 1.16, 3.30]).[13] The present study confirms the reverse relationship, and found that children meeting 7-9 lifestyle behaviours recommendations had 58% lower incidence of ADHD compared to children meeting only 1-3 recommendations.

The timing of the divergence between the KM curves in Figure 3.1 should be noted. They illustrate the early effects of lifestyle behaviours on ADHD diagnosis. The distinct divergence at ages 3 and 4 in many of the curves follows the same timing when ADHD diagnoses typically begin.[6] Of particular

interest is the difference in ADHD incidence by SES category. When stratified by parental education, clear differences are observed, with earlier, and higher incidence of ADHD in each lower category of parental education attainment. These descriptive findings are consistent with the evidence that the prevalence of ADHD is higher in children from low socioeconomic backgrounds.[24,25]

Our study adds to the existing research on physical activity and ADHD. We found children meeting physical activity recommendations had a 38% lower incidence of ADHD (HR:0.62 [95%CI: 0.49, 0.78]), compared to those not meeting the recommendation. In a sample of grade five students surveyed in 2003, we also demonstrated children engaged in organized sports have fewer ADHD diagnoses.[11] Our results are consistent with previous studies that have demonstrated the positive effects of physical activity for ADHD in children.[12,26]

Previous studies on dietary factors and ADHD have investigated the effect of individual nutrients and supplements (eg. Zinc, magnesium, omega-3 fatty acids) and restriction or elimination diets (eg. sugar, colour additives) on ADHD symptoms among children and youth.[27] However systematic reviews have reported that the findings are inconsistent on the effect of individual dietary factors.[28] In the present study, we found that meeting the dietary recommendations for vegetables and fruit, meat and alternatives, added sugar, and saturated fat were all individually associated with ADHD, each lowering the incidence by at least 25% (Model 1, Table 3.2). These findings are consistent with other studies that have found associations between well-balanced diets, high in lean meats, vegetables and fruit, and low in sugar and saturated fat, to be protective against ADHD. In an Australian cohort of adolescents, a dietary pattern identified as a "Western" type (high in fat and processed foods) was significantly associated with ADHD diagnosis.[29] Similarly, a recent case control study reported low adherence to a Mediterranean diet (rich in vegetables, and well balanced) was associated with higher prevalence of ADHD.[30] Rios-Hernandez et al. concluded that not only specific nutrients, but also the whole diet should be considered in ADHD. Other studies have confirmed overall dietary characteristics, and not only single nutrients are associated with ADHD.[22,31,32] It is important to recognize that food items and nutrients are often consumed in combinations, and the relations between food constituents are significant.[33] As such, we may shift beyond

the notion of a "silver bullet" for mental health and ADHD, and instead investigate the synergistic effects between food constituents and whole diets that may influence the risk of ADHD.

Future research would warrant multifaceted lifestyle interventions that promote whole food diets, which meet established dietary guidelines, in addition to increased physical activity. As emphasized by Holton & Nigg, an overall healthy lifestyle may be much more impactful than the combination of only one or two individual health behaviours.[13] Thus, the effects of combined lifestyle interventions on ADHD should be assessed. Our results underscore the importance of considering unhealthy lifestyle behaviours as a facet of ADHD that could pose as a feasible target for prevention or secondary intervention. Findings from this study show recommendation compliance has significant benefits for ADHD in addition to long-term benefits for physical health. Additionally, in Chapter 2 we demonstrated benefits from recommendations compliance for other mental health disorders including anxiety and depression – both of which are common ADHD comorbid conditions.

Findings of the study should be interpreted considering many limitations. This research used a cross-sectional survey linked with longitudinal administrative health data that spans time before and after the survey. Dietary habits tend to remain rather constant over time, and eating patterns would take years beyond early adolescence to evolve.[14] However, this research operates on the assumption that lifestyle observations at age 10/11 are indicative of the lifestyle behaviours at a younger age. Directionality issues between lifestyle behaviours and ADHD remain. It may be possible that the diet, physical activity, sleep, and screen time of children and youth have been affected by the symptoms of ADHD.[10] Assessment of physical activity, sedentary behaviours, and diet were based on self-report and can be subject to error, though the Harvard YAQ and PAQ-C measurements have been validated for children. Children who were seen and diagnosed by a physician at least once were considered as cases. Our sample prevalence of ADHD was 10.8%, which is higher than the 7.2% benchmark reported by a recent meta-analysis.[1] However, the prevalence of ADHD is known to vary widely depending on the case definition used. Despite adjusting for a broad set of confounders, the possibility of residual confounding related to unmeasured potential confounders exists.

There are several strengths in this study. The study was conducted in a large, population-based sample of adolescents and linked with prospective administrative health data from birth to age 14 years. The utilization of physician diagnosis of ADHD provides clinically meaningful assessments. This study employed validated questionnaires to assess physical activity and diet as well as measured height and weight. Non-response weighting was used to account for non-response. Lifestyle behaviours were evaluated with respect to established recommendations, allowing for ease of interpretation and application of results to guide health promotion initiatives. The large sample size allowed for consideration of a variety of potential confounders including coinciding health behaviours and sociodemographic factors.

3.5 Conclusion

This study contributes to the evidence of associations between multiple lifestyle behaviours and ADHD in children and adolescents. Although causal effects are not known, children predisposed to ADHD and those already diagnosed may benefit from improved lifestyle behaviours. Findings from this study show recommendation compliance has significant benefits for ADHD in addition to long term benefits for physical health. Health promotion initiatives that target multiple health behaviours have the potential to reduce the high prevalence of ADHD relative to those that target a single behaviour.

Table 3.1 Characteristics of grade 5 students and percentage (%) with ADHD diagnosis, 2011 Children's Lifestyle and School Performance Study

Characteristics	Total population (%) *N=3436*	With ADHD Diagnosis (10.8%)
Vegetables and Fruit - avg. # of servings (SD)	4.85 (3.24)	
6+ servings	31.4%	7.8%
<6 servings	68.6%	12.1%
Grain Products - avg. # of servings (SD)	4.63 (2.27)	
6+ servings	21.5%	11.6%
<6 servings	78.5%	10.5%
Milk and Alternatives - avg. # of servings (SD)	3.33 (1.98)	
3+ servings	57.4%	9.9%
<3 servings	42.6%	11.9%
Meat and Alternatives - avg. # of servings (SD)	1.47 (0.81)	
2+ servings	86.0%	10.2%
<2 servings	14.0%	14.2%
Saturated Fat - avg. intake (SD)	20.9 (10.1)	
<10% of energy intake	53.9%	8.9%
>10% of energy intake	46.1%	12.9%
Added Sugars - avg. intake (SD)	45.0 (35.7)	
<10% of energy intake	63.4%	9.1%
>10% of energy intake	36.6%	13.7%
PAQ-C - avg. score (SD)	3.27 (0.67)	
Sufficiently active	76.7%	9.1%
Not sufficiently active	23.3%	16.1%
Sleep - avg. duration (SD)	10.1 (0.50)	
9-11 hours	93.1%	10.6%
<9, >11 hours	6.89%	13.1%
Screen (TV & Computer daily hours (SD)	3.00 (1.57)	
<2hours	43.9%	9.5%
>2 hours	59.1%	11.7%
Percentage of Children Meeting Multiple Healthy Lifestyle Recommendations (9)	5.27 (1.47)	
Low (1-3)	11.9%	18.0%
Med (4-6)	67.4%	10.8%
High (7-9)	20.7%	6.3%
Body weight status – avg. BMI (SD)	19.8 (4.19)	
Normal Weight	57.7%	10.8%
Overweight	22.7%	10.1%
Obese	12.5%	11.3%
Gender		
Girl	51.0%	6.1%
Boy	49.0%	15.6%
Parental Education		
Secondary or Less (reference)	17.3%	15.8%
College Diploma	38.1%	11.2%
University or Graduate Degree	39.1%	7.5%
Missing/Prefer not to answer	5.51%	15.4%
Household Income (CAN$)		
<= 20,000	20.7%	15.3%
20,000-40,001	14.1%	13.6%
40,001-60,000	25.3%	9.6%
>= 60,001	21.8%	7.1%
Missing/Prefer not to answer	18.2%	9.7%
Region of Residence		
Urban	69.7%	11.8%
Rural	30.3%	8.7%

Table 3.2 Hazard Ratios of Attention-Deficit/Hyperactivity Diagnosis by meeting healthy lifestyle recommendations

	Model 1[a]		Model 2[b]	
	HR (95%CI)	*p-value*	HR (95%CI)	*p-value*
Vegetables and Fruit				
No (reference)	1	-	1	-
Yes	**0.72 (0.56, 0.92)**	**0.009**	0.88 (0.66, 1.16)	0.354
Grain Products				
No (reference)	1	-	1	-
Yes	0.98 (0.77, 1.26)	0.890	1.14 (0.87, 1.51)	0.350
Milk and Alternatives				
No (reference)	1	-	1	-
Yes	0.85 (0.69, 1.05)	0.134	0.80 (0.63, 1.01)	0.065
Meat and Alternatives				
No (reference)	1	-	1	-
Yes	**0.69 (0.53, 0.90)**	**0.006**	**0.66 (0.50, 0.89)**	**0.005**
Saturated Fat				
No (reference)	1	-	1	-
Yes	**0.69 (0.56, 0.84)**	**<0.001**	**0.66 (0.52, 0.83)**	**0.001**
Added Sugars				
No (reference)	1	-	1	-
Yes	**0.75 (0.61, 0.93)**	**0.008**	0.84 (0.66, 1.07)	0.161
PAQ-C				
No (reference)	1	-	1	-
Yes	**0.61 (0.48, 0.75)**	**<0.001**	**0.62 (0.49, 0.78)**	**<0.001**
Sleep				
No (reference)	1	-	1	-
Yes	0.87 (0.57, 1.30)	0.490	0.82 (0.54, 1.17)	0.375
Screen (TV & Computer)				
No (reference)	1	-	1	-
Yes	1.00 (0.80, 1.23)	0.966	1.09 (0.87, 1.38)	0.446
Body weight status				
Normal Weight (reference)	1	-	1	-
Overweight	0.88 (0.68, 1.14)	0.342	0.89 (0.68, 1.16)	0.370
Obese	0.78 (0.59, 1.02)	0.071	0.84 (0.63, 1.12)	0.228
Gender				
Girl (reference)	1	-	1	-
Boy	**3.00 (2.21, 4.09)**	**<0.001**	**2.77 (2.19, 3.50)**	**<0.001**
Parental Education				
Secondary or Less (reference)	1	-	1	-
College Diploma	0.76 (0.58, 0.99)	0.44	**0.74 (0.56, 0.98)**	**0.034**
University or Graduate Degree	**0.55 (0.40, 0.75)**	**<0.001**	**0.55 (0.40, 0.75)**	**<0.001**
Household Income (CAN$)				
<= 20,000	1	-	1	-
20,000-40,001	0.94 (0.68, 1.28)	0.683	0.97 (0.69, 1.34)	0.840
40,001-60,000	**0.74 (0.54, 0.99)**	**0.045**	0.73 (0.54, 1.00)	0.050
>= 60,001	**0.57 (0.40, 0.82)**	**0.003**	**0.60 (0.41, 0.86)**	**0.006**
Region of Residence				
Urban	1	-	1	-
Rural	**0.63 (0.50, 0.79)**	**<0.001**	**0.60 (0.47, 0.76)**	**<0.001**

HR: Hazard ratio; 95% CI; 95% confidence interval; [a]Adjusted for gender, bodyweight status, parental education, parental income, region of residence, and energy intake. [b]Mutually adjusted for all variables in the table. Estimates are weighted to represent grade five students in Nova Scotia. Results in bold are statistically significant ($p<0.05$)

Table 3.3 Associations of Composite Recommendation Compliance scores with Hazard Ratio of incident Attention-Deficit/Hyperactivity Diagnosis from birth until age 14

	Univariate		Multivariable[a]	
	HR (95%CI)	*p-value*	HR (95%CI)	*p-value*
Per recommendation met[b]				
	0.77 (0.71, 0.83)	**<0.001**	**0.82 (0.76, 0.88)**	**<0.001**
No. of recommendations met[b]				
3 or less	1	-	1	-
4 to 6	**0.58 (0.45, 0.75)**	**<0.001**	**0.65 (0.50, 0.84)**	**0.001**
7 to 9	**0.32 (0.22, 0.46)**	**<0.001**	**0.42 (0.28, 0.61)**	**<0.001**

HR: Hazard ratio; 95% CI; 95% confidence interval; [a]Adjusted for gender, bodyweight status, parental education, parental income, region of residence, and energy intake; [b]Includes meeting the recommendations for vegetables and fruit, grains, milk and alternatives, meat and alternatives, added sugar, saturated fat, physical activity, and screen time. Results in bold are statistically significant ($p<0.05$)

Table 3.4 Associations of Composite Recommendation Compliance scores with Physician Visits for Attention-Deficit/Hyperactivity Disorders from date of survey until age 14

	Univariate		Multivariable[a]	
	RR (95%CI)	*p-value*	RR (95%CI)	*p-value*
Per recommendation met[b]				
	0.81 (0.73, 0.90)	**<0.001**	**0.85 (0.77, 0.94)**	**0.002**
No. of recommendations met[b]				
3 or less	1	-	1	-
4 to 6	**0.51 (0.36, 0.72)**	**<0.001**	**0.60 (0.40, 0.90)**	**0.014**
7 to 9	**0.34 (0.20, 0.57)**	**<0.001**	**0.45 (0.27, 0.75)**	**0.002**

RR: Rate ratio; 95% CI; 95% confidence interval; [a]Adjusted for gender, bodyweight status, parental education, parental income, region of residence, and energy intake; [b]Includes meeting the recommendations for vegetables and fruit, grains, milk and alternatives, meat and alternatives, added sugar, saturated fat, physical activity, and screen time. Results in bold are statistically significant ($p<0.05$)

Table 3.5 Associations of Composite Recommendation Compliance scores with Physician Visits for Attention-Deficit/Hyperactivity Disorders from birth until age 14

	Univariate		Multivariable[a]	
	RR (95%CI)	*p-value*	RR (95%CI)	*p-value*
Per recommendation met[b]				
	0.77 (0.69, 0.86)	**<0.001**	**0.82 (0.72, 0.93)**	**0.002**
No. of recommendations met[b]				
3 or less	1	-	1	-
4 to 6	**0.43 (0.28, 0.64)**	**<0.001**	**0.51 (0.33, 0.80)**	**0.003**
7 to 9	**0.26 (0.15, 0.45)**	**<0.001**	**0.38 (0.22, 0.65)**	**0.001**

RR: Rate ratio; 95% CI; 95% confidence interval; [a]Adjusted for gender, bodyweight status, parental education, parental income, region of residence, and energy intake; [b]Includes meeting the recommendations for vegetables and fruit, grains, milk and alternatives, meat and alternatives, added sugar, saturated fat, physical activity, and screen time. Results in bold are statistically significant ($p<0.05$)

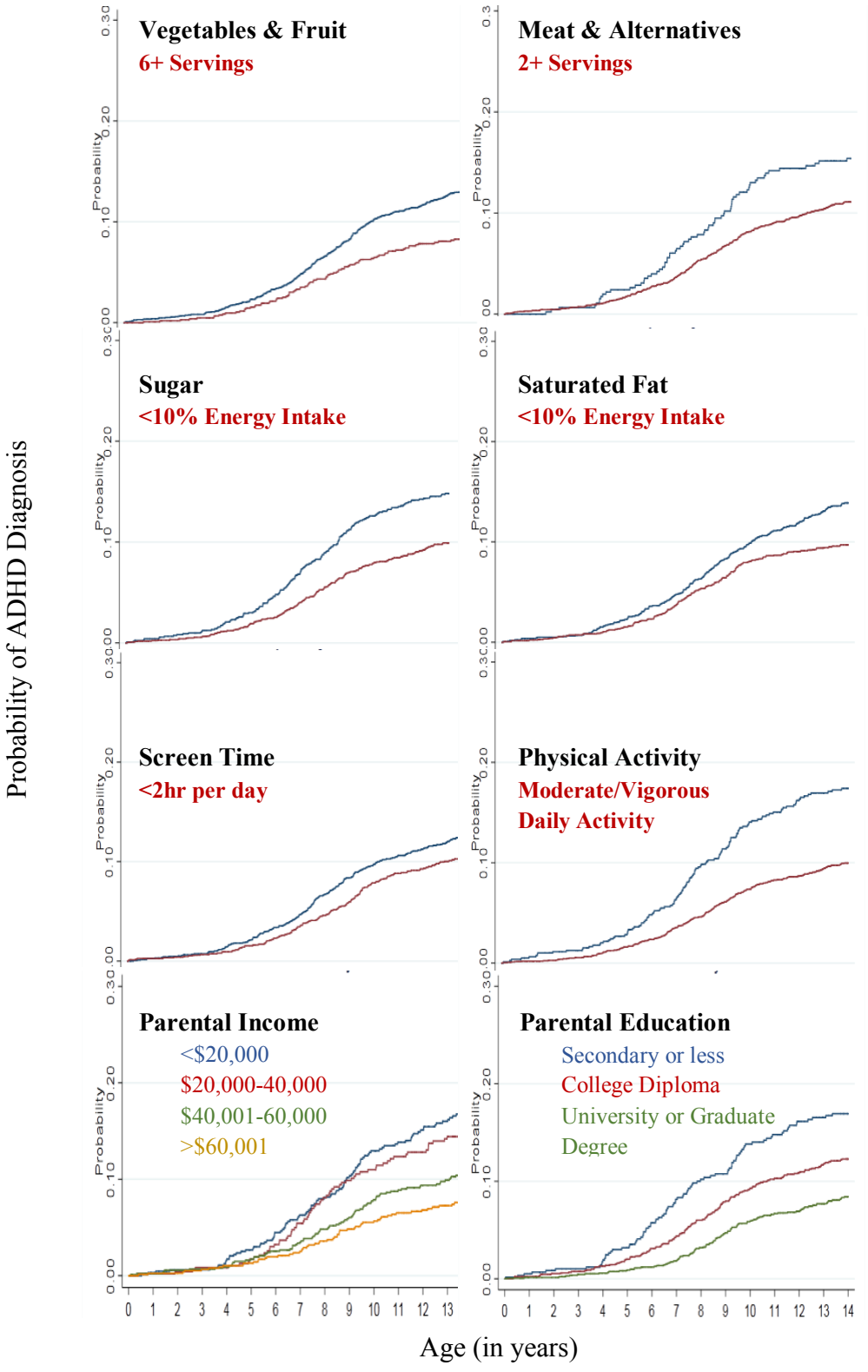

Figure 3.1 Cumulative Incidence of ADHD Diagnosis from birth to age 14 by meeting recommendations and for socioeconomic subgroups

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Chapter 4: Discussion and Conclusions

4.1 Summary

In the present thesis both the longitudinal and correlate relationships between lifestyle behaviours and mental health of children and adolescents have been examined. The two studies complement one another through the use of different outcomes (Chapter 2: all mental health outcomes, Chapter 3: examining only ADHD) and by using different analysis methods.

The results of this thesis consist of two studies performed in the Canadian province of Nova Scotia. The first study revealed a longitudinal relationship between adherence to lifestyle recommendations and health care contacts for mental health disorders in the subsequent four years. Meeting recommendations for milk and alternatives, physical activity, and screen time each independently reduced the likelihood of health care contacts for mental health disorders. The protective effect of meeting physical activity recommendations was more pronounced in boys, reducing the number of mental health visits by 56%. When multiple recommendation adherence was studied, we found for each healthy lifestyle recommendation met, the likelihood of health care contacts for mental health was further reduced. Compared to adolescents who only met 1-3 recommendations, those who met 4-6 and 7-9 lifestyle recommendations had respectively 32% and 47% less mental health visits in the subsequent four years. This suggests promotion of multiple health behaviours in childhood may have an even stronger effect on reducing the burden of mental health disorders than those targeting a single behaviour.

In the second study, which investigated the correlates of meeting lifestyle recommendations in adolescence with incidence of ADHD throughout childhood, we found meeting multiple recommendations was also important for ADHD. The individual recommendations for saturated fat, meat and alternatives, and physical activity reduced the incidence of ADHD in childhood. When assessing cumulative recommendation compliance, each additional recommendation met reduced the incidence of ADHD by 19%. Again we found that in comparison to children only meeting 1-3 recommendations, those

meeting 4-6 or 7-9 had significantly lower incidence of ADHD. In summary, these findings suggest that lifestyle behaviours do play a role in the mental health of children and adolescence. These findings also suggest there may be further merit in the promotion of multiple behaviours over single behaviour intervention strategies.

4.2 Embedding in Existing literature

Other studies have investigated the relationships between lifestyle behaviours such as diet, physical activity, screen time, and sleep with mental health individually,[1–3] but very few have simultaneously examined these health behaviours with mental health.[4,5] The majority of the literature is based on cross-sectional data that does not provide directionality, i.e. whether lifestyle behaviours have an effect on mental health or whether mental health is influencing lifestyle behaviours. Prospective observational studies are more methodologically rigorous and ascertain the exposure (lifestyle information) before the outcome (mental health status). Convenience samples were used in many of the studies, however population-based samples are preferred as they reduce selection bias and residual confounding in the sample. As such, the two studies in the present thesis are important additions to the literature for several reasons: (a) These studies expand on the paucity of research between lifestyle recommendation adherence and mental health in children. (b) Both studies emphasize what is to gain for children's mental health when more lifestyle recommendations are met. (c) The simultaneous investigation of the effects of meeting individual lifestyle recommendations, and multiple recommendations allows for the effect sizes to be compared. As all lifestyle behaviours were investigated as binary outcomes of meeting or not meeting recommendations, the differences in effect size (i.e. reduction in likelihood of mental health disorders or visits) are on the same scale and can be compared. (d) The longitudinal design of the first study provides some directionality to the associations. Exposure status for each of the 9 lifestyle behaviours was ascertained and then physician visits for mental health disorders were captured in the four year follow-up period. (e) The use of clinical outcomes in both

studies provides consistency and an objective measure of mental health. (f) The population-based sample allows for generalizability of the results to other populations of children and adolescents in Canada.

The results of the first study (Chapter 2) are supported by individual studies demonstrating relationships between the lifestyle behaviours of diet, physical activity, and screen time with mental health outcomes.[3,6–11] Specifically, in the first study meeting recommendations for physical activity and milk and alternatives each independently reduced the rate of physician visits for mental health. Physical activity has previously been shown to have positive effects on mental health.[6–8] The few studies analyzing servings of dairy with depressive symptomology have not previously found an association.[5,12] In the second study (Chapter 3) the overarching results of improved lifestyle behaviours being related to better ADHD outcomes is also corroborated by the existing literature.[13,14] We observed meeting recommendations for meat and alternatives, saturated fat intake, and physical activity all independently reduced the incidence of ADHD. The specific associations of meat and alternatives and saturated fat with ADHD have not been previously investigated. However meeting these recommendations are part of a healthy diet, which has been shown to have strong associations with better ADHD outcomes.[15,16]

The common finding between the two studies is the accumulation of effects from meeting multiple health recommendations. Both studies show that concurrent adherence to recommendations for diet, physical activity, sleep, and screen time may have synergistic effects and lead to even greater benefits for adolescent mental health than meeting individual lifestyle behaviours. This "holistic" approach has not been previously reported with regards to the primary prevention of child and adolescent mental illness. It is thus difficult to embed in the literature. However, other scholars have promoted this vein of thinking, with the notion that there is no "silver bullet" to avoiding mental illness.[17] Rather, the synergistic effects between whole diets and physical activity are key for improved mental health in adolescence.

4.3 General Implications

Despite their incredibly high personal and societal burden, mental health disorders do not receive the attention they deserve. In particular, the mental health needs of children and adolescents are neglected despite the fact that mental health disorders have life-long effects and are the leading cause of health-related disability among this group.[18] There is a need for studies that investigate innovative strategies to promote mental wellness early in the lifespan. This thesis provides evidence that combined adherence to lifestyle recommendations for diet, physical activity, screen time, and sleep has the potential to positively impact child and adolescent mental health. The findings from this study further our understanding of the relationships between lifestyle behaviours and mental health. This knowledge can inform nutrition and physical activity policy and programs due to the modifiable nature of lifestyle behaviours. Recognizing the additional benefits for children's mental health when lifestyle recommendations are met provides further evidence for the importance of programs to help children achieve a healthy lifestyle. This information is especially applicable for health advocates and policy makers as it can be used to garner additional government and financial support for the implementation of policy and programs to help children meet health recommendations. There is no harm in the promotion of adherence to lifestyle behaviour recommendations, only assured benefits for physical health and probable benefits for children's mental health. The promotion of meeting healthy lifestyle recommendations is also important to emphasize in the primary care setting, as family physicians are often the main health care contact for children and their parents. Physicians have the opportunity to encourage healthy lifestyles as a primary prevention tool to avoid mental illness, and to potentially reduce the burden of mental illness in children and adolescents who are already affected. The findings from this thesis highlight the potential reduction in health care utilization for mental health disorders in children when lifestyle behaviour recommendations are met. Therefore, the results from this thesis are important across clinical and public health settings.

Future research should focus on the longitudinal relationship between lifestyle and mental health over a longer period of time. The relationship should also be examined across different age groups to confirm the interplay of lifestyle behaviours and mental health over the life course. These studies would bolster the understanding of the directionality between lifestyle behaviours and mental health and provide

further support for intervention studies to assess the effect of an individual's lifestyle on his or her mental wellbeing. Various study designs could be utilized to further study this relationship. Randomized control trials are ideal for identifying the effect size of isolated interventions, however from our results it appears individual behaviours are not the secret ingredient, but rather the cumulative effects from multiple lifestyle behaviours have the largest effect. Thus, the time and high costs of an RCT may not be feasible for studying this relationship. Rather, longitudinal cohort studies with repeated ascertainment of exposure (lifestyle behaviours) and outcomes (mental health status) could chart the relationship between multiple lifestyle behaviours and provide detailed information on directionality and a potential dose-response relationship.

In addition to the human costs of mental health, there are substantial economic costs on society. Forecasts predict that the economic burden of mental illness will continue to grow over the coming decades and could potentially become difficult for Canadian society to bear.[19] Despite the warning signs, Canada spends less on the promotion of mental health and the prevention of mental illness than most developed nations.[20] The limited research regarding adherence to lifestyle recommendations and reductions in mental health related health care utilization prevents the development of targeted policies to lessen these burdens. Investigating the relationships between adhering to recommendations and mental health may offer sufficient evidence to influence policy and prevention strategies.

The first mental health strategy for Canada, *Changing Directions, Changing Lives,* puts forward six planned directions.[21] In brief, these directions include promotion and prevention, recovery and rights, and access to services among other strategies. The first direction translates to promoting mental health across the lifespan in homes, schools, workplaces, and preventing mental illness and suicide where possible.[22] This thesis in particular aligns with Priority 1.2, to increase the capacity of families, caregivers, schools, and post-secondary institutions to promote the mental health of infants, children, and youth, and prevent mental illness and suicide wherever possible, and to intervene early when problems first emerge as we demonstrate the potential of healthy lifestyles to significantly reduce the incidence and burden of mental health disorders. This thesis specifically demonstrates that meeting recommendations

for diet, physical activity, screen time, and sleep can have profound effects on childhood and adolescent mental health disorders. Lifestyle behaviours can be influenced in the home and research has shown an effective environment to influence children is in the school setting. Given the modifiable nature of lifestyle behaviours and their evident potential to positively influence mental health and reduce mental illness, it is clear that lifestyle behaviours (diet, physical activity, screen time, and sleep) are an ideal target for population health intervention. For example, population health interventions could promote family meals as a means to promote healthy diets. Children from families that eat together have been shown to be less likely overweight or obese.[23] Family meals discourage "mindless eating" and excess energy intake. In addition, family meals have been linked to decreased early smoking, pregnancy, drug use, and suicide.[24,25] Thus, promoting lifestyle behaviours such as diet, through family meals in the home environment, has the potential to positively influence children and adolescent's behaviour. Large-scale dietary interventions have also been demonstrated to be successful in eliciting change when used in conjunction with programs like providing nutrition labels on menus, healthy school lunches, and social marketing campaigns.[26–28] This thesis supports the need for multifaceted lifestyle interventions by providing high quality data on lifestyle behaviours and mental health in Canadian children. The incorporation of improved mental health as an additional benefit to when children meet lifestyle recommendations provides further weight to support policy and programs to ensure all Canadian children can lead physically and mentally healthy lives.

4.4 Covariates

All analyses were adjusted for a broad set of factors that could potentially confound the relationship between lifestyle recommendation adherence and mental health. Including: gender, weight status (normal, overweight, obese), energy intake, household income, parental level of education, and region of residence. The parental survey from the CLASS study provided sociodemographic information on household income, parental education, and urban/rural residence. In the analyses age was not

considered as all participants were grade five students between the ages of 10 and 11 years. Weight status was defined using the WHO age and gender specific cut-off points for children and youth. It is recommended to adjust for total energy intake when analysis involves food frequency data.[29] Thus, total energy intake was controlled for in each analysis with diet variables to ensure the relationship between diet and mental health are independent of the child's total energy intake.

The link between socioeconomic status (SES) and mental health has been well established in other studies.[30] Adolescents with lower parental education and household income are more likely to have worse mental health, thus these factors were adjusted for to ensure the relationship between lifestyle behaviours and mental health were independent of the child's SES. Additionally, SES has been shown to influence diet quality and variety. Evidence indicates that higher income allows for the purchase of foods with higher nutritional value, and also a greater variety of foods.[31,32] Therefore children from low socioeconomic status families often have less access to nutritious foods.

Weight status was considered as a confounder as it has been associated with the lifestyle behaviours of diet, physical activity, and screen time with mental health disorders independently. Studies have demonstrated an association between anxiety and depression with BMI.[33,34] However, it is not clear whether BMI is on the causal pathway between lifestyle behaviours and mental health. Improving lifestyle behaviours such as better diet and increased physical activity could lower BMI, however that will not necessarily improve mental health. Since the relationship between lifestyle factors and mental health is being examined in these two studies, BMI was controlled for to ensure it did not distort the true association between lifestyle factors and mental health.

After controlling for all of the variables, there is still the potential of residual confounding due to variables that were not measured. It is possible that some other factor, which was not accounted for in the analysis, may distort the associations between lifestyle factors and mental health. The use of secondary data limits the ability to collect data on all potential confounders. In these two studies there may be variables on which data was not collected and thus, may result in residual confounding. Some potential variables that may have distorted the relationships between lifestyle factors and mental health that were

not controlled for in the analysis include living conditions, parental history of mental illness, and family structure. However, in the two studies we did control for a wide array of sociodemographic characteristics to minimize the potential of residual confounding.

4.5. Strengths and Limitations

In the present thesis there are several limitations that should be considered. The fixed exposure ascertainment and single linking of the survey data to health care data provided study design limitations. The first study (Chapter 2) was a cohort study, with exposure ascertainment in spring of 2011 and an outcome period following this time until the end of 2014. This allowed for temporality between the exposures and outcomes, but the outcome period was relatively short for mental health disorders. A longer follow up into late adolescence or early adulthood would have been preferred as the prevalence of mental health disorders tends to increase to this time.[35]

An additional consideration in the first study was correcting for baseline mental health disorders in the cohort. It has been suggested that not including those with prior mental health disorders may cancel out the effects that lifestyle behaviours, such as diet, had in the years before the study.[36] Concordant with the concern of over-correction, we included analysis in the first study without correction for baseline mental health diagnosis. Additionally, many of the initial health care contacts for mental health disorders occurred before the time of the survey in 2011, with the majority of contacts being for ADHD. Not including the participants with these visits would have restricted cases in our sample to only those with later onset disorders and potentially biased our sample towards later onset and less severe mental health disorders. However, including those participants with a mental health visit before the date of the survey does not allow for us to calculate a true incidence, which would be considering only mental health visits of new cases. Thus, in our Negative Binomial Regression analysis we were restricted to calculating a ratio of the rate of mental health visits in those who met lifestyle recommendations in comparison to those who did not meet recommendations rather than an Incidence Rate Ratio.

The second study (Chapter 3) was cross sectional in nature, with exposure ascertainment in 2011 examined in relation to ADHD diagnosis in a window from birth until the end of 2014. A similar design to the first study was unavailable, as most ADHD diagnoses occurred before the children in the cohort were 10 and 11 in the year 2011, hence outcomes from before the time of the survey needed to be included in the analysis. Since the design was cross sectional, the temporal sequence between lifestyle behaviours and mental health are unclear. Thus reverse causation is possible and it may be that children with ADHD have less healthy lifestyle behaviours as a result of their disorder. However, the longitudinal aspect of Chapter 2 supports the directionality of lifestyle behaviours influencing mental health.

Only children who were seen and diagnosed by a physician were considered as cases in both studies. This case definition may have underestimated the number of diagnoses and physician visits for mental health disorders as children avoiding treatment or with barriers to accessing healthcare could have been missed. Further, including children who were treated or diagnosed with a mental health disorder by a physician ensures identification of only children with fairly severe disorders. Selection bias is of concern, as it may be students (and parents) who sought treatment were systematically different from those who did not. Other literature supports this notion as a significant portion of children suffering from mental health disorders do no seek or receive treatment and children from lower SES groups are less likely to seek treatment.[37] The use of mental health screening surveys may improve the ability to identify mental health disorders that are not detected by clinical data.[38] Additionally, there is evidence that suggests mental illness may affect participation in research.[39] Both studies were considered population based health surveys, and not primarily mental health research so it is unlikely the validity of the studies was affected by lower participation among those with mental health disorders.

In both studies there is the potential for information bias. Measurement error (a type of information bias) is possible in any study where data is measured and collected from individuals and the method of measurement may result in a misestimate of the exposure or outcome. The assessment of diet, sedentary behaviours, and PA were based on self-report, which can be prone to error. The potential of recall bias exists as diet was assessed using self-administered questionnaires. Social desirability bias is

also of a concern in self-reported surveys, as children may report healthier food choices and parents may report higher physical activity, less screen time, and earlier bedtime on their child's behalf.[40] Selection bias must also be considered as it may have occurred through refusal to participate or non-response biases in each of the studies. The response rate of 67% for the CLASS study is relatively high, however it doesn't rule out the potential that students not participating in the study may be systematically different from those who participated. Selection bias for those who provided health information and those who did not provide health information was investigated, and there were no significant differences in sociodemographic factors or bodyweight status between the health linked and unlinked sample. Participation rates in residential areas with lower estimates of household income were slightly lower than average. To minimize potential non-response bias, analyses were weighted for non-response to better represent provincial estimates of the grade five student population.[41]

Despite these potential limitations, this thesis has several methodological strengths. The two studies were conducted in a large, population-based sample of adolescents and linked with administrative health data from birth to age fourteen. The large sample size ensured greater accuracy and provided a larger statistical power to detect effects that might not reach significance in a smaller sample. The large sample size also allowed for consideration of a variety of potential confounders including coinciding health behaviours and sociodemographic factors. The population-based CLASS study had a high response rate and was representative of the Grade 5 students in Nova Scotia, Canada. The utilization of physician diagnosis of mental health disorders provided reliable and clinically meaningful mental health assessments. Both studies employed validated questionnaires to assess physical activity and diet as well as measured height and weight. Lifestyle behaviours were evaluated with respect to established recommendations, allowing for ease of interpretation and application of results to guide health promotion initiatives.

4.5.1 Use of administrative data

Administrative datasets are commonly used in epidemiological studies. The data sets can provide information on a large geographic region, are often readily available for analysis, are a near complete recount of a patient's interactions with the health care system, and they do not rely on self-reported information.[42] However, there are drawbacks, as administrative health databases are not designed for research, but rather for clinical and administrative purposes. There are many ethical considerations due to the confidential nature of the data that make the data difficult and time consuming to obtain. To retain anonymity in the data a third party must often be involved to create a common identification code between the data sets that will be linked. This process can be both timely and costly. Additionally, access to administrative data and the data itself may differ across regions. Once the data is obtained there are many considerations when utilizing it for mental health research. It has been shown that the use of administrative health data often leads to underestimating the burden of certain conditions as only individuals who seek care are identified.[42] Using administrative data renders the researcher unable to control what information is included in the databases and the quality of the data collection.[43] However, secondary analysis of administrative data allows for information to be accessed within vulnerable populations, such as individuals suffering from mental illness.[43] Past studies within child and youth populations have provided evidence suggesting administrative data is an effective tool for assessing prevalence of mental health disorders in this population.[38]

4.6 Conclusions

The two studies within the present thesis have contributed to our knowledge of the relationship between lifestyle behaviours of diet, physical activity, screen time, and sleep with mental health in Canadian children. In short, the present findings suggest that lifestyle behaviours may be involved in the development of mental health disorders in children. The accumulation of effects from adherence to

multiple lifestyle recommendations, as opposed to individual lifestyle behaviours, appears to play a salient role in mental health. This has important implications for prevention of mental illness due to the modifiable nature of lifestyle behaviours. These findings support the promotion of healthy lifestyle for all children to reduce the burden of mental health disorders and encourage healthy development of the next generation. Intervention studies with longer follow up times and precise lifestyle behaviour measurement are needed to expand on the present findings.

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Appendix A: Healthy Lifestyle Behaviour Recommendations

Behaviour	Recommendation	Measurement Tool	Interpretation
Vegetables and fruit	Eating Well with Canada's Food Guide[27] (6 or more servings)	Harvard Food Frequency Questionnaire[63]; 147 questions to ascertain frequency of consuming food items over the past year. Canadian Nutrient File[72]; derives nutrient, energy, and food serving information from food items.	Children eating 6 or more servings of vegetables and fruit met the recommendation.
Milk and Alternatives	Eating Well with Canada's Food Guide[27] (3 or more servings)	See above.	Children eating 3 or more servings of milk and alternatives met the recommendation.
Grain Products	Eating Well with Canada's Food Guide[27] (6 or more servings)	See above.	Children eating 6 or more servings of grain products met the recommendation.
Meat and Alternatives	Eating Well with Canada's Food Guide[27] (2 or more servings)	See above.	Children eating 2 or more servings of meat and alternatives met the recommendation.
Added Sugar	World Health Organization's Guideline: Sugars Intake for Adults and Children[64] (<10% of total energy intake)	See above.	Children with less than 10% of total energy intake from added sugar met the recommendation.
Saturated Fat	Dietary Guidelines for American Adults and Children[65] (<10% of total energy intake)	See above.	Children with less than 10% of total energy intake from saturated fat met the recommendation.
Physical Activity	Physical Activity Questionnaire for Children (PAQ-C) Cut-offs[73] (2.7 for girls, 2.9 for boys)	Physical Activity Questionnaire for Children (PAQ-C)[32]; 10-item validated physical activity recall that measures moderate-to-vigorous physical activity. A composite score from 0 to 5 was calculated.	PAQ-C scores of 2.7 and 2.9 respectively for girls and boys were considered "sufficiently active" and met the recommendation.
Screen time	Canadian 24-hour Movement Guidelines for Children and Youth[74] (<2 hours)	Home survey; Parents reported how many hours per day their child spends watching television not including school hours.	Children with total daily television screen time less than 2 hours met the recommendation.
Sleep	Canadian 24-hour Movement Guidelines for Children and Youth[74] (9-11 hours)	Home survey; Parents reported habitual wake and bed times for children on weekdays and weekends. Average nightly sleep was calculated from the mean sleep duration of five weekdays and two weekend days.	Children with average sleep duration between 9 and 11 hours met the recommendation.