EXAMINING SCHOOL DAY DIETARY QUALITY: AN ANALYSIS OF NATIONAL DIETARY DATA FROM THE 2004 AND 2015 CANADIAN COMMUNITY HEALTH SURVEYS

by

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Abstract

Schools have the potential to contribute to obesity prevention by promoting healthy eating and physical activity. Since 2004, ten Canadian provinces have created policies regarding foods and beverages that can be offered in schools, yet little is known about what Canadian children eat and drink at school, the sources of the foods and beverages consumed, and how children's dietary quality has changed, if at all, over the last decade. Drawing from nationally representative dietary surveys, this thesis includes three studies aimed at filling knowledge gaps regarding Canadian children's dietary quality on school days. The first study characterised the dietary contributions of foods consumed during school hours relative to the overall diet, and sociodemographic factors associated with school hour dietary quality. In 2004, children age 6-17 years consumed approximately one-third of their daily calories during school hours, but energy-adjusted intake of milk products and key nutrients (for example, calcium and vitamin D) was relatively lower during school hours compared to non-school hours. Meanwhile, the school hour contribution from minimally nutritious foods was higher than the average school hour energy contribution. Differences in diet quality scores were poorly explained by sociodemographic factors, although school hour dietary quality differed by age group and province of residence. The second study evaluated associations between lunch-time food source and children's dietary quality. In 2004, 73% of children reported bringing lunch from home, with few students obtaining lunch off-campus or at school. Children consuming foods from home had more favourable nutrient intake profiles compared to children obtaining foods off-campus. However, regardless of lunch-time food source, the quality of foods consumed was, on average, sub-optimal in relation to national dietary guidance. The third study assessed changes in dietary

quality of Canadian children from 2004 to 2015. Average self-reported dietary quality of Canadian children during school hours and on school days improved modestly but remained below national dietary standards. More effective efforts are needed to improve Canadian children's dietary quality. Initiatives that focus on increasing the consumption of vegetables, whole fruit, whole grains and dairy products have the potential to improve Canadian children's dietary quality.

Lay Summary

Schools have the potential to influence children’s dietary quality since students typically eat at least one or more meals during school hours. Since 2004, ten Canadian provinces have created policies about what types of foods schools should offer, yet the dietary contributions of foods consumed at school relative the overall diet remains unknown. Moreover, few studies have explored the sources of foods consumed, or whether and how children’s dietary quality has changed over the last decade. In 2004 and 2015, Statistics Canada carried out two nation-wide dietary surveys examining what Canadians eat. Drawing from both waves of national data, this research examines the contributions of foods consumed at school relative to the overall diet, whether food source influences diet quality, and whether diets have changed between 2004 and 2015. These findings provide evidence to inform policy debates about the potential roles schools could play to influence the diet of Canadian children.

Preface

All the work presented here was conducted while I was a student in the Human Nutrition Program, as part of the Public Health and Urban Nutrition research group at the University of British Columbia (UBC), Vancouver Campus. Ethics approval was granted by the Statistics Act of Canada, and data for chapters 3-5 were accessed through Statistics Canada's Research Data Centre (RDC) program.

I have published three manuscripts based on this doctoral research. I was the first author and lead investigator for projects described in chapters 2, 3, 4 and Appendix A. Dr. Black and I designed the research questions. I was responsible for data management, statistical analyses as well as drafting the manuscripts. Drs. Black and Barr provided critical comments regarding the statistical methods used and interpretation of the results. Chapter 2 has been published as Tugault-Lafleur, C. N., Black, J. L., & Barr, S. I. (2017). Examining school day dietary intake among Canadian children. *Applied Physiology Nutrition & Metabolism*, *42*(10), 1064–1072. Chapter 3 has been published as Tugault-Lafleur, C. N., Black, J. L., & Barr, S. I. (2018). Lunch-time food source is associated with school hour and school day dietary quality. *Journal of Human Nutrition and Dietetics, 31*(1), 81-107. I had primary responsibility for the final content of the manuscripts.

A version of appendix A has been published as Tugault-Lafleur C. N., Black J. L., Barr, S. I. (2017) A systematic review of methods to assess children's diets in the school context. *Advances in Nutrition 8,* 63-79. Dr. Black and I designed the research questions. I was responsible for defining the inclusion and exclusion criteria, searching and selecting studies for inclusion, extracting data from the included studies and drafting the manuscript. Dr. Black and Dr. Barr provided critical feedback and comments.

Table of Contents

List of Tables

List of Figures

List of Abbreviations

AMPM: Automated Multiple Pass Method

ASA24: Automated Self-Administered 24-hour Dietary Recall

BC: British Columbia

CI: Confidence Interval

CFI: Canada Foundation for Innovation

C-HEI: Canadian Healthy Eating Index

CCHS: Canadian Community Health Survey

CIHR: Canadian Institutes of Health Research

CNF: Canadian Nutrient File

CRDCN: Canadian Research Data Centre Network

DP: Digital Photography

DV: Daily Value

DFE: Dietary Folate Equivalents

DRI: Dietary Reference Intakes

EAR: Estimated Average Requirements

EWCFG: Eating Well with Canada's Food Guide

FFQ: Food Frequency Questionnaire

FR: Food record

HEI: Healthy Eating Index

g: gram

ICC: Intraclass Coefficient

IOM: Institute of Medicine

Kcal: Kilocalories

kg: Kilogram

LOA: Limits of Agreement

mcg: microgram

MO: Meal Observation

mg: milligram

NRF: Nutrient-Rich Food

LB: Labrador

MUFAs: Monounsaturated Fatty Acids

NSLP: National School Lunch Program

NSBP: National School Breakfast Program

NHANES: National Health and Nutrition Examination Survey

NRF: Nutrient Rich Food

OR: Odds Ratio

PEI: Prince Edward Island

PRISMA: Preferred Reporting Items for Systematic reviews and Meta-analyses

PUFAs: Polyunsaturated Fatty Acids

R^2: Coefficient of Determination

RAE: Retinal Activity Equivalents

RDC: Research Data Centre

RDAs: Recommended Dietary Allowances

School-HEI: School Healthy Eating Index

SD: Standard Deviation

SE: Standard Error

SES: Socioeconomic Status

SFC: School Food Checklist

SMI: School Meals Initiative

SNDA: School Nutrition Dietary Assessment Study

SSBs: Sugar-Sweetened Beverages

SSHRC: Social Sciences and Humanities Research Council

TDIs: Total Daily Intakes

U.K.: United Kingdom

U.S.: United States

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I am forever grateful to my mentor and committee member Dr. Susan Barr. Susan, you have supported me by helping me develop critical thinking and academic writing skills, for which I forever grateful for. In addition, you have provided me with numerous reference letters, graduate awards applications, feedback on manuscripts, presentations, conference posters, consumer articles. Despite your numerous commitments, you have always made time for me. I feel so fortunate to have had the chance to have you on my committee.

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I am also thankful of the staff at the University of British Columbia Research Data Center (UBC-RDC) (Dr. Cheryl Fu, Mr. Lee Grenon, and Dr. Wendy Kei) for their assistance when accessing the survey datasets. Thanks also to Jean-Michel Billette for his statistical advice and guidance when navigating the (many!) datasets of the CCHS.

All statistical analyses using dietary data from the Canadian Community Health Surveys (2004 and 2015) were conducted at the UBC RDC, which is part of the Canadian Research Data Centre Network (CRDCN). The services and activities provided by the UBC-RDC are made possible by the financial or in-kind support of the Social Sciences and Humanities Research Council (SSHRC), the Canadian Institutes of Health Research (CIHR), the Canada Foundation for Innovation (CFI), Statistics Canada, and UBC. The views expressed in this paper do not necessarily represent the CRDCN's or that of its partners.

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Last, but not least, I thank my family and friends who have been there to support me in this journey. Some special thanks go to my husband Gill Green. I would have not been able to do this (and have two baby boys along the way) if you had not been such a supportive husband and always there to encourage me.

Chapter 1: Introduction, Literature Review and Objectives

1.1 Diet quality of Canadian children

Ensuring that children have adequate access to healthy food to grow, learn and thrive is important for achieving developmental potential (1). From a public health standpoint, childhood and adolescence are critical windows for establishing healthy eating habits that can impact long-term weight status (2–5) and chronic disease later in life (6). There is a groundswell of interest in Canada in developing policies and programs to improve dietary outcomes for children. For example, in October 2016, Health Canada launched a multipronged Healthy Eating Strategy which includes actions to restrict marketing of unhealthy foods and beverages to children and an extensive revision of national dietary guidelines (7).

Research shows that most Canadian children do not meet national dietary recommendations for key food groups. National-level analyses suggest that in 2004, up to 37% of Canadian children 4–9 years, 61% of boys and 83% of girls 10–16 years did not meet the minimum recommended daily servings of milk products (8). Evidence also suggests that Canadian children do not meet national dietary recommendations for vegetables and fruit. In 2004, seven out of ten children aged 4-8 years consumed less than the five servings of vegetables and fruit a day recommended in the 1992 Food Guide (8). Sixty-two percent of girls and 68% of boys aged 9-13 years also failed to meet their minimum five daily servings of vegetables and fruit (8). In addition to failing to meet the dietary recommendations for these two food groups, many Canadian children are getting a large proportion of their daily calories from ‘other’ foods (typically minimally nutritious foods which are not part of the four core food groups from the 2007 Eating Well with Canada’s Food Guide (EWCFG)). An analysis of dietary patterns of

Canadian children and adolescents showed that in 2004, on average, 23-31% of daily calories consumed were derived from ‘other’ foods and beverages not recommended in the 2007 EWCFG (9).

Consequently, many Canadian children and adolescents have inadequate intakes of key nutrients. For example, more than 10% of Canadian youth (9-17 years) have inadequate intakes of vitamin A, D, calcium and magnesium (10). There is also a concern that adolescents may not be meeting their needs for potassium and fibre (10).

1.1.1 Role of schools in promoting healthy eating practices

Multiple factors operate at different scales – at the individual, household, and broader community and regional level – to influence the food practices of children (11,12). Within the socio-ecological conceptual framework, schools represent one of the physical settings exerting a potential influence on children’s dietary intakes (12). Leading national (13) and international organisations (14,15) have long acknowledged the importance of promoting health and improving dietary outcomes through schools. Schools can improve access to nutritious foods via school meal programs (16,17), and nurture healthy eating habits through nutrition education programs and supportive school food environments (12,18–21).

Canada does not have a national or provincially-administered school lunch program (22–24). Instead, funding for Canadian school lunch programs comes from provincial, municipal and non-governmental organizations, parents, corporate donations and local fundraising. Several advocacy groups (e.g. Food Secure Canada) have proposed a universal school lunch program as a means of promoting healthy eating at school (25–27). In June 2017, the Government of Canada launched a consultation process to develop a national food policy with a focus on improving health and access to affordable food (28). An understanding of what children eat during school hours and its contribution to whole day intakes is needed to inform these broader strategies and to help policy makers weigh the evidence about *how* schools could play a role in national food policies and dietary interventions. For example, if the dietary contribution of vegetables consumed during school hours was low relative to the total daily amount consumed, it would make sense for schools to target increased consumption of this dietary component at school.

1.1.2 What do Canadian children eat at school?

Studies examining children's dietary practices at school are limited in Canada, and the current evidence is limited to relatively small, region-specific samples (29–32). Findings from a sample of youth (grades 6, 7 and 8) in Ontario in the 2005-2006 academic year suggest that low intakes of vegetables, fruit and milk products at lunch-time (29). Moreover, nearly half of students in this study reported consuming sugar-sweetened beverages (SSBs) at lunch despite a school-board level policy restricting the sale of 'junk foods' (including SSBs) in schools (29). There is evidence that some Canadian secondary schools have less healthful beverages available for sale despite provincial-level nutrition policies regarding the sale of foods and beverages in schools (33–35). However, it is also possible that students are bringing in SSBs from home or purchasing them off-campus during school hours. Similarly in Vancouver (where minimally nutritious foods are prohibited from being sold in public schools) (36), nutritionally poor choices such as intake of SSBs were reported to be consumed daily by 31% of a 2012 sample of grade 5-8 students (mean age 12.5 years) (30). Another study conducted in a Prince Edward Island (PEI) suggests that grade 5-6 students in 2007 had lunches of poor nutritional quality, regardless of the source (schools vs. home and off-campus) (n = 1980) (32).

Few international studies (37–40) (and no Canadian studies) have examined whether dietary practices at school improve (or reduce) children's total dietary quality on school days. In Sweden (where all students enrolled in public schools participate in a universal school lunch program), the mean caloric contribution from lunch was 27%, with most macro- and micronutrients providing similar (27% or higher) contributions to daily intakes (37). In the United Kingdom (U.K.), two studies have examined the dietary contributions from school lunches (38,39). Nelson and colleagues reported that the nutrient contributions from the lunch meal were similar to the energy contribution except for iron and folate (which were lower than the caloric contribution for both primary and secondary students, regardless of school meal participation status) (n = 1456 children). Another U.K. study comparing the lunch-time contributions from foods by school meal participation status in a smaller sample of adolescents aged 14-15 years (n = 757) revealed that the dietary contribution for the majority of nutrients was similar to the energy contributions with the exceptions of vitamin C (lower for both boys and girls regardless of school meal participation status), vitamin A (lower among girls eating a home-packed lunch), and folate (lower among boys, regardless of school meal participation status) (38). The contribution of the lunch meals to the total 24-hour dietary intakes of children in the United States (U.S.) has been documented in the School Nutrition Dietary Assessment Study III (SNDA III), a nationally representative survey of public schools participating in the National School Lunch and Breakfast Programs (NSLP and NSBP, respectively) (n = 2314 children) (41). This study reported that both NSLP participants and non-participants obtained approximately 30% of their total energy intake from lunch. However, the lunches consumed by NSLP made significantly greater contributions to 24-hour dietary intakes of protein, fiber, cholesterol, and most vitamins and minerals (vitamins, A, B vitamins, calcium, iron, magnesium, phosphorus, potassium, sodium and zinc). This suggests that NSLP participants were less likely to obtain these nutrients from other meals and snacks consumed throughout the day compared to non-NSLP participants.

1.2 Factors associated with dietary quality among Canadian children and youth

1.2.1 Demographic and socioeconomic determinants

Within the socio-ecological model (12), individual level factors include demographic (e.g. age group, sex, ethnicity) and socioeconomic factors (e.g. household-level income, education) (12). Insights about whether school hour diet quality differs within sociodemographic sub-groups can help assess whether socioeconomic inequalities in dietary quality are substantial in the school context and warrant further investigation or intervention.

Evidence from nationally representative surveys suggests that demographic factors such as age and sex may be associated with diet quality among Canadian children. Using dietary data from the 2004 Canadian Community Health Survey (CCHS) Cycle 2.2, Garriguet examined associations between sociodemographic and economic characteristics and dietary quality using the Canadian Healthy Eating Index (C-HEI) (a composite measure of dietary quality assessing adherence to EWCFG's dietary recommendations) (42). Children aged 2-8 years had the highest C-HEI scores and scores tended to be lower among older children. Among young children (2-11 years), no significant associations emerged between diet quality and sex. However, among older children (age 12 and older), boys reported lower C-HEI index scores compared to girls. Using the same dataset, Riediger and colleagues examined the impact of demographic factors (age, sex, ethnicity, and province of residence) on the frequency of fruit and vegetable consumption (n = 18 524) (43). Fewer older adolescents (15-19 years) reported eating fruit and vegetables five to ten times per day compared to their younger peers (12-14 years). Finally, a study drawing from a smaller, urban sample of children in Vancouver (BC) showed that secondary school students were more likely to report daily consumption of fast-foods and minimally nutritious packaged snacks (e.g. candy, chocolate bars, chips) compared to elementary school-aged children (31).

Canadian studies examining associations between socioeconomic status (SES) characteristics (e.g. household-level income, parental education, food security status) and children's diet quality have reported no or weak, positive associations between SES and dietary quality among children. Analyses based on the CCHS 2.2 data (where SES measures are reported by the most knowledgeable person in the household – usually the parent or caregiver) suggest that adolescents coming from households with parents who have attained higher education and income report higher daily frequency of fruit and vegetable consumption (43). Another study based on the same dataset suggests that Canadian youth (9-18 years) living in lower income households have lower mean daily intakes of calcium and vitamin D (44). Studies drawing from smaller, regional samples have reported either no or positive (albeit weak) associations between household-level parental income and education and children's diet quality. For example, Shatenstein and Ghadirian found no clear association between dietary adequacy and any of the SES measures (parent-reported) in a sample of adults and children in Montreal (Quebec) (45). A regional study conducted among grade 5-6 students (mean age 11.3 years) in British Columbia (BC) reported that neither household-level income or education were associated with child-reported measures of fruit and vegetable consumption (children, irrespective of SES, were not meeting the national dietary guidelines for fruit and vegetable intakes) (46). In Vancouver, one study examined dietary practices of grade 5-8 students (n = 950, mean age = 12.5 years) in relation to various demographic and child-reported SES factors (parental education and food security status) (30). Students whose parents completed some college (compared with those completing high school or less) were significantly more likely to consume vegetables daily (unadjusted OR=1.85; 95 % CI 1.06, 3.22) and less likely to consume SSBs daily (unadjusted OR=0.67; 95 % CI 0.47, 0.94) during school hours on school days. However, SES was not significantly associated with any of the remaining dietary outcomes. The absence of or weak association between SES and dietary quality in children may in part be related to the fact that SES is methodologically difficult to assess in this age group. For example, children may experience difficulty reporting parental occupation, education, or income (47). Finally, it is also possible that the effect of low SES may have unequal impacts within the household. For example, younger children in lower income households may be given preferential access to healthy foods compared to their caregivers or older children (48,49).

Household-level food insecurity (defined here as when households have "inadequate or insecure access to food because of financial constraints" (50)) is thought to impact diet quality by limiting access to resources to purchase more expensive food items such as fresh produce and dairy products (51). However, the impact of food insecurity on Canadian children's dietary quality remains unclear. National-level analyses have confirmed a higher prevalence of nutrient inadequacy for some nutrients among adolescents (but not younger children) among food-insecure households (52). These findings are consistent with qualitative research suggesting that the impact of food security on dietary quality within members of the same households may differ (49). Exploring whether socioeconomic inequities in dietary outcomes are present in the school context can help determine whether school-based nutrition interventions have the potential of reducing dietary inequities within population sub-groups.

1.2.2 Lunch-time food source and dietary quality

School food environments may impact dietary practices by influencing which foods are available to eat and affect barriers and opportunities that either foster or hinder healthy eating (12). Identifying the sources of foods consumed by children during school hours (and whether lunch-time food source impacts dietary outcomes) can help clarify the potential role of schools and parents to promote healthy eating patterns in school settings.

A substantial body of U.S. literature has documented the impact of its NSLP[1] on children's dietary quality (16,53–57). A growing body of research suggests that school meals have a more healthful nutritional profile compared to lunches brought from home, which are not subject to dietary guidelines and standards (58–61). Compared to students bringing food from home, NSLP participants are more likely to consume healthy foods such as whole fruits, vegetables and low-fat dairy products (57,58,61) and less likely to consume SSBs and minimally nutritious snacks

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[1] The first NSLP nutrient standards were first put in place in 1995 through a policy initiative and related regulation known as the School Meals Initiative (SMI) for Healthy Children (236). This regulation required that all meal programs (breakfast and lunch programs) comply with the 1995 Dietary Guidelines for Americans. Under the SMI, school lunches were to provide at least one-third of the 1989 Recommended Dietary Allowances (RDAs) for select nutrients (calories, protein, iron, calcium, vitamin A and C) as averaged over five consecutive school days. In addition, the program regulations specified the maximum amounts of total fat (≤ 30% of total calories) and saturated fat (< 10% of total calories). In 2012, the NSLP underwent some revisions to align with the 2010 Dietary Guideline for Americans and revised food-based standards for the lunch and breakfast meals but retained nutrient specifications for total calories, saturated fat and sodium content of the school meals (117).

(58,59) for the lunch meal. Research suggests that NSLP participants consume more fibre (53), fewer calories (56,61), more protein (61) and protein-rich foods (57) and less sodium (58) for their lunch meal compared with students bringing in home-packed lunches. Similarly in the U.K., a meta-analysis comparing school meals by lunch type from studies published between 1997 to 2007 concluded that the nutritional quality of school meals was higher than home-packed lunches (which contained more total sugars, added sugars, saturated fats and sodium) (62).

Canada does not have a national or provincially-administered school lunch program (22–24) and therefore, these programs may (or may not) abide to nutritional criteria for foods being served. Limited research has examined where Canadian children acquire food from in the school context and whether lunch-time food source influences diet quality. In Ontario, Woodruff and colleagues examined where lunch foods were consumed, where the food was originally prepared and/or purchased in relation to energy and intakes of key food groups among grade 6-8 students in Ontario(n = 1236) (29). Most students (79%) reported purchasing their lunch originally from a grocery store (i.e. they brought a home-packed lunch to school). Compared to students who ate a lunch at home or school, students who had a lunch from off-campus locations (e.g. restaurants, fast food outlet) consumed significantly more calories, servings of meats and alternatives and servings of minimally nutritious foods at lunch. Another study conducted in a sample of grade 5 and 6 students in PEI (n = 1980) suggested differences in nutrient densities based on lunch-time food source (32). Compared to lunches from home, school meals were higher in nutrient density for protein and 10 micronutrients (calcium, zinc, magnesium, vitamins A, D, K, riboflavin, niacin, B6 and B12). Some of the differences in nutrient densities (amount of nutrient per 1000 kcal) varied considerably by food source: 44.4g vs. 30.9g for protein, 1204 mg vs 375 mg for calcium, 611 vs. 198 Retinol Activity Equivalents (RAE) for vitamin A, 9.5 vs. 0.8 μg for vitamin D for foods from school vs. home, respectively. Finally, a recent study documenting Canadian adolescents' food purchasing behaviours on week days and weekend days in relation to frequency of SSBs consumption reported that purchasing lunch from schools and off-campus locations was associated with higher frequency of consuming SSBs (63). No national study has examined where Canadian children obtain foods and beverages during school hours and whether lunch-time food source influences dietary intakes and dietary quality during school hours, and for the overall school day.

1.3 Changes in children's dietary quality over time

Within the socio-ecological framework, broader macro-level factors (e.g. governmental policies and societal norms and values) are described as having distant, yet potentially important roles in shaping what people eat (12). Over the last decade, considerable public health efforts have focused on obesity prevention among children (64) and several public health initiatives have targeted schools as a strategic place for nutrition intervention and health promotion (13,14). For example, since the early 2000's, all ten Canadian provinces have issued school-based food and nutrition guidelines (65–67). Several urban school boards have implemented food and nutrition initiatives including nutrition education, cooking and gardening programs (66,68). In the past decade, six Canadian provinces have banned the sale of 'junk foods' (for example, SSBs) on school property (69). There is evidence suggesting that local school meal programs have grown in number in the past decade. For example, as part of the Ontario's poverty reduction strategy, 700 new breakfast programs were created in 2008 (70). As part of Newfoundland and

Labrador (LB)'s poverty reduction strategy, an additional $1 million dollars is now donated to the Kids Eat Smart Foundation which provides healthy foods to school-aged children (71). Limited research has explored changes in children's dietary quality following the implementation of school-based nutrition policies in Canada (22,72). Given the wide regional variation in funding and implementation of these programs (69,73), understanding whether school hour diet quality differs by province and whether any changes have occurred over the past decade can provide foundational knowledge for local efforts.

Monitoring children's dietary quality over time can help measure progress towards national dietary standards and identify aspects of the diet which need improvement. However, national dietary data are limited in Canada. In 2004, the Canadian government conducted the first national nutrition survey since 1970, the CCHS Cycle 2.2, Nutrition. An objective of this survey was to collect detailed dietary data about the consumption of foods and dietary supplements among a representative sample of Canadians at national and provincial levels (74). Eleven years later, a second national nutrition survey (the 2015 CCHS – Nutrition) was conducted using a similar methodology to the CCHS 2.2 in order to facilitate comparison of the dietary habits of the Canadian population from 2004 to 2015 (75). The release of the 2015 CCHS – Nutrition provided an opportunity to analyze differences in school day dietary quality following a decade of provincial and local school-based initiatives aimed at improving Canadian children's dietary quality at school.

1.4 Methodological issues in measuring diets in schools

Dietary instruments used to measure dietary intakes within school settings can be broadly categorized as self-report (the subject is doing the reporting of foods and beverages consumed) or observational methods (wherein researchers/observer evaluate dietary consumption in real time). Self-reported methods include meal-specific or 24-hour dietary recalls, estimated food records (FRs), and food frequency questionnaires (FFQs). Studies reporting in-school dietary outcomes have used a broad range of instruments but the most commonly used instruments appear to be weighed FRs (an observational method when foods are being measured by the researchers before and after a meal to measure consumption) and school-meal recalls (a self-report method) (76) (see appendix A). The next section provides a review of previous research on the relative accuracy of the dietary recall method since analyses within chapters 2, 3 and 4 rely on 24-hour dietary recall data collected in the CCHS surveys in 2004 (74) and 2015 (77). A more in-depth discussion on the relative accuracy and reliability of dietary instruments used to assess the dietary intakes of children at school is provided in appendix A.

1.4.1 Relative accuracy of dietary recalls

Dietary recalls rely on children's memory to report all foods and beverages consumed at school (breakfast and/or lunches), often using specific prompting methods to elicit detailed information on types and amounts of foods consumed. If interviewer-administered, this method poses relatively low burden on children and may be designed to collect detailed, contextual information about consumption patterns (e.g. where was the food consumed and with whom). A key source of error to this method is driven by children's ability to recall foods and beverages consumed on a previous day (78) which in turn, is influenced by children's age (79). A systematic review of dietary assessment methods for use in children suggests that the use of parents as proxy reporters is the most accurate method for children age 4 to 11 years (80). The accuracy of the dietary recall method can also be potentially impacted by the retention period (defined as the length of time elapsed between the eating occasion and the time when a child is asked to report dietary intake) and use of prompting (when probing questions are asked to elicit more details about the foods consumed) (81).

The major type of measurement error in dietary recalls is random error (also known as within-person or day-to-day variation) which is the difference between an individual's reported intake on a specific administration of the dietary recall and an individual's long-term average reported intake (82). However, a single dietary recall can be used to estimate the mean usual intake at the group level (83). An advantage of using the dietary recall method over other dietary assessment instruments is that it holds less systematic error[2] (83). For example, the dietary recall method is thought to be less cognitively challenging than a Food Frequency Questionnaire (FFQ) (which requires estimating usual intake patterns over a week or month) and therefore carries less systematic error (84). Nonetheless, the dietary recall method can be affected by social desirability bias, a type of systematic error when subjects selectively misreport certain foods due to their norms and beliefs about what they should eat (85).

[2] Systematic error (or bias) is a type of measurement error in which measurements consistently depart from the true value in the same direction.

In a systematic review documenting the accuracy of dietary instruments used to assess dietary intakes at school (76), 15 studies that tested the relative accuracy of the school meal recall method against an observational method (usually in-person meal observations by trained research staff) were compared. The majority of studies were conducted among elementary school-aged children age 9-10 years (see appendix A). The relative accuracy of the school meal recall method was poor when using measures such as the frequency of discrepancies for individual foods reported at lunch-time. In other words, children had difficulty recalling all the specific foods and beverages consumed at lunch-time. Omission (a measure of reporting error that reflects the rate of foods reported relative to all foods observed to be consumed) and intrusion (a measure of reporting error that reflects the rate of foods reported but not observed to be consumed) rates for individual foods tended to be above the 15% cut-off[3] used as a criterion for 'acceptable' accuracy. Similarly, 'match' rates (the proportion of foods and beverages both reported to be consumed and observed to be consumed) often fell below a proposed cut-off of 85%. However, there are limitations to using measures such as omission rates and match rates as measures of accuracy since some of the forgotten meal items (e.g. condiments) may not have a substantial impact on energy or nutrient intake estimates. In the above systematic review (76), many of the studies reported that children aged 9-10 years were able to reasonably report *amounts* consumed among foods correctly reported (86–90). Two of three studies comparing

[3] There are currently no established cut-offs classifying dietary instruments as having 'acceptable' or 'poor' validity. To facilitate the interpretation and comparison in findings across methodological studies, new scoring criteria and cut-offs were used in this systematic review. These cut-offs were based on previous standards used in the methodological literature (88).

reported vs. observed energy intakes reported acceptable energy report rates (the percent of energy reported consumed by the total observed energy was between 85-115%) (91,92).

1.4.2 Measures used to assess dietary intakes in the school context

In a systematic review which documented measures used to evaluate the quality of foods and beverages consumed at school (76), the majority of studies evaluated (n = 44/47) used multiple, single individual dietary components (e.g. amounts of fruit and vegetables, grams of sodium, fiber, etc.) (see appendix A). Only three studies used a more comprehensive assessment of dietary intakes in the school context (57,93,94). Sabinsky et al. developed a composite meal-based diet quality index (the 'Meal IQ') to measure the quality of foods for Danish children aged 7-13 years based on seven dietary criteria (total fat, saturated fat, snacks, whole grains, fish, fruit, and vegetables) (93). In Finland, Tilles-Tirkkonen et al. used a cruder measure where they classified children as either 'balanced' or 'unbalanced' school lunch eaters based on whether they reported consuming three meal components (main dish, salad and bread) or not (94). In the U.S., Hanson and Olson used the U.S. Healthy Eating Index 2005 (HEI-2005) to assess in-school dietary intakes between breakfast and lunch meal diet quality on school days vs. weekend days (57). Unlike other Canadian adaptations of the HEI (42,49,95,96) which uses scoring criteria based on a whole day's intakes, the U.S. HEIs can be used to assess diet quality for any time period (e.g. the whole day, meals and snacks) because its scoring standards are based on standardized amounts per 1,000 kcal.

Using multiple, single dietary components to evaluate overall diet quality is appropriate when there are national food-based or nutrient-based criteria available to provide a nutritional benchmark for evaluation (e.g. NSLP food-based standards in the U.S.) (17,97–99). In Canada (where no national universal school meal program exists), there are no nutrient or food-based criteria to evaluate the quality of foods and beverages for foods consumed for a particular eating occasion (e.g. lunch) (73). Instead, the Canadian dietary guidelines are designed to provide dietary guidance for a whole day's intake. An analytical approach to measure diet quality specifically for the school context could provide a means of assessing compliance with Canadian national dietary guidelines. The approach should ideally be reproducible in order to measure the impacts of school-based nutrition interventions on children's overall dietary quality.

Among the composite diet quality indicators available for Canada, the C-HEI developed by Garriguet (42) reflects most recent food-based dietary guidelines and was designed to assess dietary quality using 24-hour dietary recall data used in the CCHS 2.2 and the 2015 CCHS Nutrition. Because the C-HEI reflects recommendations from the 2007 EWCFG, it has good content validity (42). The C-HEI has also demonstrated good construct validity by providing high scores for menus developed by nutrition experts (Dietary Approaches to Stop Hypertension (DASH) diet, the Healthy Eating Pyramid and the 'No-Fad' diet) (42). However, the scoring criteria for the C-HEI were developed based on a whole day's (24-hour) intake, so its scoring system cannot be used to assess the quality of foods consumed only in the school context.

1.5 Summary

Multiple factors operate at the individual, social and physical environmental, and the broader macro level to influence children's dietary practices (11,12). Schools have been long recognised as important physical and social environments to promote healthy eating behaviours among children (13–15,100). Despite numerous calls to ameliorate the quality of foods consumed at school (25,67,101), little research has examined children's dietary practices during school hours, and whether foods consumed during school hours improve or worsen overall dietary intakes for Canadian children. No study has compared in-school dietary outcomes across sociodemographic characteristics in a large nationally representative sample of Canadian children. Only two Canadian studies (29,32) have examined the sources of foods consumed by Canadian children at school and whether lunch-time food source influences diet quality. Finally, while many public health initiatives have targeted children's diet quality in Canada (22,69,70,72), little research has explored differences in Canadian children's dietary intakes before and after these policy interventions.

1.6 Research objectives and overview of thesis

Guided by the socio-ecological framework (12), I conducted three studies to improve our understanding of Canadian children's dietary patterns on school days and explore factors associated with dietary quality. The specific objectives and layout of the dissertation are outlined below.

1.6.1 The dietary contributions of foods and beverages consumed during school hours by Canadian children and the sociodemographic correlates of school hour dietary quality

A secondary analysis of the CCHS 2.2 was undertaken to: *i)* describe the mean proportion of total (24-hour) intakes provided by foods and beverages consumed during school hours by Canadian children; *ii)* examine differences in dietary intake patterns between school hours and non-school hours; *iii)* evaluate the influence of potential demographic and socioeconomic factors on the school hour diet quality of Canadian children. I hypothesized that dietary patterns would not differ between school hours and non-school hours on school days. Based on the literature presented in section 1.2.1, I hypothesized that: *i)* school hour diet quality would significantly differ by age group; and *ii)* school hour diet quality would not differ by any of the other demographic and socioeconomic characteristics examined (sex, ethnicity, residential location, province of residence, household-level education, income and food security status).

1.6.2 Lunch-time food source and school hour dietary quality

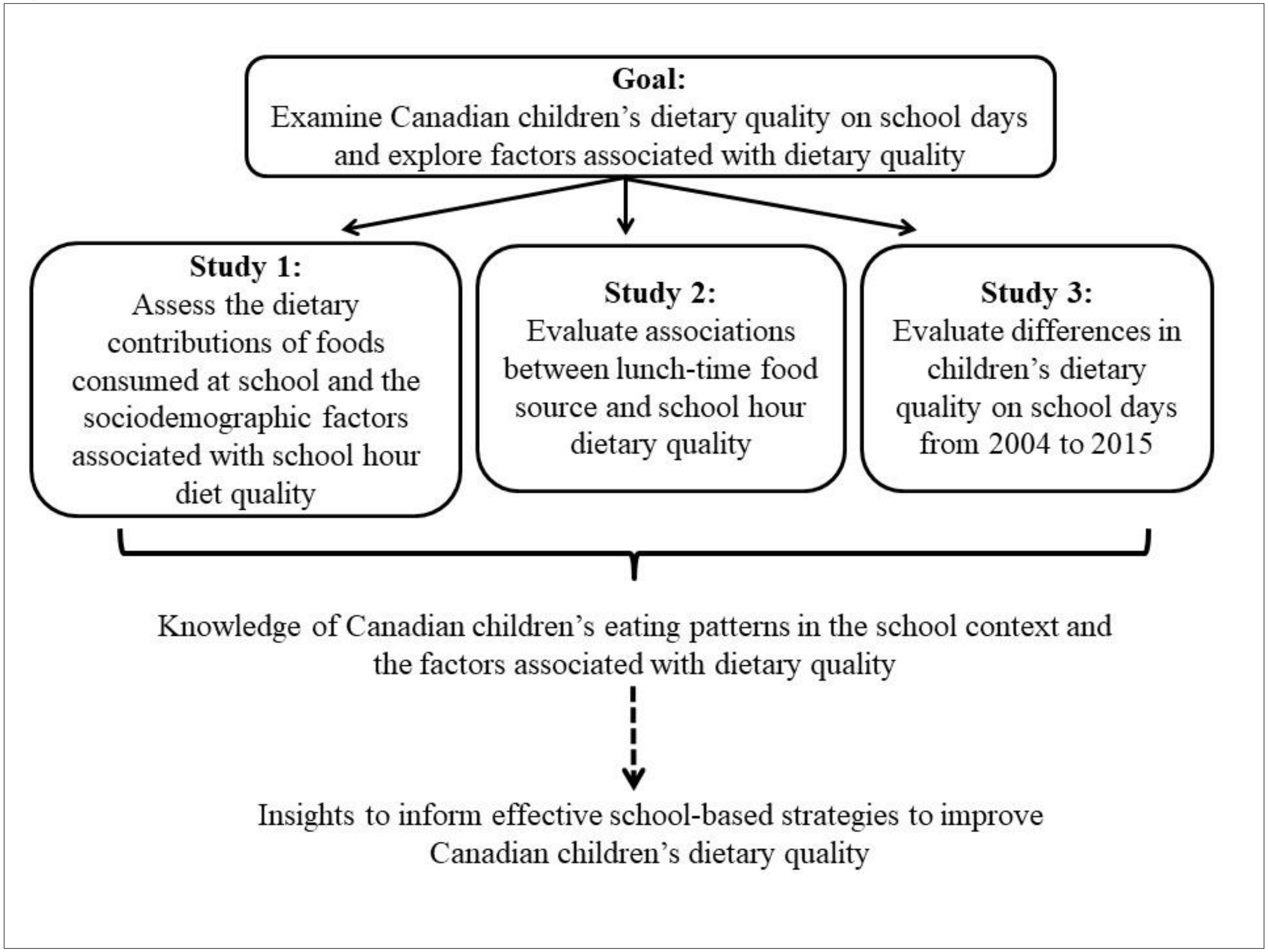
A secondary analysis of the CCHS 2.2 was undertaken to test whether lunch-time food source (where children reported their food to be prepared – home, schools or off-campus locations) was associated with differences in school hour and school day dietary quality. Based on the literature review presented in section 1.2.2, I hypothesized that students who brought a home-packed lunch would have different nutrient intake profiles compared to students who obtained lunch from schools or off-campus.

1.6.3 Differences in Canadian children's dietary quality from 2004 to 2015

A repeat cross-sectional study was conducted to compare school hour and whole day dietary intakes from 2004 to 2015. Based on new provincial and locally-based initiatives to improve the quality of food environments within Canadian schools (66,69,102), I hypothesized that: *i)* school hour and school day dietary quality would improve from 2004 to 2015; *ii)* differences in school hour dietary quality among age groups and provinces (observed in 2004 – see findings from chapter 2) would persist in 2015; and *iii)* differences in school hour diet quality scores would be similar across provinces and other sociodemographic factors.

An overview of the three studies is shown in figure 1. The methods, results and interpretation of the findings of the three studies are described in chapters 2, 3 and 4. Chapter 5 consists of a general discussion of the key findings of this body of work and their implications along with research limitations and an overall conclusion. The studies undertaken for this dissertation provide empirical evidence to inform the design of effective school-based strategies to address areas of concerns in the diet of Canadian children.

Figure 1 Research overview



Chapter 2: Examining School Day Dietary Intakes among Canadian children

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2.1 Introduction

In Canada, like other affluent countries (103–106), evidence suggests that the majority of children and adolescents do not meet national dietary guidelines for vegetables and fruit as well as dairy products (8). Moreover, 'other' foods (which do not fall within the four 'core' food groups of the EWCFG and are typically minimally nutritious) account, on average, for 25% of the total daily calories consumed among adolescents aged 14 to 18 years (8). Schools are a proposed site for health promotion since most children consume one or more meals during school hours on week days. Moreover from a health equity standpoint, schools can reach a large number of children from diverse socioeconomic backgrounds (18,21). Leading national (13) and international agencies (14,15) have long acknowledged the importance of promoting health and improving dietary outcomes through schools.

Understanding the nutritional impact of foods consumed during school hours relative to the whole school day can help inform the design of effective school-based interventions by identifying salient areas of concern and potentially modifiable loci for intervention. Yet, few national studies in Canada or elsewhere have examined the dietary contributions of foods consumed during school hours (37–40). From the modest available literature, it is estimated that in Sweden, the mean caloric contribution from school lunches was 27%, with most macro- and micronutrients providing similar (27% or higher) contributions to daily intakes (37). In the U.K., one study examining dietary contributions of nutrients from lunch among older adolescents reported relatively lower intakes of vitamin C, folate, calcium and iron compared to the mean caloric contribution (38). In the U.S., evidence from the SNDA studies showed that both NSLP participants and NSLP non-participants obtained approximately 30% of their total energy intake from lunch, but the lunches consumed by NSLP participants had greater contributions to 24-hour dietary intakes of protein, fiber, cholesterol, and most vitamins and minerals (41). In Canada, a limited number of studies from regional, context-specific samples have examined in-school dietary intakes suggesting overall sub-optimal dietary practices (29,30,32,107), but no study has assessed the dietary contributions from foods eaten during school hours in relation to whole day intakes or compared nutrient intake patterns between school and non-school hours.

Understanding whether dietary inequities at school exist among sociodemographic sub-groups can help inform school-based health promotion efforts. U.S. and Canadian literature has shown that age is a well-established determinant of consumption practices, with diet quality declining as children transition into adolescence (42,43,108). Previous international (109) and Canadian (42,43) research also suggests that household SES (e.g. parental income, education, food security status) is positively associated with adolescents' dietary quality. For example, national-level Canadian analyses indicate that adolescents coming from households with higher education and income reported higher daily frequency of fruit and vegetable consumption (43). Moreover, adolescents living in food-insecure households are more likely to report poorer quality diets (52). However, Canadian studies drawing from smaller, regional samples report either no, or weak positive associations between household-level SES and dietary quality outcomes in younger children (30,46). No study has compared in-school dietary outcomes across demographic and socioeconomic characteristics in a large nationally representative sample of Canadian children.

This first study therefore addresses gaps in the literature by: *i)* describing the mean proportion of total (24-hour) intakes provided by foods and beverages consumed during school hours by Canadian children; *ii)* examining differences between school hour and non-school hour dietary intakes; and *iii)* assessing demographic and socioeconomic correlates of school hour diet quality among Canadian children age 6-17 years.

2.2 Methods

2.2.1 Data sources

Nationally representative data were obtained from the 2004 CCHS (Cycle 2.2), which used a complex multistage stratified cluster sampling design to achieve a sample that is nationally representative based on age, sex, geography and SES (n = 35 107; response rate, 76.5%) (74,110). The survey targeted residents of all ages living in private dwellings in Canada's ten provinces. A computer-assisted 24-hour dietary recall method asked respondents about all foods and beverages consumed from midnight to midnight on the previous day, including types and amounts of foods consumed, eating occasion (e.g. breakfast, lunch, snack) and time of consumption (74). The approach used for the 24-hour recall was based on the United States Department of Agriculture Automated Multiple-Pass Method (AMPM). The AMPM is an automated questionnaire that guides the interviewer through a series of questions and probes to maximize the interviewees' opportunities for remembering and reporting foods eaten in the previous 24 hours (111). Although a second telephone-administered dietary recall was performed in a sub-sample of participants, this study used only the first in-person, interviewer-administered 24-hour recall. The mean of one-day intakes is an acceptable estimate of the mean 'usual', or long-term daily average, intake of a population when it is properly estimated; that is, when the days of the week and seasons of the year are adequately represented (112) which was the case for the CCHS Cycle 2.2 (74). Interviews for children age 6 to 11 years were conducted with parental assistance (at least for the dietary recall portion of the interview). Interviews with children aged 12 years and above were asked to provide their own information. All foods and beverages were analyzed using the food composition data from the 2001b version of the Canadian Nutrient File database (110). Permission to conduct these analyses and access to these data was provided by Statistics Canada's Research Data Center Program.

Analyses included respondents (n = 4945) age 6 to 17 years who reported attending school full-time and who completed a first 24-hour dietary recall that fell on a week day (Monday through Friday) but excluded recalls that fell on days from December 22 through the first week of January (typical Christmas/winter breaks), other statutory/national holidays, or during summer months (June 21 to September 7). Similar to the approach used by Sheehy et al. (113), diet recalls with extreme daily energy intakes (mean ± 3 Standard Deviations (SDs), >6365 kcal or <486 kcal/day) were considered extreme outliers and were excluded (n = 28). Sensitivity analyses were conducted to determine whether including these respondents changed the results, but since including these children did not change the direction of these findings, these children were dropped from this analysis. Children who did not report consuming any energy during school hours or outside of school hours were also excluded from these analyses (n = 90). The final analytical sample consisted of 4827 children.

2.2.2 Measures

Foods reported to be consumed between 9:00 to 14:00 were classified as those consumed during school hours. Time of consumption was used to classify foods and beverages as either falling within or outside of school hours as the CCHS 2.2 did not ask respondents to state *where* the food or beverage was consumed (110). Since public school hours vary by Canadian jurisdictions (114), it was not possible to determine the exact time window which would include school hours for all Canadian children. The 9:00 to 14:00 time frame was chosen since it was most likely to include school hours for most Canadian children and this study did not aim to capture consumption related to participation in school breakfast programs or after-school programs. Sensitivity analyses confirmed that widening this time by 30-minute increments did not result in substantial increases in energy intake up until 15:00, when Canadian schools are often at or near closing time and hence a substantial number of children are likely to be consuming food at or en route home (see table 1).

Table 1 Energy intake and relative change for varying time periods defining school hours on school days*

Time	Mean energy intake (kcal)	Absolute difference (kcal)	Relative difference† (%)
	Mean ± SE		
9:00-14:00‡	730 ± 11	-	-
9:00-14:30	748 ± 12	18	2.4
9:00-15:00	791 ± 12	61	8.1
9:00-15:30	840 ± 13	110	13.9
8:30-14:00	743 ± 11	13	1.5
8:30-14:30	761 ± 12	31	4.1
8:30-15:00	804 ± 13	74	6.7
8:30-15:30	853 ± 13	123	15.3
9:00-15:30	840 ± 13	110	13.9

*The sample size (n = 4917) for these preliminary analyses included children who did not report consuming any foods during school hours; † The relative difference (in percent) from the reference period was calculated as the difference in energy intake between the wider time window and the reference period divided by the energy intake from the reference period and multiplied by 100. For example, the percent change between 9:00-14:30 and the reference period was calculated as: (18 kcal / 730 kcal) x 100 = 2.5%. ‡ The 9:00 to 14:00 period was chosen as the reference period for school hours since most children attend school during this time in Canada.

Dietary intake variables included the amounts of energy, nutrients and food groups consumed during school hours on school days, outside of school hours on school days, and the relative contributions (percentage intake) from school hours relative to total daily intakes (TDIs). Preliminary analyses confirming that foods consumed during school hours provided, on average, one-third (33.6%) of the daily calories consumed. The relative school hour contributions from dietary components were subjectively defined as ‘low’ if the relative contribution (percentage intake) was less or equal to 31% of their TDIs and subjectively defined as ‘high’ if the relative contribution was more or equal to 36% of their TDIs.

To address the multidimensional nature of diet quality and measure adherence with the national dietary guidelines (recommendations of the 2007 EWCFG), I adapted a validated measure of diet quality for Canadians (the C-HEI (42)). The C-HEI is based on the U.S. 2005

HEI (115), with modifications to reflect how well diets comply with Canadian dietary guidance from the most recent 2007 version of the Canadian Food Guide (EWCFG) (116). The C-HEI contains 11 components (maximum score = 100 points), reflecting both the adequacy and moderation dimensions of a healthy diet. The C-HEI components are based on *daily* intake standards (e.g. 2 servings of milk and alternatives/day recommended for children age 6-8 years) which are then used to compute sub-scores for each of its components. To compute C-HEI scores adapted specifically for school hours, the scoring criteria for each component were scaled to reflect the mean energy contribution from school hours (9:00-14:00) to daily energy intake (see table 2 for a list of the components of the School HEI (School-HEI)). The food group components' scoring criteria for the School-HEI were scaled to reflect one third of the total daily servings recommended for each age and sex group, based on preliminary analyses confirming that foods consumed during school hours provided, on average, one-third of the daily calories consumed. For example, the scoring criterion for total fruit and vegetables for earning maximum points on the sub-score for children age 6-8 years (whose recommended daily intake are 5 servings/day) was 1.67 servings. This approach is similar to the standards set by U.S. NSLP, which uses 1/3 of the 1989 RDAs[4] for energy, protein, iron, calcium, vitamin A and C as minimal nutritional quality criteria for school meals (117). A similar approach has been used in previous Canadian studies which used 1/3 of the daily recommended intakes as nutritional criteria for meals consumed at school (32,107). For the C-HEI, diet quality categories have been

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[4] The RDAs are defined as "the levels of intake of essential nutrients that, on the basis of scientific knowledge, are judged by the Food and Nutrition Board to be adequate to meet the known nutrient needs of practically all healthy persons" (247). For nutrients, these are amounts intended to be consumed as part of a normal diet composed of a variety of foods. The RDAs are neither minimal requirement nor necessary optimal levels of intake. The RDAs have been mostly applied to groups when establishing standards for planning and procuring foods as well as for food assistance programs (e.g. the NSLP) in the U.S.

previously established (but not validated) (42). A ‘high quality diet’ is defined as above 80 points; a diet ‘requiring improvement’ falls within 50-80 points, and a ‘poor quality diet’ is < 50 points. Like the C-HEI, scores for the School-HEI range from 0 to 100 points, so the same categories were used for interpretation of School-HEI scores.

Table 2 Scoring criteria for the School Healthy Eating Index (School-HEI)

Component	Ranges of scores	Maximum score criteria*	Minimum score criteria*
Adequacy	**0-60 points**		
Total vegetables and fruit	0-10	1.67-2.67 servings†	0 serving
Whole fruit	0-5	0.35-0.56 servings† (21% of the recommendation for 1/3 of the total daily vegetables and fruit for each age-sex group)	0 serving
Dark green and orange vegetables	0-5	0.35-0.56 servings† (21% of the recommendation for 1/3 of the total daily vegetables and fruit for each age-sex group)	0 serving
Total grain products	0-5	1.33-2.33 servings†	0 serving
Whole grains	0-5	0.67-1.17 servings† (50% of the recommendation for 1/3 of the total grains for each age-sex group)	0 serving
Milk and alternatives	0-10	0.67-1.17 servings†	0 serving
Meat and alternatives	0-10	0.33-1 servings†	0 serving
Unsaturated fats	0-10	10-15g†	No oil
Moderation‡	**0-40 points**		
Saturated fats	8-10	<7% of school hour energy intake	10% of school hour energy intake
	0-8	10% of school hour energy intake	>15% of school hour energy intake
Sodium	8-10	<1/3 of Adequate Intake	1/3 of Tolerable Upper Level intake
	0-8	1/3 of Tolerable Upper Level intake	≥2/3 of Tolerable Upper Level intake
Other foods§	0-20	≤5% of school hour energy intake	≥40% of school hour energy intake

*Scoring criteria for the School-HEI were adapted from the C-HEI (42); † Scores differ according to age and sex, as specified in 2007 EWCFG (116). These scoring criteria represent one third of the scoring criteria used to compute sub-scores for the C-HEI. The cut-offs for whole fruit, dark green and orange vegetables and whole grains reflect the recommendations in the EWCFG for each age-sex group. Guidelines in Canada recommend one serving each of dark green and orange vegetable per day, and the consumption of whole fruits and vegetables rather than juice. The Canadian threshold used the same American threshold (0.8 servings of whole fruit or dark green and orange vegetable per 1000 kcal) but it is expressed here as a percentage of total vegetable and fruit intake. The U.S. HEI-2005 density standards for total fruit are 1.6 servings per 1,000 kcal and 2.2 servings of total vegetables per 1,000 kcal. So, 0.8 servings of whole fruit or dark green and orange vegetables (per 1000 kcal) represent 21% of the total number of servings of vegetables and fruit (per 1000 kcal): 0.8 / (1.6 + 2.2) = 21%. In Canada, it is recommended that whole grains make up half of total grain products so the cut-offs for total grains for each age-sex group were divided in half to obtain the whole grain School-HEI cut-offs for each age-sex group; ‡ For moderation components, 10 or 20 points were given for minimum or less, 0 points for maximum or more, and proportional points for amounts between the minimum and maximum. § Other foods include any foods not part of the four core food groups in Canada's Food Guide (for example, chocolate, candies, sugar-sweetened beverages, salty snacks and condiments).

To compare the School-HEI scores with another composite measure of diet quality, Nutrient-Rich Food (NRF) scores were derived using the algorithm proposed by Fulgoni and colleagues (118). The NRF index is a composite nutrient-based diet quality indicator that has been used previously to evaluate the quality of foods and beverages consumed for specific meal occasions (e.g. lunch) (119). The NRF index algorithm assigns higher diet quality scores to foods which provide higher amounts of recommended Daily Values (DV) for 'desirable' nutrients and/or lower amounts of the recommended DV for 'undesirable' nutrients. Conversely, lower NRF scores are given for foods which provide higher amounts of the DV for 'undesirable' nutrients and/or lower amounts of the DV for 'desirable' nutrients. For this analysis, the NRF 9.3 was slightly modified to a 'NRF 8.2' index, which excluded vitamin E and the added sugars since these are not available in the Canadian Nutrient Files. That is, I applied an algorithm which assigned a score based on the sum of the percent consumed of the reference U.S. daily values for eight nutrients to encourage (i.e. protein, fibre, vitamin A, vitamin C, calcium, iron, magnesium, and potassium) from which was subtracted the sum of the percent consumed of reference daily values for two nutrients to limit (saturated fat and sodium), expressed per 100 kcal (118).

2.2.3 Statistical analyses

Descriptive statistics (survey-weighted means and robust standard errors (SEs) of the mean) were used to obtain average absolute dietary intakes and dietary contributions (in percent) from school hours relative to whole day intakes. Nutrient and food group *densities* (amounts per 1000 kcal) were calculated for foods consumed during school hours and during non-school hours to allow for comparison in quality, while accounting for differences in the quantity of foods (and calories) consumed between school hours and non-school hours. Survey-weighted simple linear models then tested for significant differences in nutrient and food group densities across period using a dichotomous variable for school hours as the independent variable. Since nutrient intakes are measured in different units (e.g. carbohydrate in grams vs. vitamin C in mg), a common unit of comparison was needed to compare the magnitude of the differences between school and non-school hours. Results were therefore expressed as percent differences from school hours relative to non-school hours. This was calculated by taking the estimated mean difference in nutrient or food group density between time periods divided by the nutrient or food group density during non-school hours. The difference was then multiplied by 100 to express this difference in relative terms.

To examine differences in school hour diet quality by select sociodemographic characteristics, simple linear regression models were used with a Bonferroni adjustment to account for multiple comparisons in regression models with multiple dummy variables (e.g. province of residence). These models did not include an energy term since the algorithm for the C-HEI and School-HEI computes scores based on age and sex specific food and nutrient requirements. Since age group emerged as a significant correlate of school hour diet quality, I estimated mean School-HEI total and sub-scores (for example, School-HEI sub-scores for whole fruit) and NRF 8.2 scores by age group.

Missing data were handled with case-wise deletion. Therefore, analytical sample sizes varied slightly across analyses. Sampling weights were applied to all analyses to generate nationally representative estimates. The 500 sets of bootstrap weights supplied by Statistics Canada were used to derive robust standard errors to account for the complex sampling design of the CCHS (110). All analyses were conducted using Stata 13 (LP Stata Corp, Texas, USA), with significance defined as p-value < 0.05 (Bonferroni-adjusted p-value $< 0.05/n$, with n being the number of comparisons).

2.3 Results

Table 3 provides the sample characteristics of Canadian children age 6-17 years whose first 24-hour dietary recall fell on a Canadian school day in 2004. Young children (6-8 years) comprised approximately a quarter of all children surveyed, 43% were age 9-13 years and close to one third were older adolescents (14-17 years). Fifty-one percent of participants were male. Most children identified themselves as having a White/European background, lived in urban areas, and had at least one household member who had completed some post-secondary education (college or university). Close to 9% of children were classified as food-insecure while slightly over one-third lived in a low-income household.

Table 3 Sample Characteristics of Canadian children 6-17 years whose first 24-hour dietary recall fell on a Canadian school day in 2004 (n = 4827)

Sociodemographic characteristics	Survey-weighted percent (%)
Age group	
6-8 years	24.7
9-13 years	43.1
14-17 years	32.1
Females	49.4
Household highest level of education*	
Secondary school education or lower	16.7
Some post-secondary education	83.3
Income adequacy†	
Low	36.0
High	64.0
Food security status‡	
Food-secure	91.1
Food-insecure	8.9
Residence type	
Urban	80.5
Rural	19.5
Ethnicity§	
Other background (including mixed origins)	19.8
White/European background	80.2

* Educational attainment was recoded as a dichotomous variable which grouped respondents as either having at least one adult household member who completed high school or less vs. households which had at least one adult member who completed some post-secondary education (trades, college, or university education). Sample for parental education was smaller as there were missing education data for 76 children; † To align with the coding method adapted by Health Canada, a dichotomous indicator of 'low' and 'high' income was created by grouping households in the first two lower and the last two higher income adequacy groups from the original income adequacy classification. This classification grouped households into income groups based on household size and before-tax income (50). Sample for income was smaller as there were missing income data for 620 children; ‡ A dichotomous food security variable was constructed characterising respondents as food-insecure (marginal, moderate and severely food-insecure) or food-secure to enhance comparability with previous Canadian research on food security (52). The prevalence of food insecurity was estimated using respondent (individual) sampling survey weights. Hence, the prevalence of food insecurity may not be reflective of all the respondents living in the households (and therefore not nationally representative of *household*-level food insecurity status). Sample for food security was smaller as there were missing data for 36 children. § Self-reported ethnicity was dichotomized as either being of White/European descent *vs.* belonging to any other ethnic group (including mixed origins).

2.3.1 School hour dietary intakes and their relative contribution to total daily intakes

Mean school hour dietary intakes and their relative contributions to whole school day dietary intakes are shown in table 4. The mean energy from foods and beverages consumed during school hours was 746 kcal, representing 33.6% of the total daily energy consumed on school days. The relative dietary contributions of total carbohydrates, fibre, total sugars, total fats and saturated fats were similar to the energy contribution. However, the relative dietary contribution of polyunsaturated fatty acids (PUFAs), linoleic and linolenic fatty acids tended to be higher during school hours (defined as providing $\geq$ 36% of their TDIs). In contrast, the relative contributions from protein and cholesterol were lower during school hours (defined as providing $\leq$ 31% of their TDIs). Foods consumed during school hours provided lower contributions of vitamin A, D, riboflavin, B6, B12, calcium, phosphorus, magnesium, zinc and potassium (all $\leq$ 31% of their TDIs) but higher contribution of vitamin C (38% of TDI).

On average, children consumed 2.5 servings of grain products, 1.5 servings of vegetables and fruit (including fruit juice), and 0.6 servings each of milk products and meat and alternatives during school hours. Children consumed on average 175 kcal from 'other' foods during school hours. The contribution from 'other' foods was also higher during school hours. The school hour contribution from 'other' foods was 37% of the whole day caloric intake from these 'other' foods. The contribution from grain products was also higher (37% of TDI) whereas the contribution of milk products was lower (25% of TDI) during school hours.

Table 4 Dietary intakes and relative dietary contributions from school hours (9:00-14:00) to whole day intakes for Canadian children 6-17 years (n = 4827)

	Dietary intakes School hours	**Contributions from school hours to daily intakes* (%)**
	Mean ± SE	Mean ± SE
Energy, kcal	746 ± 11	33.6 ± 0.4
Carbohydrates, g	103.8 ± 1.6	34.0 ± 0.4
Fibre, g	5.2 ± 0.1	33.8 ± 0.5
Total sugar, g	47.6 ± 1.0	34.6 ± 0.5
Total fat, g	27.0 ± 0.6	34.6 ± 0.4
Saturated fat, g	9.0 ± 0.2	33.4 ± 0.5
MUFAs, g	10.8 ± 0.3	35.3 ± 0.5
PUFAs, g	4.7 ± 0.1	36.5 ± 0.5
Linoleic FAs, g	3.97 ± 0.12	37.2 ± 0.5
Linolenic FAs, g	0.61 ± 0.02	36.6 ± 0.6
Cholesterol, mg	63.8 ± 1.8	29.4 ± 0.6
Protein, g	24.7 ± 0.5	30.8 ± 0.4
Retinol Activity Equivalents (RAE)	167.8 ± 4.5	27.4 ± 0.6
Vitamin D, µg	1.25 ± 0.04	21.8 ± 0.6
Vitamin C, mg	58.5 ± 1.7	37.6 ± 0.7
Thiamin, mg	0.61 ± 0.01	33.1 ± 0.5
Riboflavin, mg	0.66 ± 0.01	30.6 ± 0.5
Niacin, mg	11.52 ± 0.22	32.2 ± 0.4
B6, mg	0.48 ± 0.01	29.2 ± 0.5
B12, µg	1.05 ± 0.03	27.3 ± 0.6
Dietary Folate Equivalents (DFE)	156.1 ± 2.9	34.5 ± 0.5
Calcium, mg	315.7 ± 7.3	29.3 ± 0.5
Phosphorus, mg	412.2 ± 7.6	29.7 ± 0.4
Magnesium, mg	86.1 ± 1.5	29.8 ± 0.4
Iron, mg	4.7 ± 0.1	32.3 ± 0.4
Zinc, mg	3.2 ± 0.1	30.7 ± 0.5
Sodium, mg	1163.5 ± 23.0	36.1 ± 0.5
Potassium, mg	844.3 ± 14.9	29.9 ± 0.4
Grain products, servings†	2.49 ± 0.05	36.9 ± 0.5
Vegetables and fruit, servings†	1.48 ± 0.04	32.9 ± 0.8
Milk and alternatives, servings†	0.63 ± 0.02	24.9 ± 0.7
Meat and alternatives, servings†	0.63 ± 0.02	33.1 ± 0.8
Energy from 'other' foods‡, kcal	175 ± 6	37.1 ± 0.8

* The relative contribution of school hour dietary intakes to whole day intakes considered food sources only and excluded intakes from nutritional supplements; † Servings for each food group are defined according to the 2007 EWCFG (e.g. 1 slice of bread is equivalent to 1 serving of grain product) (116); ‡ Other foods included foods outside of the four core food groups from the EWCFG which are often minimally nutritious foods such as SSBs, chocolate bars, and salty packaged snacks.

2.3.2 Comparing dietary intakes during school and non-school hours

Mean nutrient and food group densities for both school and non-school hours, and relative percent differences between school and non-school hours are shown in table 5. Statistically significant differences were found between nutrient and food group densities during school and non-school hours for most dietary outcomes. However, the magnitude of these differences was often small ($\leq$ 20% relative difference between school hours and non-school hours). Larger differences (> 20%) were observed for cholesterol, vitamin A, D, B_{12}, calcium, and milk product densities, intake of which was *lower* during school hours, while vitamin C density was *higher* during school hours. Vitamin D and milk product densities emerged as those with largest relative percent differences between time periods (54% and 33% lower during school hours, respectively). For milk products, this translated into an estimated difference of 0.4 servings/1000 kcal consumed between time periods.

Table 5 Comparison of nutrients and food group densities during school hours (9:00-14:00) and non-school hours and relative percent differences (school vs. non-school hours) on Canadian school days (n = 4827)

	School hour intakes (per 1000 kcal)*	Non-school hour intakes (per 1000 kcal)*	Linear regression coefficient†	p-value	Relative % difference‡
	Mean ± SE	Mean ± SE	β ± SE		Mean ± SE
Carbohydrates, g	144.2 ± 0.9	139.8 ± 0.6	4.4 ± 1.1	<0.001	3.2 ± 0.9
Fibre, g	7.31 ± 0.10	7.30 ± 0.09	0.01 ± 1.12	0.918	0.1 ± 1.6
Total sugar, g	66.8 ± 1.0	62.1 ± 0.6	4.7 ± 1.1	<0.001	7.6 ± 1.8
Total fat, g	34.3 ± 0.3	33.5 ± 0.2	0.8 ± 0.4	0.036	2.4 ± 1.2
Saturated fat, g	11.6 ± 0.2	11.9 ± 0.1	-0.3 ± 0.2	0.122	-2.5 ± 1.7
MUFAs, g	13.48 ± 0.16	12.76 ± 0.11	0.73 ± 0.18	<0.001	5.7 ± 1.4
PUFAs, g	5.98 ± 0.09	5.39 ± 0.07	0.59 ± 0.11	<0.001	10.9 ± 2.0
Linoleic FAs, g	5.04 ± 0.08	4.43 ± 0.06	0.61 ± 0.10	<0.001	13.8 ± 2.3
Linolenic FAs, g	0.76 ± 0.02	0.69 ± 0.02	0.08 ± 0.03	0.003	11.6 ± 4.3
Cholesterol, mg	82.4 ± 2.2	107.6 ±2.3	-25.3 ± 3.2	<0.001	-23.5 ± 3.0
Protein, g	32.7 ± 0.4	38.2 ± 0.3	-5.5 ± 0.5	<0.001	-14.4 ± 1.3
RAE	239.3 ± 6.3	328.7 ± 6.4	-89.4 ± 8.9	<0.001	-27.3 ± 2.7
Vitamin D, μg	1.57 ± 0.05	3.39 ± 0.07	-1.82 ± 0.08	<0.001	-54.0 ± 2.4
Vitamin C, mg	91.4 ± 2.7	68.7 ± 1.6	22.7 ± 3.1	<0.001	33.0 ± 4.5
Thiamin, mg	0.83 ± 0.01	0.89 ± 0.01	-0.06 ± 0.02	<0.001	-6.7 ± 2.2
Riboflavin, mg	0.90 ± 0.01	1.05 ± 0.01	-0.16 ± 0.02	<0.001	-15.2 ± 1.9
Niacin, mg	15.46 ± 0.17	16.70 ± 0.16	-1.24 ± 0.23	<0.001	-7.4 ± 1.4
B6, mg	0.67± 0.01	0.83 ± 0.01	-0.16 ± 0.02	<0.001	-19.3 ± 2.4
B12, μg	1.33 ± 0.03	2.04 ± 0.07	-0.71 ± 0.08	<0.001	-35.0 ± 3.9
DFE	217.6 ± 3.1	211.8 ± 2.6	6.3 ± 4.0	0.149	3.0 ± 1.9
Calcium, mg	423.4 ± 7.6	546.7 ± 7.4	-123.3 ± 10.1	<0.001	-22.6 ± 1.8
Phosphorus, mg	550.3 ± 6.7	678.2 ± 5.7	-127.9 ± 8.5	<0.001	-18.9 ± 1.3
Magnesium, mg	120.9 ± 1.5	143.5 ± 1.1	-22.5 ± 1.7	<0.001	-15.7 ± 1.2
Iron, mg	6.46 ± 0.08	7.20 ± 0.09	-0.74 ± 0.12	<0.001	-10.3 ± 1.7
Zinc, mg	4.31 ± 0.05	5.13 ± 0.07	-0.82 ± 0.10	<0.001	-16.0 ± 1.9
Sodium, mg	1599.2 ± 25.8	1393.0 ± 14.6	206.2 ± 28.5	<0.001	14.8 ± 2.0
Potassium, mg	1203.1 ± 17.8	1418.9 ± 12.7	-215.8 ± 20.8	<0.001	-15.2 ± 1.5

	School hour intakes (per 1000 kcal)*	Non-school hour intakes (per 1000 kcal)*	Linear regression coefficient†	p-value	Relative % difference‡
	Mean ± SE	Mean ± SE	β ± SE		Mean ± SE
Grains products, servings	3.40 ± 0.05	2.99 ± 0.04	0.41 ± 0.06	<0.001	13.7 ± 2.0
Vegetables and fruit, servings	2.29 ± 0.07	2.11 ± 0.04	0.18 ± 0.08	0.016	8.5 ± 3.8
Milk and alternatives, servings	0.81 ± 0.02	1.21 ± 0.02	-0.40 ± 0.03	<0.001	-33.1 ± 2.5
Meat and alternatives, servings	0.83 ± 0.03	0.88 ± 0.02	-0.04 ± 0.03	0.190	-4.5 ± 3.4

* Because energy intake during school hours was significantly lower than non-school hours, densities (nutrient and food group amounts per 1000 kcal) were calculated for foods consumed during school hours and during non-school hours to standardise dietary intakes and compare energy-adjusted differences across time periods.; † Simple linear models tested for significant differences in nutrient and food group densities across time period using a dichotomous variable for school hours as the independent variable. Non-school hours are the reference period; ‡ Relative difference is the energy-adjusted difference in amounts consumed between school and non-school hours divided by non-school hour amounts, then multiplied by 100 to express relative percent differences.

2.3.3 Demographic and socioeconomic determinants of school hour diet quality

Table 6 shows the results from linear regression analyses testing associations between school hour diet quality with select demographic and socioeconomic characteristics. Age, household-level education and province of residence were associated with statistically significant differences in school hour diet quality. Children age 6-8 years had, on average, school hour diet quality scores which were 9 points higher than children aged 14-17 years. Children in Quebec had, on average School-HEI scores which were at least 5 points higher compared to children living in Newfoundland & LB, Nova Scotia, Ontario and Manitoba. Children whose parents had some post-secondary education had slightly higher School-HEI scores compared to their peers whose parents had not completed any post-secondary education. No differences in School-HEI scores were observed across any of the other demographic or socioeconomic characteristics (sex, ethnicity, residential location, income, or food security status). Moreover, none of these models had a large (>0.05) coefficient of determination (R^2), suggesting that apart from age group ($R^2 =$ 0.05) none of the other characteristics examined explained a substantial proportion of the variation in school hour diet quality scores.

Table 6 School-HEI scores and linear regression coefficients, by demographic, geographic, and SES characteristics for Canadian children age 6-17 years (n = 4827)

	School-HEI scores*	**Linear regression coefficients**	**p-value**	**R^2**
	Mean ± SE	β ± SE		
Sex				
Male	53.0 ± 0.5	*Reference*	0.335	0.00
Female	53.7 ± 0.5	0.8 ± 0.7		
Age group				
6-8 years	58.4^{a} ± 0.7	*Reference*	<0.001	0.05
9-13 years	53.5^{b} ± 0.5	-4.8 ± 0.9		
14-17 years	49.3^{c} ± 0.6	-9.0 ± 0.9		
Ethnicity				
White/European	53.6 ± 0.4	*Reference*	0.311	0.00
Other	52.7 ± 0.8	-1.1 ± 0.9		
Residence type				
Rural	54.4 ± 0.8	*Reference*	0.137	0.00
Urban	53.1 ± 0.4	-1.3 ± 0.9		
Provinces				
Newfoundland & LB	48.4^{a} ± 1.1	-3.8 ± 1.2	0.001	0.02
PEI	53.7^{abc} ± 1.3	1.5 ± 1.4	0.308	
Nova Scotia	50.6^{ab} ± 1.3	-1.6 ± 1.4	0.266	
New-Brunswick	54.7^{bc} ± 1.2	2.5 ± 1.3	0.064	
Quebec	56.9^{c} ± 0.8	4.6 ± 1.0	<0.001	
Ontario	52.2^{ab} ± 0.5	*Reference*	-	
Manitoba	52.7^{ab} ± 0.9	0.5 ± 1.0	0.658	
Saskatchewan	53.6^{abc} ± 1.1	1.3 ± 1.2	0.272	
Alberta	52.3^{abc} ± 1.2	0.0 ± 1.3	0.983	
British Columbia	52.9^{abc} ± 0.9	0.7 ± 1.0	0.533	
Education†				
≤ secondary school	51.9^{a} ± 0.8	*Reference*	0.044	0.00
Some post-secondary	53.8^{b} ± 0.4	1.9 ± 0.9		
Household Income‡				
Low	53.5 ± 0.6	*Reference*	0.902	0.00
High	53.6 ± 0.4	0.1 ± 0.8		
Household-level food insecurity§				
Food-secure	53.4 ± 0.4	*Reference*	0.897	0.00
Food-insecure	53.3 ± 1.2	-0.2 ± 1.2		

* Differences in total School-HEI scores were tested using survey-weighted univariate (simple) linear regression models with a Bonferroni correction for variables with more than 2 levels. Estimated marginal means sharing a group letter ($^{a, b, c}$) are not significantly different; † Sample for parental education was smaller as there were missing education data for 76 children; ‡ Sample

for income was smaller as there were missing income data for 620 children; [§] Sample for food security was smaller as there were missing data for 36 children.

Table 7 shows total and sub-scores for the School-HEI, stratified by age group. The average total School-HEI score was 53.4 points, suggesting that mean diet quality during school hours for Canadian children 'required improvement' (School-HEI 50-80 points). School-HEI scores (means ± SEs) by age group ranged from 58 ± 0.7 points (children age 6-8 years) to 49 ± 0.6 points (children age 14-17 years) and were significantly different between young children (6-8 years) vs. pre-adolescents (9-14 years) and adolescents (14-17 years). Children age 6-13 years had significantly higher School-HEI scores for total vegetables and fruit, whole fruit, and meat and alternatives compared to children age 14-17 years. Compared to children age 9-17 years, children age 6-8 years also had higher School-HEI sub-scores for milk products. Compared to children age 14-17 years, children age 6-8 years had significantly higher School-HEI sub-scores for dark green and orange vegetables (although these sub-scores were, in absolute terms, low for all age groups), and percent energy from minimally nutritious foods. NRF 8.2 scores declined significantly with age, with children age 6-8 years having significantly higher NRF 8.2 scores compared to children age 9-17 years.

Table 7 School-HEI scores by age group for Canadian children age 6-17 years (n = 4827)

	Maximum score	**6-8 years***	**9-13 years***	**14-17 years***
		Mean ± SE	**Mean ± SE**	**Mean ± SE**
Adequacy components† (higher scores indicate higher consumption)				
Vegetable and fruit	10	$5.7^{a} \pm 0.2$	$5.1^{a} \pm 0.1$	$4.4^{b} \pm 0.2$
Dark green or orange vegetable	5	$0.7^{a} \pm 0.1$	$0.6^{ab} \pm 0.05$	$0.5^{b} \pm 0.05$
Whole fruit	5	$2.0^{a} \pm 0.1$	$2.0^{a} \pm 0.1$	$0.3^{b} \pm 0.1$
Grain product	5	$4.4^{a} \pm 0.1$	$3.8^{b} \pm 0.1$	$3.6^{c} \pm 0.1$
Whole grains	5	1.1 ± 0.1	1.0 ± 0.1	0.9 ± 0.1
Milk & alternatives	10	$5.5^{a} \pm 0.2$	$4.1^{b} \pm 0.2$	$3.9^{b} \pm 0.2$
Meat & alternatives	10	$6.3^{a} \pm 0.2$	$6.0^{a} \pm 0.2$	$4.9^{b} \pm 0.2$
Unsaturated fats	10	$8.6^{ab} \pm 0.1$	$8.8^{b} \pm 0.1$	$8.3^{a} \pm 0.1$
Moderation components† (higher scores indicate lower consumption)				
Saturated fat	10	6.1 ± 0.2	6.3 ± 0.1	6.3 ± 0.2
Sodium	10	5.2 ± 0.2	4.9 ± 0.1	5.1 ± 0.2
% kcal other foods	20	$12.7^{a} \pm 0.4$	$10.9^{b} \pm 0.3$	$10.2^{b} \pm 0.3$
Total School-HEI index	**100**	$\mathbf{58.4^{a} \pm 0.7}$	$\mathbf{53.5^{b} \pm 0.5}$	$\mathbf{49.3^{c} \pm 0.6}$
NRF 8.2† index scores	-	$30.1^{a} \pm 1.1$	$26.5^{b} \pm 0.7$	$25.4^{b} \pm 1.1$

* Means sharing a group letter (a, b, c) are not significantly different between age groups (Bonferroni-adjusted, $p < 0.016$); † The NRF indices are a group of nutrient-based composite diet quality indicators (118) designed to assign higher diet quality scores to foods which provide higher amounts of recommended Daily Values (DV) for 'desirable' nutrients and/or lower amounts of the recommended DV for 'undesirable' nutrients. Conversely, lower NRF scores are given for foods which provide higher amounts of the DV for 'undesirable' nutrients and/or lower amounts of the DV for 'desirable' nutrients. For the purposes of this analysis, the NRF 9.3 was slightly modified to a 'NRF 8.2' index, which excluded vitamin E and the added sugars since these are not available in the Canadian Nutrient Files.

2.4 Discussion

Findings revealed that in 2004, foods and beverages consumed by Canadian children between 9:00 to 14:00 provided close to one third of the total energy consumed on a school day. While relative intakes of most nutrients and food groups were proportional to the contribution to energy intake (~33%), dietary intakes from milk products and key nutrients found in milk (protein, vitamin A, D, B12, calcium) consumed during school hours provided smaller contributions to TDIs. Moreover, nutrient densities for these dietary components were significantly lower during school hours. Finally, only age group was a substantive correlate of school hour diet quality (although school hour diet quality required improvement for all age groups).

To my knowledge, this is the first Canadian study to compare dietary intakes between school hours and non-school hours on school days and few other studies are available for comparison. In a sample of Swedish children in grade two and five, the mean energy contribution of school lunches was 27% of daily intake, and the mean nutrient contributions were either proportional or higher than the caloric contribution, apart from carbohydrates which provided a relatively smaller contribution (24%). In contrast, Canadian findings here suggest that total carbohydrates (and grain products) represented a similar or higher dietary contribution relative to the mean energy contribution. In the U.K., Nelson and colleagues compared the lunch-time contributions from foods across school meal participation status and between elementary and secondary school students (39). In contrast to this current study, the contributions from protein and calcium were close to the energy contribution regardless of age or school meal participation status. Another U.K. study comparing the lunch-time contributions from foods by school meal participation status revealed the dietary contribution for the majority of nutrients was similar to the energy contributions with the exceptions of vitamin C (lower for both boys and girls regardless of school meal participation status), vitamin A (lower among girls eating a home-packed lunch), and folate (lower among boys, regardless of school meal participation status) (38). In the U.S., students participating in the NSLP had dietary contributions from vitamin A, B12, calcium, magnesium and phosphorus, and potassium which mirrored the caloric contributions from foods consumed for lunch (30% of the daily calories consumed), whereas non-NLSP had overall lower dietary contributions than the average caloric contribution (41). Although it is not possible to directly compare my findings to these studies due to methodological differences on how dietary contributions were defined (contributions from the lunch meal vs. all foods consumed during school hours), these findings suggest differences in the dietary contributions from lunch relative to TDIs for Canadian children. Moreover, substantially lower intakes were reported for key nutrients such as vitamin A, D, calcium, phosphorus and magnesium during school hours compared to non-school hours for Canadian children. Between-country differences could reflect differences in patterns of foods consumed at lunch-time by school-age children and differences in access to school meal programs.

Specific aspects of consumption patterns during school hours could be improved for Canadian children. The mean School-HEI score was 53 points out of a possible maximum score of 100 points. Similar to previous U.S. studies characterizing the quality of foods consumed in the school context (97,120), the lowest School-HEI sub-scores (for all age groups) were for green and orange vegetables, whole fruit, whole grains and milk products. Hence, Canadian school-based nutrition policies and program should focus on improving access to and affordability of healthy food choices (particularly vegetables, whole fruit, whole grains and milk products) in Canadian schools.

Vitamin A, D, B12, calcium, and milk products densities were at least 20% lower during school hours compared to non-school hours. These findings align with other Canadian studies reporting low intakes of milk products at school (29) and low frequency of milk consumption during school hours (30,31). Considering that in 2004, more than a third (37%) of children aged 4-9 years and up to 61% of boys and 83% of girls age 10-16 years did not meet their recommended daily servings of milk (8), the school context represents an opportunity to increase intakes of milk products among Canadian children and youth.

Age was a meaningful correlate of school hour diet quality, with mean School-HEI scores among young children being significantly higher compared to older youth. These findings align with other studies reporting declining diet quality as children age (8,31,42,43,108). No differences in School-HEI scores were reported across sex, ethnicity, residential location, household-level income and food security status. Although the association between School-HEI scores and parental education was significant (p = 0.044), the low R^2 (<1%) suggests it did not explain a meaningful proportion of variation in-school hour diet quality. The lack of association between household income and school hour diet quality was not surprising. A large repeat cross-sectional study among U.S. children and adolescents reported no association between parental income and U.S. HEI-2010 scores over a 13 year period (106).

Similarly, the associations between food insecurity and diet quality among young children in Canada remain unclear. Food security is thought to impact diet quality by limiting access to resources to purchase more expensive food items such as fresh produce and dairy products (51). Previous analyses using the CCHS 2.2 have confirmed differences in nutritional adequacy between food-secure and food-insecure households, but only among adolescents and not younger children (52). It is possible that the effect of food insecurity on household members may differ whereby parents compromise their own intake to buffer younger children (49), although more recent research suggests this is unlikely (121). Children living in food-insecure households may also have access to local school-based meal programs in some regions. However, the CCHS 2.2

did not include any questions on children's participation in a local school meal program that could have allowed examination of their potential buffering effect.

Strengths of this study included its large, nationally representative sample and the use of a composite diet quality indicator to capture the multidimensional nature of diet quality in the specific context of school hours. Analytical approaches to assess the quality of foods and beverages consumed in the school context can help evaluate the impact of school-based nutrition interventions. Most diet quality indices for use in children assess the quality of the *total* diet (122). The School-HEI index is one measure which can be used to measure Canadian children's adherence to Canadian national dietary recommendations specifically in the school context. However, some limitations should be acknowledged. First, the School-HEI (and its categorical scale for 'poor', 'require improvement' and 'good' diet quality ratings) has not been validated against specific health outcomes among children or compared to nutritional criteria for school meals (to my knowledge, no such standards currently exist in Canada). Second, I did not assess whether differences in dietary intakes observed on school days were similarly observed on weekend days (when children are not in school), so it is not possible to determine whether these differences are solely due to the school context. In other words, differences in dietary intake patterns between time periods could reflect specific socio-cultural patterns in the types of foods typically eaten at lunch compared to the remainder of the day (regardless of whether lunch is consumed on a week day or a weekend day) since this analysis focused on school days. Third, this study only included the first 24-hour dietary recall, although in hindsight, the second 24-hour dietary recall could have been included to increase sample size. Another limitation was the use of self-reported data. The accuracy of dietary recall methods among children can vary widely depending on children's age, interview conditions (e.g. the retention period, type of prompting, and use (or not) of parental assistance) (76,81). Studies conducted among children have also confirmed substantial under-reporting of foods and beverages which then leads to under-estimation of energy intake (80,123). Dietary recall methods can be affected by social desirability bias, a type of systematic error when subjects selectively misreport certain foods due to their norms and beliefs about what they should eat (85). However, it is reasonable to believe that both the recall and social desirability biases would be similarly distributed during school and non-school hours for older children who completed the recall without any parental assistance. Yet for children aged 6-11 years who completed the recall with parental assistance, the presence of a parent could have been a selective confounder. The parent would know what was in a home-packed lunch, but the child might have been reluctant to report that he/she had not eaten part of the lunch.

2.5 Implications for school-based nutrition programs in Canada

Given that foods eaten during school hours for Canadian children represent one-third of the total daily energy consumed, the school context provides an opportunity to promote healthy eating among Canadian children. Energy-adjusted intakes of vitamin A, D, B12, calcium, and milk products were substantially lower during school hours compared to non-school hours. The quality of Canadian children's dietary intakes during school hours could potentially be improved by increasing intake of nutritious foods including milk and alternatives, thus increasing the intake of key nutrients such as protein, vitamin A, D, calcium and magnesium. More Canadian studies are needed to explore the effect of interventions such as school meal programs and/or subsidised milk programs on children's overall diet. Mean school hour diet quality scores required improvement for all age groups and declined as children aged. Therefore, school-based nutrition strategies should target lunch meals for all children, but particularly among adolescents who are at highest risk of lower quality diets.

Chapter 3: Lunch-time Food Source is Associated with School Hour and School Day Diet Quality among Canadian Children

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3.1 Introduction

Schools can provide important safety nets to ensure children have access to healthy and nutritious foods (16,17,124). In the U.S. and Europe, the beneficial effects of children's participation in universal school meal programs on dietary outcomes are well-established (53,57,125–127). A growing number of U.S. (58–61,120) and U.K. studies (38,62,128–130) suggest that students who bring home-packed lunches to school have poorer nutritional outcomes compared to students participating in school meal programs. However, little research has explored whether lunch-time food source translates into dietary intake differences in the Canadian school context and for the whole school day (38,131).

To date, only two Canadian studies drawing from small, context-specific samples have examined whether in-school dietary practices are associated with food source (29,32). One study reported that students grades 6-8 who reported foods from off-campus locations had lower dietary quality compared to children bringing a home-packed lunch or obtaining a lunch at school (29). Conversely, another study reported that nutrient densities for key nutrients of concern (vitamins A, D, B6, B12, calcium, zinc) were higher in school lunches compared to home-packed lunches and foods from off-campus locations (32). No national study has examined the sources of the foods and beverages consumed by Canadian children during school hours, whether lunch-time food source is associated with differences in dietary intakes and quality during school hours, or whether nutritional implications of school hour choices ‘carry over’ and influence whole day dietary quality. Understanding the sources of foods consumed by Canadian children during school hours and its potential influence on dietary quality is needed to inform policy debates about school meal programs for Canadian children. Therefore, this study examined whether lunch-time food source was associated with school hour and school day dietary intakes using a nationally representative sample of Canadian school-aged children. I hypothesized that students who obtained lunch-time foods from home would have different nutrient intake profiles compared to students who obtained lunch from schools or off-campus.

3.2 Methods

3.2.1 Analytical sample

Nationally representative data were obtained from the 2004 CCHS Cycle 2.2. An overview of the survey sampling strategy, design and method used for collecting dietary data is described in chapter 2. Analyses included 4945 respondents age 6 to 17 years attending school full-time who reported a first 24-hour dietary recall which occurred on a weekday (Monday through Friday), but excluded recalls which occurred on any days after December 22 or the first week of January (typical Christmas/winter breaks) and summer school vacation periods (June 21 to September 7) and Canadian national holidays. The 9:00 to 14:00 time frame was chosen since it was most likely to include school hours for most Canadian children and this study aimed to capture dietary intakes occurring within school food environments. Similar to the approach used by Sheehy et al. (113), diet recalls with extreme daily energy intakes (mean ± 3SDs, > 6365 kcal or < 486 kcal/day) were considered extreme outliers and were excluded (n = 28). Children who reported obtaining foods from more than one source for the lunch meal (n = 22), who did not report eating any lunch (n = 305), or who had missing data on lunch food source (n = 1) were excluded. The final analytical sample size (n = 4589) was used to compare dietary intakes and diet quality scores across lunch-time food source.

3.2.2 Categorization of food source

Preliminary analyses were conducted to inform categorization of food source patterns during school hours. Food source (defined in the 2004 CCHS Cycle 2.2 as 'location of food preparation') was a categorical variable that included 15 different locations including a respondent's home, the school cafeteria, restaurants (with service), restaurant (fast food), restaurant (no additional information), tavern/bar, take-out, vending machine, work cafeteria, child care centre, adult care centre, someone else's home, grocery or convenience stores, workplace or 'other' (110,132). While children who skipped lunch were excluded from the main analyses, I examined the proportion of children who skipped lunch across socio-demographic subgroups. To be consistent with previous literature exploring associations between diet quality and lunch-time food source among children (133,134), food source was recoded to classify foods consumed for each eating occasion as coming from home, schools (school cafeteria and vending machines[5]), or off-campus locations (e.g. fast foods, convenience stores, restaurants) during

[5] Foods from the school cafeteria and vending machines were grouped together as one category since the main objective of this study was to compare the quality of all foods and beverages obtained from schools (including cafeterias, vending machines, fundraising events, etc.).

school hours. Preliminary analyses confirmed that the median energy contribution from foods consumed at lunch-time provided the clear majority (93%) of calories consumed during school hours, so children were classified based on whether they reported *lunch* from home, school, or off-campus locations. That is, other eating occasions (e.g. snacks) were not considered when classifying children into distinct (non-overlapping) food source groups.

3.2.3 Variables of interest

Dependent variables included the amounts of energy, macronutrients (e.g. protein) and micronutrients (e.g. vitamin C), food group servings and calories from ‘other’ foods (foods not part of the four core food groups from the EWCFG (116) such as chocolate, candies, SSBs, and salty snacks) consumed during school hours (9:00-14:00) and for the whole day. To address the multidimensional nature of diet quality and measure adherence to the EWCFG recommendations, I used a composite measure of diet quality for Canadians (the C-HEI (42)) but adapted its scoring criteria to reflect the energy contribution from school hours (see table 2 in chapter 2). To examine whether lunch-time food source was associated with whole day dietary quality, I also compared whole day C-HEI (42) scores across lunch-time food source group.

Other demographic and socioeconomic variables were derived from the CCHS 2.2 general health questionnaire (110). Demographic characteristics included sex, age group (6-8, 9-13 and 14-17 years corresponding to the Canadian food guide age and sex-based dietary recommendations (116)), self-reported ethnicity, province of residence, and location of residence (urban vs. rural). Household-level SES variables included income adequacy (a four-group classification based on household size and before-tax income), highest educational attainment (among members of the respondent's household age ≥ 25 years) and food security status. Household food security status was a derived composite variable based on respondents' answers to 18 questions, adapted from the U.S. Department of Agriculture module on food security (110).

3.2.4 Statistical analyses

Rao-Scott Chi-square tests were used to test associations between lunch-time food source and sociodemographic characteristics. Multivariable linear regression models examined differences in nutrients and food group servings across lunch-time food source groups. Energy adjustment applied the standard multivariable model approach with energy intake as a control variable (49). Significance was defined as p-value < 0.05 with a Bonferroni-adjustment when assessing the significance of multiple comparisons. To examine the potential moderating effect of age group on the association between school hour diet quality and lunch-time food source, two-way interaction terms between age group by lunch food source were tested as covariates. The Wald test (135) assessed differences in model fit between the two nested models (before and after adding interaction terms). To test the potential confounding effect of age (rather than age group) on the association between food source and diet quality, additional analyses tested whether mean age significantly differed by lunch-time food source within each age group stratum. No significant differences in mean age were observed across food source group among 9-13 year and 14-17-year-old children, so age was not included as a covariate in these analyses.

Sensitivity analyses compared whether the differences in dietary outcomes observed during school hours (across lunch-time food source group) were also present when only foods and beverages consumed for the lunch meal were considered. Finally, sampling weights were applied to all analyses to generate nationally representative estimates and account for unequal probability of selection and non-response. Robust standard errors were derived using the 500 sets of bootstrap weights provided by Statistics Canada (110). All analyses were conducted using Stata 13 (LP Stata Corp, Tex., U.S.).

3.3 Results

Table 8 shows the demographic and socioeconomic characteristics for the sample as a whole, and by lunch-time food source group. Most children (73%) consumed foods from home, while nearly 10% reported consuming foods from school locations and 12% consumed foods from off-campus locations. Age and sex were associated with lunch-time food source, but no significant associations were found between lunch-time food source and any other sociodemographic characteristic.

3.3.1 Lunch food source, school hour and school day dietary intakes

Children who brought a home-packed lunch reported significantly lower energy intake during school hours (118 kcal) compared to children who obtained foods from off-campus locations, but not compared with children who obtained foods from schools (table 9; see left-hand columns). After controlling for differences in school hour energy intake, age group and sex, lunch-time food source was associated with differences in school hour intakes of 14 of the 33 dietary outcomes. Home-packed lunches were higher in total carbohydrates but had lower total fat than lunches from school. Compared to lunches from school and off-campus locations, home-packed lunches were higher in fibre but lower in MUFAs. Home-packed lunches were also higher in vitamin A, C, thiamin, servings of vegetables and fruit and lower in calories from minimally nutritious foods compared to off-campus lunches. Home-packed lunches were higher in magnesium, iron, and servings of grain products compared to foods from school and off-campus locations. Children who reported a home-packed lunch or foods from school locations reported higher intakes of vitamin D compared to children who obtained foods from off-campus locations.

These findings suggest that children who brought home-packed lunches had slightly better nutrient intake profiles compared to children obtaining foods from off-campus locations. In sensitivity analyses examining differences in dietary outcomes for lunch foods only (not all foods consumed during school hours) across food source, most of the differences remained in the same direction and remained statistically significant (see Appendix B). However, no significant differences were identified in lunch-time intakes of vitamin A and vegetable and fruit servings across lunch food source group, suggesting that differences by food source were slightly impacted by the composition of snacks consumed by children for some nutrients and food groups.

Table 8 Association between lunch-time food source and sociodemographic characteristics for children age 6-17 years (n = 4894)*

	All food sources	**No lunch**	**Home**	**School**	**Off-campus**	**p-value**†
	Mean % ± SE	Mean % ± SE	Mean % ± SE	Mean % ± SE	Mean % ± SE	
All children	100	5.9 ± 0.6	72.8 ± 1.1	9.6 ± 0.7	11.6 ± 0.7	
Age group						<0.001
6-8 years	24.2 ± 1.1	2.4 ± 0.7	83.6 ± 2.0	6.7 ± 1.6	7.3 ±1.2	
9-13 years	42.7 ± 1.2	3.1 ± 0.6	79.9 ± 1.4	7.7 ± 1.0	9.3 ± 1.0	
14-17 years	33.1 ± 1.1	12.1 ± 1.4	55.8 ± 2.1	14.3 ± 1.3	17.8 ± 1.5	
Sex						0.032
Male	51.1 ± 1.2	7.4 ± 0.9	72.7 ± 1.5	8.7 ± 1.0	11.3 ± 1.0	
Female	48.9 ± 1.2	4.4 ± 0.6	72.9 ± 1.5	10.7 ± 1.0	12.0 ± 1.1	
Ethnicity						0.219
White	79.8 ± 1.0	5.4 ± 0.6	73.9 ± 1.1	9.3 ± 0.7	11.4 ± 0.8	
Other	20.2 ± 1.0	7.8 ± 1.6	68.6 ± 2.7	11.0 ± 2.0	12.6 ± 1.8	
Residence type						0.088
Rural	19.4 ± 1.0	4.7 ± 1.1	76.1 ± 2.2	10.7 ± 1.5	8.5 ± 1.3	
Urban	80.6 ± 1.0	6.2 ± 0.7	72.0 ± 1.2	9.4 ± 0.8	12.4 ± 0.9	
Food security status‡						0.905
Food-secure	91.1 ± 0.7	5.7 ± 0.6	73.0 ± 1.0	9.7 ± 0.7	11.6 ± 0.8	
Food-insecure	8.9 ± 0.7	7.1 ± 2.1	71.9 ± 3.9	9.1 ± 2.5	11.9 ± 2.8	
Parental education§						0.637
No post-secondary	16.6 ± 0.9	5.9 ± 1.3	71.8 ± 2.4	8.8 ± 1.4	13.5 ± 1.8	
≥Post-secondary	83.4 ± 0.9	5.7 ± 0.6	73.2 ± 1.2	9.8 ± 0.8	11.3 ± 0.8	
Income¶						0.158
Low	35.8 ± 1.3	5.6 ± 1.0	77.1 ± 1.8	8.0 ± 1.1	9.3 ± 1.2	
High	64.2 ± 1.3	5.4 ± 0.7	72.6 ± 1.4	10.0 ± 1.0	12.1 ± 1.0	

* Lunch-time food source categories are mutually exclusive (excluding the 'all food sources' column). The weighted percentages for the "All food sources" column sum downwards (i.e. 24.2 + 42.7 + 33.1 = 100). However, percentage values in the other percent

columns need be summed sideways since they represent the percent within each sociodemographic sub-group. Row percentages may not add up to 100% due to rounding error. Children who reported no lunch (n = 305) were included in this table so the analytical sample is higher than in other result tables where children who reported no lunch were dropped from the analyses. [†] Rao-Scott Chi-square tests were used to test for significant associations between lunch type and each of the listed independent variables (age group, sex, ethnicity, residence type, food security, parental education, and income). [‡] A dichotomous food security variable was constructed characterizing respondents as food-secure or food-insecure (including marginal, moderate and severe food insecurity). Missing data on n = 41 children. [§] Missing data on n = 78 children. [¶] A dichotomous indicator of 'low' and 'high' income was created grouping households in the first two lower and the last two higher income adequacy groups from the original income adequacy classification. Missing data on n = 639 children.

While energy intake differences were reported during school hours across lunch types, no significant differences were found for whole day (24-hour) energy intake (table 9; see right-hand columns). However, lunch-time food source was associated with differences in daily intakes of some nutrient and food groups. Moreover, the magnitude of the difference observed across lunch food source groups was similar for whole day and school hour intake for several dietary components (total carbohydrates, fibre, vitamin D, magnesium, iron and calories from 'other' foods). This suggests that for those dietary components, no compensatory effects occurred outside of school hours. Meanwhile, some differences detected during the school hour time window did not persist when daily intakes were compared across food source group. For example, no differences in daily intakes of vitamin A, C, thiamin, or servings of vegetables and fruit were reported across lunch-time food source group.

Table 9 Energy-adjusted school hour and school day dietary intakes for Canadian children estimated from covariate-adjusted linear regression models (n = 4589)

	School hour dietary intakes*			School day dietary intakes*		
	Home	School	Off-campus	Home	School	Off-campus
	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE
Energy†, kcal	740[a] ±11	743[ab]±48	858[b]±33	2,245±23	2,309±83	2,300±55
Carbohydrate, g	107.1[a]±1.0	93.0[b]±3.6	101.8[ab]±2.0	315.6[a]±1.7	299.3[b]±5.3	314.1[ab]±3.1
Fibre, g	5.5[a]±0.1	4.3[b]±0.2	4.4[b]±0.2	16.3[a]±0.2	14.1[b]±0.4	14.5[b]±4.4
Total sugar, g	49.4±1.1	42.7±2.8	45.5±2.7	142.0±1.7	134.9±4.5	143.7±4.4
Total fat, g	26.5[a]±0.3	31.5[b]±1.4	28.4[ab]±0.7	77.7[a]±0.6	83.0[b]±1.9	78.9[ab]±1.2
Saturated fat, g	9.0±0.2	9.7±0.3	9.4±0.3	26.9±0.3	28.3±0.8	27.6±0.6
MUFAs, g	10.4[a]±0.2	13.3[b]±0.8	11.8[b]±0.4	30.0[a]±0.3	32.9[b]±1.2	31.0[ab]±0.6
PUFAs, g	4.7±0.1	5.5±0.5	4.8±0.2	13.0±0.2	13.4±0.7	12.7±0.3
Linoleic fatty acids, g	4.0±0.1	4.2±0.3	4.0±0.2	10.7±0.2	10.5±0.4	10.6±0.3
Linolenic fatty acids, g	0.6±0.02	0.9±0.1	0.6±0.1	1.7±0.03	1.8±0.2	1.6±0.1
Cholesterol, mg	63±2	70±5	61±3	221±5	244±10	218±8
Protein, g	24.9±0.4	26.7±1.2	25.2±0.9	81.7±0.9	84.3±2.1	80.0±1.8
Vitamin A, RAE	173[a]±5	175[ab]±18	138[b]±11	660±12	638±41	596±28
Vitamin D, µg	1.27[a]±0.04	1.45[a]±0.15	0.89[b]±0.09	6.32[a]±0.13	6.28[ab]±0.38	5.40[b]±0.32
Vitamin C, mg	62.0[a]±1.8	54.8[ab]±8.3	45.4[b]±3.7	159.0±3.5	158.7±10.6	157.1±8.9
Thiamin, mg	0.64[a]±0.02	0.54[ab]±0.04	0.51[b]±0.03	1.94±0.02	1.79±0.06	1.84±0.06
Riboflavin, mg	0.68±0.01	0.62±0.03	0.62±0.04	2.23±0.02	2.17±0.07	2.14±0.07
Niacin, mg	11.68±0.17	11.63±0.49	11.97±0.45	36.48±0.43	36.03±0.85	36.43±0.82
B6, mg	0.50±0.01	0.51±0.04	0.45±0.02	1.72±0.02	1.67±0.06	1.62±0.04
B12, mcg	1.08±0.03	1.10±0.10	0.90±0.08	4.01±0.10	4.40±0.44	3.81±0.36
DFE	158.2±2.7	144.6±11.1	164.8±7.6	473.0±5.4	439.6±13.7	484.0±14.3
Calcium, mg	318±8	325±23	305±16	1122±16	1119±45	1077±46
Phosphorus, mg	419±7	416±17	397±14	1424±12	1410±34	1345±35
Magnesium, mg	90.2[a]±1.3	79.2[b]±3.1	71.7[b]±2.2	302[a]±2	277[b]±7	271[b]±6
Iron, mg	4.9[a]±0.1	4.1[b]±0.2	4.3[b]±0.2	15.7[a]±0.2	13.9[b]±0.4	14.4[b]±0.3
Zinc, mg	3.3±0.1	3.3±0.2	3.1±0.1	11.0±0.2	11.1±0.3	10.3±0.3
Sodium, mg	1205±23	1098±55	1127±47	3256±36	3247±122	3204±81
Potassium, mg	856±13	908±44	798±26	2938±24	2938±86	2812±67

	School hour dietary intakes*			School day dietary intakes*		
	Home	**School**	**Off-campus**	**Home**	**School**	**Off-campus**
	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE
Grain products, servings	2.63^{a}±0.05	1.92^{b}±0.16	2.23^{b}±0.13	7.08^{a}±0.09	6.43^{b}±0.22	6.71^{ab}±0.22
Vegetables and fruit, servings	1.54^{a}±0.05	1.52^{ab}±0.21	1.25^{b}±0.09	4.52±0.09	4.42±0.34	4.33±0.27
Milk products, servings	0.62±0.02	0.71±0.07	0.61±0.05	2.40±0.05	2.47±0.14	2.28±0.13
Meat and alternatives, servings	0.65±0.02	0.72±0.11	0.58±0.05	1.96±0.05	2.10±0.15	1.81±0.10
'Other' foods‡, kcal	166^{a}±5	187^{ab}±18	224^{b}±13	483^{a}±10	500^{ab}±31	578^{b}±26

* Differences in nutrients and food group intakes were tested using survey-weighted linear models with lunch-time food source (main independent variable) while controlling for sex, age group and either school hour energy intake (left-handed columns) or whole school day energy intake (right-handed columns). Means within each of school hour intakes and school day intakes sharing a group letter ($^{a,\ b}$) are not significantly different at the 5% level (Bonferroni-adjusted p-value < 0.016). Children who reported no lunch were excluded from these analyses (n = 305). † No energy adjustment for energy outcomes. ‡ 'Other' foods include any foods not part of the four core food groups in the EWCFG (for example, chocolate, candies, SSBs, condiments, salty snacks).

3.3.2 Lunch food source, school hour and school day diet quality

In this study, the mean diet quality score during school hours (total School-HEI) was 53.1 points (out of a 100-point scale), indicating that on average, Canadian children's school hour diet quality 'required improvement'. Age moderated the association between food source and total School-HEI scores (p-value from Wald test for models with food source X age interaction term = 0.003) such that the association between food source and school hour diet quality was stronger in older versus younger children.

Table 10 shows marginal means from age-stratified linear models comparing School-HEI total and sub-scores by lunch-time food source. There were no significant differences in School-HEI total and sub-scores across lunch food source group for children age 6-8 years, apart from whole grains. Among children age 9-13 years, School-HEI sub-scores for whole grains, whole fruit, 'other' foods, and total School-HEI scores were higher for children with home-packed lunches compared to their peers who obtained foods off-campus. Among children age 14-17 years, School-HEI sub-scores for whole fruit, whole grains, 'other' foods, and total School-HEI scores were higher for children who brought a home-packed lunch compared to their peers who obtained foods from school and off-campus locations. However, no differences in School-HEI sub-scores for total vegetables and fruit, dark green or orange vegetables and for milk and alternatives were detected across lunch type.

Table 10 Age-stratified survey-weighted linear regression analyses comparing School-HEI scores[*] by lunch-time food source for children (n = 4589)

School HEI scores (maximum scores)	6-8 years Home	6-8 years School	6-8 years Off-campus	9-13 years Home	9-13 years School	9-13 years Off-campus	14-17 years Home	14-17 years School	14-17 years Off-campus
Vegetable and fruit (10)	5.8±0.2	6.9±0.8	5.3±0.7	5.3±0.2	4.1±0.6	5.0±0.4	4.7±0.2	3.9±0.4	4.5±0.3
Dark green & orange vegetable (5)	0.7±0.1	1.5±0.7	0.5±0.3	0.6±0.1	0.4±0.1	0.7±0.2	0.4±0.1	0.6±0.1	0.5±0.1
Whole fruit (5)	2.1±0.1	2.2±0.6	1.3±0.4	2.3[a]±0.1	1.0[b]±0.2	0.9[b]±0.2	2.0[a]±0.1	0.5[b]±0.1	0.5[b]±0.1
Grain product (5)	4.5±0.1	4.0±0.4	3.8±0.4	3.9±0.1	3.5±0.2	4.0±0.2	3.9[a]±0.1	2.7[b]±0.2	3.5[a]±0.2
Whole grains (5)	1.2[a]±0.1	0.7[ab]±0.2	0.4[b]±0.2	1.1[a]±0.1	0.3[b]±0.1	0.4[b]±0.2	1.2[a]±0.1	0.2[b]±0.1	0.4[b]±0.1
Milk and alternatives (10)	5.4±0.3	6.9±1.3	6.3±0.7	4.0±0.2	4.8±0.7	5.1±0.5	4.0±0.2	3.8±0.4	4.3±0.4
Meat and alternatives (10)	6.4±0.3	6.8±1.0	6.2±0.7	6.2±0.2	5.1±0.6	6.0±0.5	5.4[a]±0.2	3.6[b]±0.4	5.0[a]±0.4
Unsaturated fats (10)	8.6±0.1	8.4±0.6	9.2±0.3	8.9±0.1	8.5±0.4	9.2±0.2	8.3[a]±0.2	8.3[ab]±0.2	9.0[b]±0.2
Saturated fats (10)	6.2±0.2	5.1±1.0	5.6±0.7	6.5±0.1	5.5±0.5	5.5±0.4	6.8[a]±0.2	6.2[ab]±0.4	5.5[b]±0.3
Sodium (10)	5.2±0.2	5.0±0.9	4.8±0.6	4.8±0.2	5.3±0.6	3.9±0.4	4.8[ab]±0.2	5.8[b]±0.4	4.4[a]±0.4
% energy other foods[†] (20)	12.8±0.4	12.7±1.5	12.3±1.3	11.1[a]±0.3	12.0[ab]±1.0	8.9[b]±0.9	11.4[a]±0.4	8.4[b]±0.7	7.4[b]±0.6
Total School-HEI scores (100)	58.8±0.7	60.0±2.3	55.5±1.9	54.7[a]±0.6	50.5[ab]±1.8	49.7[b]±1.3	52.9[a]±0.8	44.0[b]±1.2	45.2[b]±1.0

[*] Values are survey-weighted means ± SE. Differences in School-HEI scores were tested using survey-weighted simple linear regression models with diet quality scores as the main dependent variable and lunch-time food source (lunch type) as the main independent variable. There was no covariate adjustment needed as the scoring algorithm of the School-HEI already accounts for age and sex specific dietary requirements. These models were not adjusted for any of the household-level SES variables since there were no significant associations found with lunch-time food source. Means within an age group with different letters ([a, b]) were significantly different at the 5% level (Bonferroni-adjusted p-value<0.017). Lunch skippers were excluded from these analyses. [†] ‘Other’ foods include any foods not part of the four food groups in the EWCFG (for example, chocolate, candies, SSBs, condiments, salty snacks).

Analyses using a similar diet quality index for the whole day (the C-HEI (42)) supported the earlier findings suggesting that children who brought a home-packed lunch had slightly better nutrient intake profiles for the whole day compared to children who obtained foods from off-campus locations. Whole day age-and sex- adjusted C-HEI scores (± SE) were significantly higher among children who brought a home-packed lunch (mean C-HEI = 62.4 ± 0.3) compared to children who obtained a lunch from off-campus locations (mean C-HEI = 57.7 ± 0.7). No significant difference was detected among children who obtained lunch foods from school locations (mean C-HEI = 60.5 ± 1.2) and either lunch-time food source group.

3.4 Discussion

This study is the first to examine the associations between school hour and school day diet quality and lunch-time food source in a large, nationally representative sample of Canadian children and adolescents. In 2004, most Canadian children (or their caregivers) reported bringing foods from home for their lunch meal. This study found that the nutritional quality of home-packed lunches was slightly more desirable compared to foods obtained from off-campus locations. Among older youth (14-17 years), the nutritional profile of foods obtained from schools was similar to foods and beverages obtained from off-campus food outlets. On average, diet quality during school hours required improvement, particularly among adolescents.

In 2004, very few children (just under 10%) consumed foods from school locations and the proportion of students who consumed lunch from a school meal program (i.e. a government or school-run program that provides lunch regularly and which may or may not provide free or subsidized meals or adhere to nutritional criteria for foods served) was likely even smaller. These findings align with other Canadian studies reporting that the majority of foods consumed during school hours comes from home (29,32,63). The CCHS 2.2 did not ask respondents if they were participating in a local school meal program, so it is not possible to explicitly describe the nature of where students obtained food at school (e.g. school meal programs vs. *à la carte* cafeteria purchases). Existing Canadian studies evaluating school meal programs have been small-scale and largely qualitative, but scholars have argued that these uncoordinated school meal strategies fail to reach nutritionally vulnerable children, lack nutritional standards or formal evaluations (136,137) and likely often provide meals that do not support Canada's national recommendations for healthy eating (25).

Outside of Canada, federally funded meal programs commonly operate in schools and aim to provide nutritionally balanced meals to students. Previous U.S. and U.K studies have found that school meal participants have more desirable lunch-time nutrient intakes, including higher intakes of fibre (53,129,138), protein (38,61,130,138), and key micronutrients such as vitamin A, D and calcium (61,129,138) compared to students bringing foods from home. Studies measuring types of foods consumed have also reported that children consuming meals from schools have higher intakes of fruit (58,60,61,97), vegetables (38,57,58,60,97,131), milk and dairy products (16,57,58,60,97,131), and whole grains (57,58,97) compared to children eating home-packed lunches. In contrast, I found that Canadian children who brought a home-packed lunch had *higher* energy-adjusted intakes of carbohydrates, fibre, magnesium, iron, total grains and whole grains and lower total fat compared to children obtaining foods from schools. My findings also suggest no differences in intakes of vegetables, fruit and milk products between students bringing in home-packed lunches and students obtaining foods from schools. This could reflect the absence of a national school lunch program and/or inadequate access to nutritious options at school for Canadian children. Moreover, few school-based policies on nutritional requirements of foods and beverages sold within schools were in place in 2004, although it is worth noting that all 10 Canadian provinces have implemented provincial school food and beverage sales policies since the time of this survey (66).

When comparing energy-adjusted nutrient and food group intakes across lunch food source groups, significant differences were found between children who brought a lunch from home vs. those who obtained lunch from an off-campus location. On average, children who brought a home-packed lunch reported higher amounts of desirable nutrients such as fibre, vitamin A, D, C, vegetables and fruit servings, more whole grain products, and fewer calories from minimally nutritious foods compared to children who obtained a lunch from an off-campus location. These findings align with another Canadian study reporting that students who obtained meals at off-campus locations for lunch were more likely to have lower quality diets compared to their peers bringing in lunches from home (29).

Some dietary intake differences were observed across lunch-time food source groups, both during school hours and for the whole school day. This suggests that some of the dietary differences observed between lunch groups persisted outside of school hours on school days (although total daily energy intake did not differ across groups). Similar to another study reporting dietary intake differences at lunch and for the whole day across lunch type (131), I found that children who brought home-packed lunches had slightly healthier nutritional intakes both during school hours and for the entirety of the school day compared to children obtaining lunch off-campus.

This study highlights the importance of considering children's age when examining the association between food source and diet quality. In this national sample, the association between lunch-time food source and lower diet quality (among children obtaining foods from off-campus and school locations) was apparent only in older children. These findings could reflect shifting dietary practices when transitioning into adulthood (108,139), greater exposure to food retailers and fast-foods nearby Canadian secondary schools (140,141), and greater autonomy over purchasing practices as children age.

Overall, average school hour diet quality required improvement in relation to national dietary guidelines. Among adolescents aged 14-17 years procuring lunch at school or off-campus, average school hour dietary quality was poor. Similar to previous U.S. studies comparing lunch-time diet quality by lunch food source (97,120), the lowest School-HEI sub-scores were for green and orange vegetables, whole fruit, whole grains and milk products. My results parallel findings from Canadian research documenting low consumption of milk products in school settings (29) and could reflect the absence of school meal programs providing milk as a beverage of choice to Canadian children in schools. There is a potential role for schools to mitigate barriers associated with consuming milk and alternatives in school settings. Qualitative work has shown that milk costs is perceived as a barrier for consumption among children at school (142) and there may be barriers for home-packed lunches, particularly for milk, relating to access to cold storage facilities for students. Since up to 37% of Canadian children 4–9 years, 61% of boys and 83% of girls 10–16 years do not meet the minimum recommended daily servings of milk products (8), providing free or subsidised milk products (e.g. milk or alternatives such as yogurt) at school could potentially help improve the overall diet quality of Canadian children.

Strengths of this study included its large, nationally representative sample and detailed 24-hour dietary data which allows examining contextual factors associated with consumption. However, this study is not without limitations. First, while the 2004 CCHS 2.2 data represent the first nationally representative dietary data since 1970 (74), school food policy and resultant dietary practices may have changed since 2004. Still, these findings are potentially useful for informing future analyses and comparisons over time (for example, an examination of natural experiments in locations where school-based interventions took place between 2004 and 2015). A second issue relates to the exclusivity of the food sources. The version of the AMPM that was used in CCHS 2.2 did not query where each *individual* food or beverage item was prepared. Instead, a single question was asked about where a meal or a snack was prepared (74). It is possible that some children obtained foods from more than one source, but only the 'primary' source was reported. Third, I used an adapted version of the C-HEI (42) specifically for Canadian children in the school context. However, this index has not been validated against specific health outcomes among children or compared to nutritional criteria for school meals. Fourth, there are inherent issues when using self-reported dietary data such as recall error, inaccurate estimation of portion size and systematic error in dietary reporting to produce socially desirable answers (143). However, the issue of under-reporting would not likely pose a problem for the current analyses unless the bias differed across lunch-time food source groups. For example, it is possible that among younger children (<12 years) who had parents to assist with the recall, children who brought a home-packed lunch to school reported more accurately foods consumed compared to children who obtained foods from schools or an off-campus location (who did not have caregivers involved with the preparation of the lunch meal at home). Finally, analyses likely included some days or time periods when some children were not physically in school, as the CCHS 2.2 did not include a question asking respondents where food was *consumed*. However, I limited the potential to include such days by eliminating any reporting days that occurred on a Canadian national holiday or possible school break.

3.5 Conclusions

This study found that lunch-time food source was associated with differences in school hour diet quality, but more so for children age 9 years and older. Strategies are needed to enhance access to nutritious foods in Canadian schools, particularly in secondary schools where children who obtain foods from schools have similar nutrient intake profiles as children obtaining foods from off-campus locations. However, the average quality of foods consumed by Canadian children during school hours required improvement, regardless of food source. Since most Canadian children bring foods from home to school, future school-based interventions must target change not only in school food environments, but also parents and caregivers who oversee meal planning in the household. Future research should also examine the extent to which Canadian children are responsible for packing their own lunches and snacks, as well as barriers and constraints experienced by children and caregivers when packing lunches for school. This knowledge would help design effective nutrition education interventions to encourage children and caregivers to pack healthier lunch foods to school.

Chapter 4: Examining Differences in School Hour and School Day Dietary Quality among Canadian Children between 2004 and 2015

4.1 Introduction

Schools have the potential to contribute to children's health by promoting healthy eating and physical activity (20). Findings from chapters 2 and 3 indicate that in 2004, the quality of foods consumed by Canadian children during school hours and on school days was sub-optimal in relation to Canadian national dietary standards. Over the past decade, many Canadian provinces and school jurisdictions have developed and implemented nutrition policies and guidelines as a means of improving children's dietary quality (see Appendix C). For example in 2005, New Brunswick and PEI became the first provinces to take actions against the sale of 'junk' food on school property (69,102). In 2004, few provinces had issued school-based nutrition standards for foods sold at school. However in 2015, all ten Canadian provinces had issued nutrient and/or food-based criteria as a means to reduce the sale of minimally nutritious foods on school campuses (65,69). Still, little is known about how children's dietary quality on school days has changed over the last decade and whether school nutrition policy interventions have had any impact (at the population level) on Canadian children's dietary practices at school, and for the whole day.

While limited Canadian research has documented changes in students' dietary practices associated with changing school nutrition policies, current evidence comes from small, regional samples focused on specific age groups. Two studies suggest that Canadian children have decreased their intake of minimally nutritious foods such as SSBs on school days (22,72). However, there is modest evidence linking implementation of provincial school food and nutrition policies on students' consumption of more healthful dietary components such as vegetables and fruit (22,72). No study has described changes in the quality of foods consumed during school hours (or on whole school days) in a representative sample of Canadian children before and after the introduction of school food and nutrition policies across the country.

Monitoring children's dietary quality using diet quality indices which capture the multidimensional nature of food intake can provide insights to design interventions and policies addressing specific aspects of the diet which would most benefit from improvement at the population level (144–146). In 2004, Statistics Canada conducted the first national nutrition survey since 1970, the Canadian Community Health Survey (or CCHS) Cycle 2.2. In 2015, Statistics Canada conducted a follow-up national nutrition survey (the 2015 CCHS – Nutrition), providing an opportunity to compare differences in Canadian children's school day dietary intakes from 2004 to 2015 (75).

In chapter 2, I have shown how school hour dietary quality differed by age group and province of residence. Understanding whether differences between sociodemographic subgroups (previously reported in 2004 (147)) have narrowed, widened or remained unchanged from 2004 to 2015 can help target limited funds and resources to children who are at the highest nutritional risk.

While all Canadian provinces have developed specific nutrition standards regarding foods made available to students in schools since 2004 (65), research suggests variation across provinces in the implementation and enforcement of these policies (33,63,73,102). For example, while all Canadian provinces have developed school nutrition policies to support healthy eating at school, studies have also reported some variation in the content and implementation of these policies (33,63,73,102). For example, nutrition standards regarding the sale of foods and beverages in schools are voluntary in some provinces (e.g. in Alberta (148)) as opposed to being mandatory in others (e.g. Ontario (149) and Nova Scotia (22)). Moreover, non-compliance with school nutrition policies has been reported in studies examining beverages and foods sold in school vending machines in Alberta and Ontario (34,35). Given the differences in policy contexts as well as provincial variations in the timing of these policies, it is possible that changes in children's dietary quality over time differ regionally.

The aim of this study was to compare school hour and school day dietary quality among Canadian children from 2004 to 2015. I hypothesized that: *i)* school hour and school day dietary quality would improve over time from 2004 to 2015; *ii)* differences in school hour dietary quality among age groups and provinces (observed in 2004) would persist in 2015; and *iii)* changes in school hour diet quality over time would be similar across province of residence and other sociodemographic factors.

4.2 Methods

4.2.1 Data source and study sample

Nationally representative data were obtained from the 2004 CCHS (Cycle 2.2) and the 2015 CCHS (Nutrition) surveys. Both surveys used a multistage stratified cluster sampling design to obtain a sample nationally representative in terms of age, sex, geography and socioeconomic status (n = 35 107; response rate, 76.5% in 2004 (74,110); n = 20 487; response rate 61.6% in 2015 (75)). The surveys targeted residents of all ages (in 2004) and ages 1 year and above (in 2015) living in private dwellings in Canada's 10 provinces (75). A computer-assisted 24-hour dietary recall method asked respondents about all foods and beverages consumed from midnight to midnight, including types and amounts of foods consumed, eating occasion (e.g. breakfast, lunch, snack) and time of consumption (74). This study used the first interviewer-administered 24-hour recall for both survey years (2004 and 2015). Foods and beverages in 2004 were analyzed using the food composition data from the 2001b version of the Canadian Nutrient File database (110) and foods and beverages in 2015 were assessed using the 2015 updated version of the Canadian Nutrient File. Permission to conduct these analyses and access to these data was provided by Statistics Canada's Research Data Center Program.

Analyses included respondents (n = 4945 children in 2004; n = 2516 in 2015) age 6 to 17 years who completed a first 24-hour dietary recall which fell on a Canadian week day (Monday through Friday) but excluded recalls which fell on any days after December 22 or the first week of January (typical Christmas/winter breaks), other statutory/national holidays (Easter, Victoria Day and Canadian Thanksgiving) or during summer months (from June 21 and up to Labour Day). Using the same approach presented in chapter 2, diet recalls with daily energy intakes reported below 486 kcal and above 6365 kcal were considered extreme energy reporters and therefore dropped (n = 28 children in 2004 and n = 15 children in 2015). Children who reported 0 kcal intake during (or outside) of school hours were also excluded (n= 90 in 2004 and n = 54 in 2015). This resulted in a final analytical sample of 7274 children (n = 4827 children in 2004 and n = 2447 in 2015).

4.2.2 Measures

Time of consumption was used to classify foods and beverages as either falling within or outside of school hours as the first CCHS in 2004 did not ask respondents to state where the food or beverage was consumed (110). As described in chapter 2, since public school hours vary by Canadian jurisdictions (114), it was not possible to determine the exact time window which would include school hours for all Canadian children. Foods consumed between 9:00 to 14:00 were classified as foods consumed during school hours since this time period was most likely to include school hours for most Canadian children and this study aimed to capture dietary intakes occurring only in school food environments.

Dependent variables included school hour intakes of energy, macro- and micronutrients, food group servings (using standard servings from the 2007 Canadian Food Guide (116)), tier 4 food group servings, and calories from ‘other’ foods (foods not part of the food guide). In addition to providing recommendations for the number of daily servings from each of the four major food groups, Canada’s Food Guide provides guidance on the types of foods to choose from each group through directional statements (for example, “choose vegetables and fruit prepared with little or no added fat, sugar or salt” (116)). Created by Health Canada in 2014 (150), the tier system was devised based on this guidance and categorizes foods as ‘tier 4’ if they do not align with this guidance. For example, tier 4 foods from the vegetables and fruit group and the milk and alternatives group exceed at least two of the upper thresholds for total fat (> 10g per reference amount), saturated fat (> 2 g per reference amount), total sugars (> 19 g per reference amount) and sodium (>360 mg/ reference amount). Examples could be deep-fried or battered foods (e.g. French fries) and some milk-based desserts (e.g. ice cream). Tier 4 foods are not counted towards the total number of food guide servings and thus they were reported separately. ‘Other’ foods are foods which fall outside of the four food groups of the Canadian food guide and may include, for example, sugar-sweetened beverages, chocolate bars, and salty snacks.

To provide a multidimensional measure of children’s diet quality specific to the school context and measure adherence to Canadian national dietary guidelines, I used an adaptation of the Canadian Healthy Eating Index (C-HEI (42)) (see table 2 for the components and scoring criteria of this index). The C-HEI components are based on *daily* intake standards (e.g. 2 servings of milk and alternatives/day recommended for children age 6-8 years) to provide sub-scores for each of its components. Preliminary analyses were conducted to examine the average caloric contribution of foods and beverage consumed during school hours (9:00-14:00) in 2004 and 2015. The proportion of energy from foods consumed during school hours (± SE) relative to whole day intake was 33.6% (± 0.4) in 2004 compared to 34.3% (± 0.4) in 2015 (p-value from t-test = 0.222). Therefore, the scoring criteria for each component of the School-HEI index were scaled by one-third in 2004 and 2015.

Sociodemographic variables included sex, age, age group, cultural background/origin (white/European background vs. non-white), location of residence (urban vs. rural), province of residence, parental education level (no post-secondary education vs. some post-secondary education) and household food security status. In both 2004 and 2015, food security was based on a set of 18 questions to indicate whether households were able to afford the food they needed in the previous 12 months. In 2004, this variable captured four situations: food-secure, food-insecure without hunger, food-insecure (moderate), and food-insecure (severe), reflecting the

U.S. model of food security status (151). In 2007, Health Canada introduced a new classification for the household food security module of the survey (50). The model for classifying food insecurity changed to capture three situations: food-secure, food-insecure (moderate), and food-insecure (severe). In both 2004 and 2015, respondents were classified as food-secure if they provided an affirmative response to 0 or 1 response item on either the child or adult scale (152,153). In these analyses, food insecurity was recoded as a dichotomous variable (food-secure vs. food-insecure which collapsed the moderate and severely food-insecure children) to facilitate comparisons between survey cycles.

4.2.3 Statistical analyses

Rao-Scott Chi square tests were used to test whether the characteristics of Canadian school children differed from to 2004 to 2015. When making comparisons between the nutrition surveys of 2004 and 2015, one must consider potential reasons for differences in demographics over time (75). These may include, but are not limited to, demographic changes (e.g., a greater proportion of adolescents). Table 11 provides the sample characteristics of Canadian children age 6-17 years whose first 24-hour dietary recall fell on a Canadian school day in both survey waves. Multivariable regression models were used to compare differences in nutrients, food group servings, School-HEI and whole day HEI (C-HEI) scores from 2004 to 2015. All models were adjusted for energy intake (school hour or for the whole school day as appropriate), cultural background and food security status.

To test for significant differences in School-HEI scores among sociodemographic sub-groups (in 2004 and 2015), simple linear models were used with the sociodemographic characteristic (e.g. sex, age group, cultural background, food security status) as the independent variable and School-HEI score as the dependent variable. A Bonferroni adjustment was used to account for multiple comparisons in models with multiple dummy variables (e.g. province of residence).

To determine whether sociodemographic variables (sex, age group, cultural background, residence type, province of residence, household-level education and food security status) moderated any change in School-HEI over time, Wald tests for the joint significance of the interaction product terms (e.g. survey year X province of residence) were used.

Missing data (n = 63) were handled with case-wise deletion. Therefore, analytical sample sizes varied slightly across analyses. Survey sampling weights were applied to generate nationally representative estimates. Each set of the 500 sets of bootstrap weights (2004 and 2015) supplied by Statistics Canada was used to derive robust standard errors, as recommended by Thomas and Wannell (154). All analyses were conducted using Stata 13 (LP Stata Corp, Texas, USA), with significance defined as p value < 0.05 (Bonferroni-adjusted p value $<0.05/n$, with n being the number of comparisons).

4.3 Results

Table 11 provides the sample characteristics of Canadian children age 6-17 years whose first 24-hour dietary recall fell on a Canadian school day in both survey waves. The sociodemographic profile of the children was similar between both survey cycles. However, the proportion of respondents self-identifying as non-white rose from 18% in 2004 to 31% in 2015.

Table 12 compares energy and covariate-adjusted mean nutrient intakes consumed during school hours in 2004 and 2015. Reported energy intake was, on average, 90 kcal lower during school hours in 2015. After adjusting for school hour energy, cultural background and food security status, intake of fibre, PUFAs, linoleic fatty acids, cholesterol and protein increased from 2004 to 2015, while intake of total sugars and MUFAs significantly decreased. Children reported higher intakes of vitamin A, thiamin, niacin, B6, DFE, calcium, phosphorus, magnesium, zinc, and potassium during school hours in 2015 compared to 2004.

Table 11 Sample Characteristics of Canadian children age 6-17 years who provided a 24-hour dietary recall on a school day in 2004 and 2015

	CCHS Cycle		p-value*
	2004	**2015**	
Sample size, *n*	*4,827*	*2,447*	
Sex			0.795
Male	50.6	51.1	
Female	49.5	48.9	
Age, mean years			0.741
	11.4	11.5	
Age group			0.326
6-8 years	24.7	25.8	
9-13 years	43.1	40.0	
14-17 years	32.1	34.3	
Cultural/racial background†			<0.001
Not white	17.6	31.4	
White	82.4	68.6	
Residence type			0.957
Urban	80.5	80.4	
Rural	19.5	19.6	
Household highest level of education‡			0.681
Secondary school or lower	16.7	16.1	
Some post-secondary school education	83.3	83.9	
Food security status§			0.030
Food-secure	91.1	88.2	
Food-insecure (moderate or severe)	8.9	11.8	

* Apart from age (continuous variable), all values are survey-weighted percentages. Differences in the sociodemographic profile of children between sample years were tested using survey-weighted Rao Scott Chi-Square tests. The difference in mean age between survey samples was tested using a two-sample t test. † Missing data (don't know, refusals or not stated) for 2 people so n = 7272. ‡ Missing data (don't know, refusals or not stated) for 79 people so n = 7195; § Missing data ("not stated") for 62 respondents so n = 7212. In 2015, no household sample weight was created for the analysis of the prevalence of food security. The prevalence of food insecurity was estimated using respondent (individual) sampling survey weights for 2004 and 2015. Hence, the prevalence of food insecurity may not be reflective of all the respondents living in the households (and therefore not representative of *household*-level food insecurity status).

Table 12 Nutrient intakes from school hours (9:00-14:00) for children aged 6-17 years in 2004 and 2015

	CCHS Cycle Year			
	2004	2015		
	Mean ± SE	**Mean ± SE**	**β (95% CI)**	**p-value**
Energy, kcal*	746 ± 11	656 ± 11	-90 (-120, -60)	<0.001
Carbohydrates†, g	98.1 ± 0.8	96.6 ± 0.9	-1.5 (-3.9, 0.8)	0.200
Fibre†, g	4.9 ± 0.1	6.5 ± 0.1	1.6 (1.3, 1.9)	<0.001
Total sugar†, g	45.0 ± 0.8	40.8 ± 0.8	-4.2 (-6.4, -2.0)	<0.001
Total fat†, g	25.0 ± 0.3	24.6 ± 0.3	-0.3 (-1.1, 0.5)	0.426
Saturated fat†, g	8.4 ± 0.1	8.5 ± 0.2	0.1 (-0.4, 0.5)	0.750
MUFAs†, g	10.0 ± 0.1	8.6 ± 0.2	-1.3 (-1.7, -0.9)	<0.001
PUFAs†, g	4.3 ± 0.1	5.2 ± 0.1	0.9 (0.6, 1.2)	<0.001
Linoleic fatty acids†, g	3.6 ± 0.1	4.5 ± 0.1	0.9 (0.6, 1.2)	<0.001
Linolenic fatty acids†, g	0.6 ± 0.02	0.6 ± 0.01	-0.01 (-0.1, 0.0)	0.627
Cholesterol†, mg	60.1 ± 1.5	69 ± 2.5	9 (3, 14)	0.005
Protein†, g	23.3 ± 0.3	25.6 ± 0.4	2.4 (1.3, 3.4)	<0.001
Vitamin A†, RAE	157 ± 4	194 ± 7	37 (20, 54)	<0.001
Vitamin D†, µg	1.17 ± 0.04	1.28 ± 0.05	0.11 (-0.01, 0.24)	0.075
Vitamin C†, mg	56.4 ± 1.6	57.6 ± 2.45	1.2 (-4.7, 7.0)	0.693
Thiamin†, mg	0.57 ± 0.01	0.62 ± 0.01	0.05 (0.01, 0.08)	0.005
Riboflavin†, mg	0.62 ± 0.01	0.60 ± 0.01	-0.02 (-0.05, 0.01)	0.164
Niacin†, mg	10.8 ± 0.01	12.4 ± 0.2	1.6 (1.1, 2.1)	<0.001
B6†, mg	0.46 ± 0.01	0.48 ± 0.01	0.02 (0.00, 0.05)	0.031
B12†, µg	0.99 ± 0.03	1.03 ± 0.04	0.04 (-0.04, 0.13)	0.310
DFE†	147 ± 2	168 ±3	21 (13, 28)	<0.001
Calcium†, mg	295 ± 6	316 ± 7	21 (2, 40)	0.029
Phosphorus†, mg	386 ± 5	443 ± 6	58 (42, 74)	<0.001
Magnesium†, mg	81.0 ± 0.9	94.4 ± 1.1	13.4 (10.6, 16.2)	<0.001
Iron†, mg	4.5 ± 0.1	4.6 ± 0.1	0.1 (-0.1, 0.3)	0.262
Zinc†, mg	3.0 ± 0.0	3.3 ± 0.1	0.3 (0.1, 0.5)	0.005
Sodium†, mg	1096 ± 19	1077 ± 19	-19 (-74, 36)	0.502
Potassium†, mg	798 ± 9	867 ± 12	69 (39, 100)	<0.001

* Differences in energy intake between survey cycle tested using a simple linear model, n = 7274 children. † Differences in covariate-adjusted nutrient intakes were tested using multivariable linear models adjusted for school hour energy, cultural background and food security status (n = 7211 due to missing data for cultural origin and food insecurity).

Table 13 shows covariate-adjusted mean intakes of food groups during school hours by Canadian children in 2004 and 2015. Children reported higher intakes of grains, vegetables and fruit, milk and meat products in 2015 compared to 2004. At the same time, children also reported decreased intakes of Tier 4 vegetable and fruit, milk and meat servings. Energy from minimally nutritious foods (Tier 4 foods and 'other' foods) also decreased by approximately 80 kcal from 2004 to 2015.

Table 13 Food group intakes from school hours (9:00-14:00) for children aged 6-17 years in 2004 and 2015

	CCHS Cycle Year			
	2004	**2015**		
	Mean ± SE	**Mean ± SE**	**β (95% CI)***	**p-value**
Grain products, servings†	1.91 ± 0.03	2.13 ±0.05	0.22 (0.10, 0.35)	0.001
Grain products, Tier 4 servings‡	0.43 ± 0.02	0.39 ± 0.03	-0.03 (-0.11, 0.04)	0.353
Vegetables and fruit, servings†	1.35 ± 0.04	1.77 ± 0.06	0.42 (0.28, 0.56)	<0.001
Vegetables and fruit, Tier 4 servings ‡	0.09 ± 0.01	0.01 ± 0.00	-0.08 (-0.10, 0.06)	<0.001
Milk and alternatives, servings†	0.53 ± 0.02	0.60 ± 0.02	0.07 (0.01, 0.12)	0.018
Milk and alternatives, Tier 4 servings ‡	0.08 ±0.01	0.03 ± 0.01	-0.05 (-0.07, -0.04)	<0.001
Meat and alternatives, servings†	0.43 ± 0.02	0.52 ± 0.03	0.09 (0.03, 0.15)	0.002
Meat and alternatives, Tier 4 servings ‡	0.14 ±0.01	0.10 ± 0.01	-0.04 (-0.07, -0.01)	0.004
Energy from Tier 4 foods‡, kcal	124 ± 4	85 ± 4	-39 (-51, -27)	<0.001
Energy from 'other' foods§, kcal	147 ± 4	108 ± 5	-40 (-52, -27)	<0.001

Differences in covariate-adjusted intakes were tested using multivariable linear models adjusted for school hour energy, cultural background and food security status (n = 7211 due to missing data for cultural background and food security status). ‡ Servings for each food group are defined according the EWCFG (e.g. 1 slice of bread is equivalent to 1 serving of grain product, 250 ml of milk is equivalent to 1 serving of milk and alternatives) (116). A standard portion size variable was given for all foods belonging to the first 3 tiers of the 4 core food groups of the 2007 EWCFG. Because Tier 4 foods are minimally nutritious food choices within each food group (e.g. French fries in the vegetables and fruit food group, donuts and cookies in the grains group), these do not count towards the total number of EWCFG servings) (150). § 'Other' foods are foods that do not fall within the core food groups of the 2007 EWCFG (fats and oils, high calorie beverages, condiments, alcoholic beverages, high fat and/or high sugar foods that could not be assigned into one of the four food groups as well as high fat/sugar foods that are usually eaten in small quantities i.e. not large enough to contribute to a food guide serving).

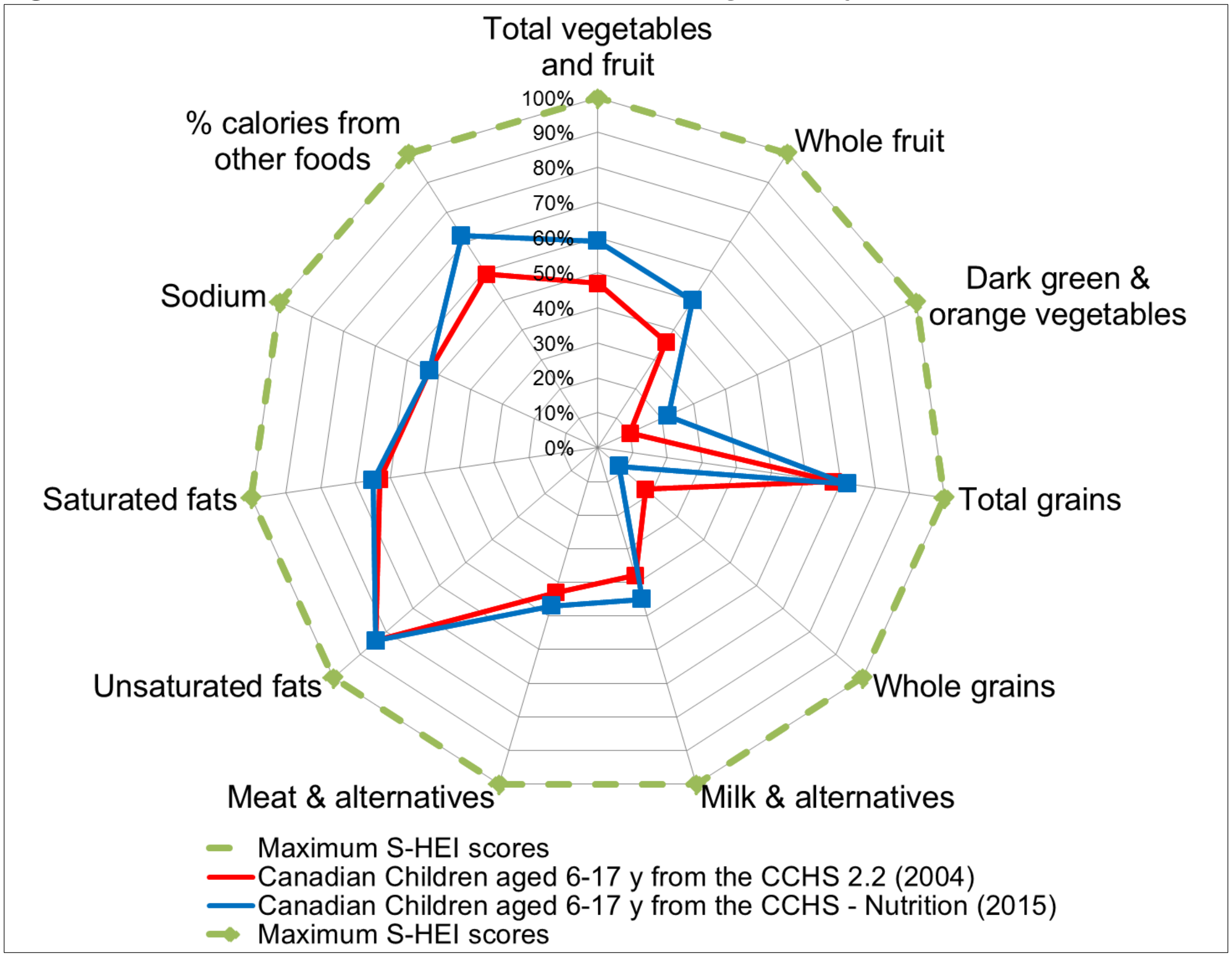
Table 14 compares the covariate-adjusted means from multivariable models with School-HEI scores in 2004 and 2015. Total School-HEI scores increased by approximately 6 points from 2004 to 2015 (out of a possible maximum score of 100 points) (p-value < 0.001). Sub-scores for total vegetables and fruit, whole fruit, dark green and orange vegetables, total grains, milk and alternatives, meat and alternatives significantly increased over time. Sub-scores for 'other' foods also improved, indicating that the proportion of school hour energy coming from these minimally nutritious foods declined from 2004 to 2015. Indeed, the improvement in sub-scores for 'other' foods accounted for a substantial proportion of the difference in total School-HEI scores from 2004 to 2015 (~43% of the total change). Sub-scores for unsaturated fat, saturated fat and sodium remained unchanged while sub-scores for whole grains declined. Despite the overall improvements, the sub-scores were, in relative terms, very low (defined as being below 50% of their maximum possible score) (see figure 2). Sub-scores for whole fruit, dark green and orange vegetables, whole grains and milk and alternatives were the farthest from the HEI optimal scores in 2004 and 2015.

Table 14 The quality of Canadian children's diet during school hours by cycle year, as measured by the School-HEI index* for Canadian children aged 6-17 years

	Maximum points	**CCHS Cycle**			
		2004	**2015**		
		Mean ± SE	**Mean ± SE**	**β (95% CI)** †	**p-value**
School-HEI adequacy components (higher score indicates higher consumption)					
Total vegetable and fruit	10	4.7 ± 0.1	5.9 ± 0.1	1.2 (0.9, 1.5)	<0.001
Whole fruit	5	1.8 ± 0.1	2.5 ± 0.1	0.7 (0.5, 0.9)	<0.001
Dark green or orange vegetable	5	0.5 ± 0.0	1.1 ± 0.1	0.6 (0.4, 0.7)	<0.001
Grain products	5	3.4 ± 0.0	3.6 ± 0.1	0.2 (0.1, 0.3)	0.007
Whole grains	5	0.9 ±0.1	0.4 ± 0.0	-0.5 (-0.6, -0.4)	<0.001
Milk & alternatives	10	3.8 ±0.1	4.5 ± 0.1	0.7 (0.4, 1.0)	<0.001
Meat & alternatives	10	4.3 ± 0.1	4.7 ± 0.1	0.4 (0.1, 0.8)	0.012
Unsaturated fats	10	8.4 ± 0.1	8.4 ± 0.1	0.0 (-0.1, 0.2)	0.816
School-HEI moderation components (higher score indicates lower consumption)					
Saturated fats	10	6.3 ± 0.1	6.5 ± 0.1	0.2 (-0.1, 0.4)	0.254
Sodium	10	5.3 ± 0.1	5.3 ± 0.1	0.0 (-0.2, 0.2)	0.974
% kcal other foods	20	11.8 ± 0.2	14.4 ± 0.2	2.6 (2.0, 3.2)	<0.001
Total School-HEI	100	51.2 ± 0.3	57.3 ± 0.5	6.1 (4.9, 7.2)	<0.001

* The scoring criteria for computing School-HEI scores are presented in table 2. † Differences in covariate-adjusted School-HEI total and sub-scores between 2004 and 2015 were tested using multivariable linear models adjusted for school hour energy, cultural origin and food security status (n = 7211 due to missing data for cultural background and food security status).

Figure 2 School-HEI sub-scores for Canadian children aged 6-17 years from 2004 to 2015



Each component score is scaled as a percentage of the maximum score for that component. For moderation components (saturated fats, sodium and the percent of calories from other foods), higher scores indicate lower consumption.

Table 15 compares the covariate-adjusted means from multivariable models examining changes in whole day HEI total and sub-scores over time. Reported daily energy intake was, on average, 289 kcal lower in 2015 compared to 2004 (2250 ± 21 kcal/d and 1961 ± 24 kcal/d in 2004 and 2015, respectively) (p-value from t-test < 0.001). After adjusting for covariates (school day energy, cultural background and food security status), average whole day HEI scores (± SE) increased by approximately 4 points, from 51.2 (± 0.3) to 57.3 (± 0.5) points from 2004 to 2015 (p-value < 0.001). Some of the changes in HEI sub-scores observed *during school hours* paralleled the changes in *whole day* HEI sub-scores. For example, during school hours and for the whole school day, sub-scores improved for total vegetables and fruit, whole fruit, dark green and orange vegetables, and percent energy from 'other' foods but declined for whole grains. However, *school hour* HEI sub-scores for unsaturated and saturated fats remained unchanged from 2004 to 2015, yet *whole day* HEI scores improved slightly for unsaturated fats and declined slightly for the percent energy from saturated fats. *School hour* sub-scores for grains, milk products and meat products all improved significantly from 2004 to 2015, but there was no difference in *whole day* sub-scores for these dietary components.

Table 15 The quality of Canadian children's diet during school days by cycle year, as measured by the whole day C-HEI* index for Canadian children aged 6-17 years

	Maximum points	**CCHS Cycle**			
		2004	**2015**		
		Mean ± SE	**Mean ± SE**	**β (95% CI)** †	**p-value**
Adequacy component (higher score indicates higher consumption)					
Total vegetable and fruit	10	5.7 ± 0.1	6.1 ± 0.1	0.4 (0.1, 0.6)	0.002
Whole fruit	5	2.6 ± 0.1	3.5 ± 0.1	0.9 (0.7, 1.1)	<0.001
Dark green or orange vegetable	5	1.2 ± 0.0	2.5 ± 0.1	1.3 (1.1, 1.5)	<0.001
Grain products	5	3.8 ± 0.0	3.9 ± 0.0	0.1 (-0.0, 0.2)	0.084
Whole grains	5	1.3 ± 0.0	1.0 ± 0.1	-0.3 (-0.5, -0.2)	<0.001
Milk & alternatives	10	6.3 ± 0.1	6.5 ± 0.1	0.1 (-0.2, 0.4)	0.380
Meat & alternatives	10	6.2 ± 0.1	6.4 ± 0.1	0.2 (-0.1, 0.5)	0.190
Unsaturated fats	10	9.3 ± 0.0	9.4 ± 0.0	0.1 (0.0, 0.2)	0.011
Moderation component (higher score indicates lower consumption)					
Saturated fats	10	6.5 ± 0.1	5.9 ± 0.1	-0.5 (-0.8, -0.3)	<0.001
Sodium	10	5.3 ± 0.1	5.4 ± 0.1	0.1 (-0.1, 0.3)	0.410
% kcal other foods	20	12.1 ± 0.1	13.8 ± 0.2	1.7 (1.3, 2.2)	<0.001
Whole day C-HEI	100	60.4 ± 0.3	64.5 ± 0.4	4.1 (3.1, 5.1)	<0.001

* The algorithm for the C-HEI is from Garriguet (42) † Differences in covariate-adjusted C-HEI scores between 2004 and 2015 were tested using multivariable linear models adjusted for whole day energy, cultural background and food security status (n = 7211 due to missing data for cultural background and food insecurity).

Table 16 shows the mean (unadjusted) School-HEI scores across various sociodemographic groups for each survey cycle year. In both survey years, younger children reported higher school hour dietary quality compared to older peers. There were provincial-level differences in School-HEI scores for each survey cycle, but scores improved over time for all provinces. In 2015 (but not 2004), children in food-insecure households had significantly lower School-HEI scores compared to their peers in food-secure households.

Table 17 show the beta coefficients and p-values from Wald tests testing the moderating effect of various sociodemographic variables on the difference in School-HEI scores from 2004 to 2015. There was no evidence of a moderation effect for any of the sociodemographic variables examined. There was a tendency for some provinces to gain more than others (p-value from Wald test joint interaction for the product terms = 0.055) (figure 3). For example, the change in School-HEI scores from 2004 to 2015 tended to be greater for provinces such as Ontario and Newfoundland and Labrador compared to Saskatchewan and New Brunswick. However, the interaction effect was overall not significant. Although significant differences in School-HEI scores were observed between food-secure and food-insecure children in 2015 (but not 2004), the overall interaction in covariate-adjusted models was not significant.

Table 16 The quality of Canadian children's diet during school hours in 2004 and 2015 measured by the School-HEI index for Canadian children aged 6-17 years

	CCHS cycle	
	2004	**2015**
	Mean ± SE*	**Mean ± SE***
All children	51.4 ± 0.3	57.0 ± 0.5
Sex		
Male	51.0 ± 0.5	56.8 ± 0.7
Female	51.9 ± 0.5	57.2 ± 0.7
Age group		
6-8 years	$56.1^{a} \pm 0.6$	$62.7^{a} \pm 0.9$
9-13 years	$51.3^{b} \pm 0.5$	$57.3^{b} \pm 0.7$
14-17 years	$48.0^{c} \pm 0.6$	$52.4^{c} \pm 0.8$
Cultural/racial origin		
Not white	51.2 ± 0.8	57.0 ± 0.9
White	51.4 ± 0.4	57.1 ± 0.5
Residence location		
Rural	52.1 ± 0.8	57.7 ± 1.2
Urban	51.3 ± 0.4	56.9 ± 0.5
Province of residence		
Newfoundland & LB	$47.6^{a} \pm 0.9$	$54.0^{ab} \pm 1.4$
PEI	$52.4^{ab} \pm 1.3$	$55.9^{ab} \pm 1.7$
Nova Scotia	$50.1^{ab} \pm 1.4$	$55.1^{ab} \pm 1.7$
New-Brunswick	$52.6^{b} \pm 1.2$	$54.6^{ab} \pm 1.3$
Quebec	$53.5^{b} \pm 0.9$	$59.5^{b} \pm 1.0$
Ontario	$50.3^{ab} \pm 0.5$	$57.5^{ab} \pm 0.9$
Manitoba	$50.8^{ab} \pm 0.8$	$54.5^{ab} \pm 1.2$
Saskatchewan	$51.7^{ab} \pm 1.2$	$53.8^{a} \pm 1.4$
Alberta	$51.0^{ab} \pm 1.2$	$55.6^{ab} \pm 1.2$
BC	$52.4^{b} \pm 0.8$	$55.4^{ab} \pm 1.2$
Household-level of education		
Secondary school or lower	50.3 ± 0.8	55.6 ± 1.0
Some post-secondary school education	51.7 ± 0.4	57.3 ± 0.5
Household food security status		
Food-secure	51.4 ± 0.4	$57.4^{a} \pm 0.5$
Food-insecure (moderate or severe)	51.2 ± 1.2	$54.2^{b} \pm 0.9$

* Differences in School-HEI scores across sub-groups were tested using survey-weighted simple linear models with a Bonferroni correction for variables with more than 2 levels in both cycle years (n = 4827 for 2004 and n = 2447 for 2015). However, sample sizes may vary slightly due to missing data for household-level education and food security status). Means sharing a group letter ($^{a, b, c}$) are not significantly different within each survey year (each column). Values for School-HEI scores for 2004 are all slightly lower than those presented in chapter Two (Table 6) due to a change in the classification system for foods into food guide servings. In 2014, Health Canada introduced a new classification system whereby

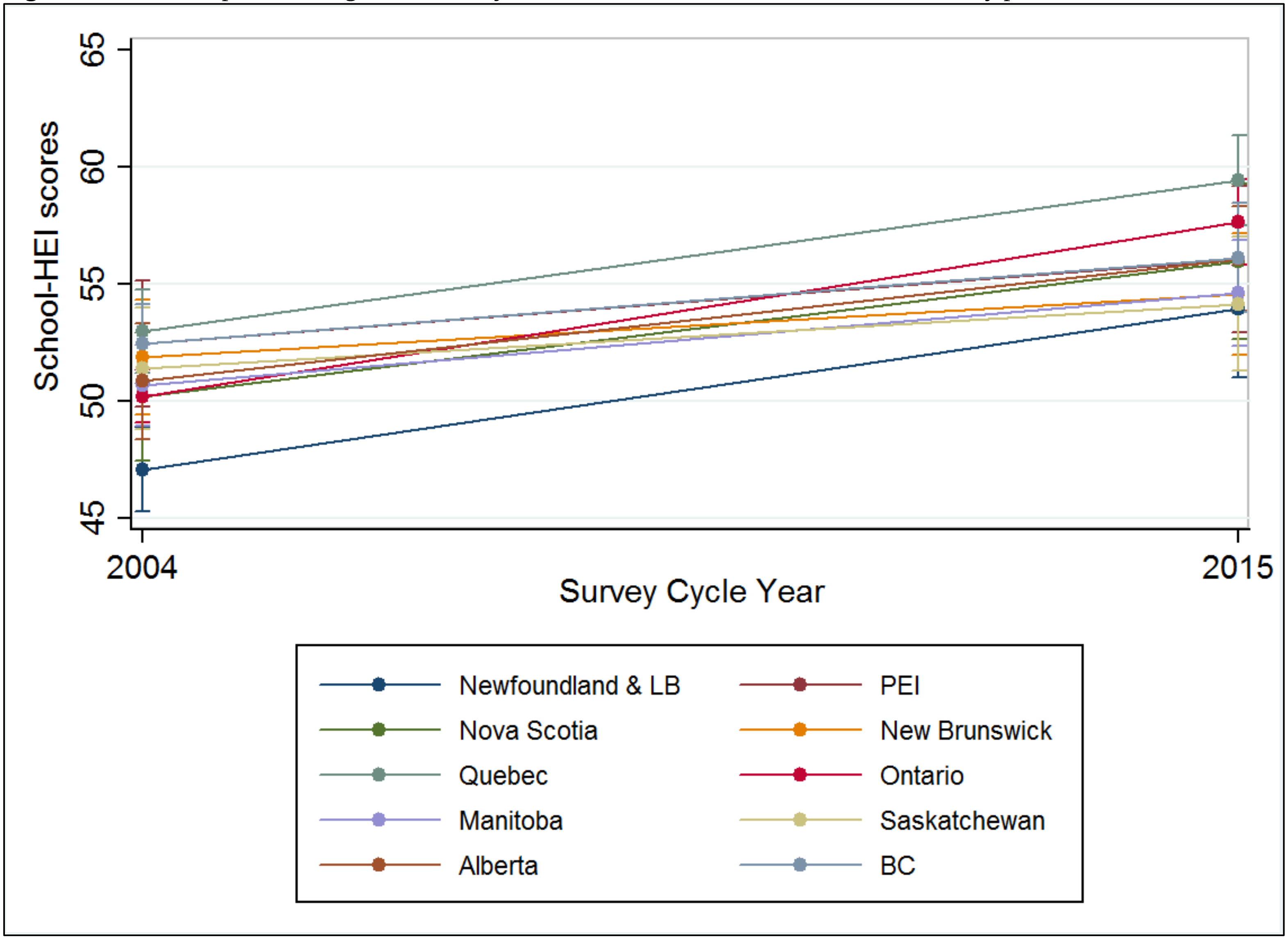
Tier 4 foods from each of the four food groups were excluded from the total number of EWCFG servings. These foods are thus not counted towards the total number of servings within a food group.

Table 17 The p-value from Wald tests determining whether adding interaction product terms improved the overall fit of the multivariable linear regression models with survey year as the focal independent variable, sociodemographic variables as moderating variables, and School-HEI score as the outcome variable among Canadian children aged 6-17 years*

	p-value testing the joint significance of the interaction product terms
Sex	0.521
Age group	0.092
Cultural origin	0.875
Residence location	0.868
Province of residence	0.055
Parental education	0.831
Food security status	0.088

* Sample size for these models is slightly smaller (n = 7211) due to missing data on cultural origin and food security status in multivariable linear models adjusted for school hour energy, cultural background and food security status.

Figure 3 Interaction plot showing covariate-adjusted mean School-HEI scores with 95% CI by province in 2004 and 2015



4.4 Discussion

The dietary quality of Canadian children and adolescents during school hours and on school days improved from 2004 to 2015, but the magnitude of the change was modest, and the dietary quality of foods consumed on school days remains below national dietary recommendations. Gaps in dietary quality among younger and older children were similar both in 2004 and 2015. Finally, school hour dietary quality improved similarly across all provinces.

Improvement in multiple dietary components, including increased intakes of vegetables and fruit, milk and meat products, and fewer calories from minimally nutritious foods (Tier 4 foods and ‘other’ foods) led to an overall improvement in school hour and school day dietary quality. Within the School-HEI sub-scores, the components that showed more meaningful improvement over time were total vegetables and fruit (increased intakes) as well as the percent of energy from other foods (decreased intake). The improvement in total scores for dietary quality are consistent with a U.S. study reporting improvement in children’s entire day dietary quality from 1999 to 2012 (106). A 9-point increase in U.S. 2010-HEI scores (for the whole day) was reported in a nationally representative sample of children age 2-18 years. Although this U.S. study used a different diet quality index, the magnitude of the difference (9 points) appears to be larger compared to what was observed among Canadian children (only a 4-point increase over an 11-year period). Similarly to Gu and Tucker who reported that a reduction in minimally nutritious calories accounted for one-third of the improvement in scores (106), I found that a reduction in the proportion of other foods accounted for 43% of the change in School-HEI scores. It is possible that provincial, regional and local policies regarding the sale of ‘junk’ foods in schools may have had an impact, although the repeated cross-sectional nature of this study does not allow an examination of the impact of such policies. Since the majority of children in Canada obtain their lunch foods from home (155), it is also possible that nutrition education campaigns and public dialogues could have led to increased awareness from parents of the health risk of minimally nutritious foods, leading them to pack more healthful foods in children's lunch boxes.

These findings are consistent with other Canadian studies that have demonstrated improvement in some (but not all) dietary components following the introduction of school nutrition policies (22,72,156). In Nova Scotia, children's dietary intakes were compared before (2003) and after the implementation of a provincial level school nutrition policy (2011) (22). This policy included nutrition-based criteria for foods sold in schools, mandatory policies regarding the sale of food and beverages in schools, regulations on advertising and price interventions to promote the affordability of school meals. From 2003 to 2011, children reported lower *daily* intakes of SSBs (-0.20 cans per day, 95% CI: -0.27, -0.12), with concurrent increases in milk product (+0.24 servings/day, 95% CI: 0.18, 0.31) (22). However, there were no changes in reported daily intake of vegetable and fruit. A PEI study reported differences in students' dietary intakes before and after a school nutrition policy issued in 2006 which addressed issues of food availability, student access to food, food used in school fundraising initiatives, food safety, and nutrition education (72). Compared to grade 5-6 students surveyed in 2001, students surveyed in 2007 were more likely to meet their recommended number of *daily* servings of vegetables and fruit recommended in the EWCFG, and less likely to consumed more than three servings a day of minimally nutritious foods. Similarly, I found that Canadian children reported significantly higher amounts of vegetables and fruit but less energy from minimally nutritious foods over an eleven-year period (both during school hours and for the whole school day).

In unadjusted models, I found few significant differences in School-HEI sub-scores between sociodemographic sub-groups. However, younger children had significantly higher school hour dietary quality compared to older children, both in 2004 and 2015. I also found significant differences in School-HEI scores across provinces in 2004 and 2015. Although the interaction effect approached significance, all provinces saw similar improvement in school hour diet quality from 2004 to 2015. While variation in the content and implementation of provincial school nutrition policies has been reported in the literature (63,73,102), it appears that Canadian children's school hour dietary quality has improved similarly across all provinces.

Among the sociodemographic variables examined here, there was little evidence of a disparity in school hour dietary practices among sub-groups of children. In unadjusted models, I also found that children from food-insecure households had significantly lower school hour dietary quality compared to their peers in food-secure households in 2015, but not 2004. However, the magnitude of the difference between children from food-secure and food-insecure households was small (a difference of ~3 points). In a nationally representative U.S. sample, NSLP participants reported slightly lower U.S. 2010-HEI scores (a 2-3 point difference depending on the NHANES cycle year) compared to non-NSLP participants (p-value < 0.05) (106). Canadian children living in food-insecure households may have access to charity-based local school meals in some regions, but their expected impact on overall diet remains unclear. The CCHS 2.2 and CCHS 2015 - Nutrition did not include any questions on children's participation in any form of food assistance program that could have allowed me to examine their potentially buffering effect.

Strengths of this study included its large nationally representative sample. However, there are important limitations that should be acknowledged. There are important limitations to this study. There were differences in the execution of the survey (e.g. different sample sizes, response rates, changes to the food booklet used to collect dietary intakes) and data processing (e.g. changes to the nutrient databases used to analyze the 24-hour dietary recalls) between survey cycles, which could have implications when comparing dietary intakes between survey years (75). For example, a smaller response rate (61.6% in 2015 compared to 76% in 2004) increases the potential for non-response bias. Additionally, differences in misreporting (specifically increases in energy under-reporting from 2004 to 2015 (157)) could alter these findings. A study assessing the prevalence of energy misreporting from 2004 to 2015 suggests that while the prevalence of plausible energy reporters did not change, the proportion of energy under-reporters increased while the prevalence of over-reporters decreased from 2004 to 2015 (157). Recent analyses from the 2004 and 2015 CCHS suggest that self-reported energy intake has decreased substantially in almost all age groups (158). Within Canadian children, the percentage decreases in reported energy intake ranged from 9% to 18% depending on age and sex groups (highest among male adolescents), suggesting again that energy intake was more under-reported in 2015 compared to 2004. Greater energy under-reporting in 2015 could mean that intakes of nutrients and foods (e.g. sugar-sweetened beverages) would also be under-reported, although controlling for energy intake difference should help in mitigating the effect of increased energy under-reporting over time. Finally, nutrition education policies and campaigns could have resulted in respondents' tendency to minimize the reporting of minimally nutritious foods (and/or exaggerate the reporting of healthy foods such as fruit and vegetables), thereby leading to an overestimation of the improvement observed in school hour dietary quality.

4.5 Conclusions

The dietary quality of Canadian children and adolescents during school hours and on school days has improved modestly from 2004 to 2015 but remains below national dietary standards. These findings suggest that more effective efforts are needed to improve the quality of foods consumed by Canadian children during school hours and on school days. Interventions which aim to increase children's consumption of vegetables and fruit, whole grains, and dairy products have the potential of helping Canadian children move closer towards national dietary recommendations.

Chapter 5: Conclusion, Discussion and Future Research Directions

Childhood and adolescence are critical windows for shaping eating practices that can affect long-term adult dietary behaviours, with long-term implications for weight status and chronic disease risk. Schools have the potential to contribute to obesity prevention by promoting healthy eating and physical activity, but studies examining children's dietary practices in the school context are limited in Canada. The studies in this thesis point to the need for additional public health action to help Canadian children meet the national dietary guidelines for key dietary components (vegetables and fruit, whole grains, dairy products). In this chapter, I review key findings of my research and discuss their implication for future school-based nutrition interventions. I then elaborate on the strengths and limitations and potential avenues for future research.

5.1 Key findings

5.1.1 The dietary contributions of foods consumed during school hours by Canadian children

Prior to this research, no nation-wide Canadian study had examined what children eat during school hours or whether foods consumed during school hours improved (or reduced) children's overall dietary quality. Understanding the dietary contribution of foods consumed at school can inform the design of effective school-based interventions by identifying salient areas of concern (potentially modifiable loci for interventions) and help policy makers prioritize settings for health promotion efforts.

My findings suggest there is room to improve the nutritional quality of foods and beverages consumed during school hours (in relation to national dietary standards). This finding was not surprising and reflects nutritional concerns which have been previously reported regarding the diet of Canadian children. For example, previous research has reported that a substantial proportion of Canadian children do not meet the national dietary recommendations for vegetables, fruit and dairy products (8).

In this first study, I found that the school hour dietary contributions of vitamins A, D, B12, calcium, and dairy products were all relatively lower than the average energy contribution. Meanwhile, the school hour contribution from minimally nutritious foods was relatively higher than the average school hour energy contribution. Therefore, school-based interventions aimed at increasing the consumption of milk products and decreasing intakes of minimally nutritious foods and beverages (such as SSBs) have the potential of improving Canadian children's overall diet quality.

In the U.S., findings from the SNDA III studies have reported that NSLP participants have dietary contributions from vitamin A, B12, calcium, magnesium and phosphorus, and potassium which mirror the caloric contributions from foods consumed for lunch (~30% of the daily calories consumed) (41). Although it is not possible to directly compare my findings to the dietary contributions reported in the U.S. SNDA studies due to methodological differences on how dietary contributions were defined (contributions from the lunch meal vs. all foods consumed during school hours), it is interesting to note that the dietary contributions of calcium, magnesium and phosphorus among NSLP non-participants is lower than NSLP participants.

Indeed, the average proportion of TDIs for calcium, magnesium and phosphorus more closely resembles those reported by Canadian children in the first study.

5.1.2 Factors associated with school hour diet quality

5.1.2.1 Sociodemographic factors

Apart from age group, few of the sociodemographic characteristics examined here explained a substantial amount of variation in school hour dietary quality among Canadian children in 2004. Differences in school hour dietary quality between younger and older children persisted from 2004 to 2015. In both 2004 and 2015, school hour diet quality varied provincially, but the differences were modest (see Table 16). In 2004, Quebec, New Brunswick, PEI and BC had the highest school hour diet quality scores. In 2015, Quebec and Ontario had the highest scores. There were no significant differences across provinces except between Quebec and Newfoundland & LB (in 2004) and between Quebec and Saskatchewan (in 2015). Small regional variations in Canadian's eating habits has been previously reported (8). For example, national-level analyses suggest regional differences in fruit and vegetable consumption patterns between regions, with the Atlantic provinces and the Prairies having relatively higher proportions of children eating fewer than five daily servings of vegetables and fruit (the minimum recommended number of servings from the older 1992 version of the Canadian Food Guide) (8). In 2004, the proportion of children and adolescents who consumed fewer than five servings of vegetables and fruit daily were 79% in the Atlantic region and 75% for the Prairies compared to 64% for Canada overall (8). Quebec had the lowest percentage of children and youth having fewer than five daily servings of vegetables and fruit (51% of children and adolescents) (8).

To assess whether dietary inequities existed within the school context, I explored whether SES measures were significant correlates of school hour dietary quality. In 2004, SES factors examined (household-level income, parental education and food security status) were not meaningful correlates of school hour dietary quality. That is, none of the SES characteristics explained a large proportion of the variation in School-HEI scores. It is possible that the association between SES and diet quality may develop with age (such that the impact of SES on diet may only be meaningful in older adolescents).

The finding that in 2015 (but not 2004), Canadian children living in food-insecure households had slightly (but significantly) lower school hour diet quality scores compared to their peers living in food-secure households is worrisome. Recent research has suggested that Canadian families experiencing food insecurity may not be actively seeking access to subsidized school meal programs (though not always available) and some families may choose to send their child to school with food or money to purchase lunch so as to not appear different from other children (159). My findings suggest that current school-based interventions could be more effective to reach the most nutritional vulnerable students who, in 2015, are at a higher risk of lower diet quality during school hours compared to their peers coming from food-secure households.

5.1.2.2 Lunch-time food source and dietary quality

Prior to this work, no study had examined where Canadian children acquired food from during school hours, and whether lunch-time food source behaviours (obtaining lunch foods from home, schools or off-campus locations) was associated with differences in dietary quality at the national level. In 2004, most children reported bringing lunch from home for their lunch meal, while fewer students obtained lunch from off-campus locations or schools. Among children age 9 years and older, the nutritional quality of home-packed lunches was more desirable compared to foods obtained from off-campus locations while the nutritional profile of foods obtained from schools resembled that of foods obtained from off-campus locations. I found no evidence of an association between lunch-time food source and school hour dietary quality among children aged 6-8 years.

These findings contrast with previous U.S. and U.K studies reporting that school meal participants have more desirable lunch-time nutrient intakes, including higher intakes of fibre (53,129,138), protein (38,61,130,138), and key micronutrients such as vitamin A, D and calcium (61,129,138) compared to students bringing foods from home. U.S. and U.K-based studies have also reported that children consuming meals from schools have higher intakes of fruit (58,60,61,97), vegetables (38,57,58,60,97,131), milk and dairy products (16,57,58,60,97,131), and whole grains (57,58,97) compared to children eating home-packed lunches. The vastly different school meal contexts across countries could potentially explain why my findings differ from the current (largely U.S. and U.K.-based) body of research. Since the CCHS did not ask respondents if they were participating in a local school meal program, it is impossible to distinguish foods which were bought from school food vending operations (which could have offered less healthy food choices to students depending on municipal school nutrition policies) vs. those from a school meal program (i.e. a government or charity-based organisation seeking to provide free or subsidized meals which may or may not adhere to nutritional criteria for foods served).

My findings align with previous Canadian research which has documented that Canadian youth who bring a home-packed lunch to school have more desirable nutritional intake profiles compared to their peers who obtain foods off-campus during school hours (29,63). A recent study surveying secondary school students in Alberta and Ontario in 2013-2014 reported that purchasing lunch or snacks at school or from an off-campus location was positively associated with higher frequency of SSBs consumption on week days; in contrast, eating a home-packed lunch was protective against SSBs consumption (63). My findings, coupled with recent evidence documenting the availability of less healthful foods and beverages available for sale in Canadian schools (33–35), suggest there is room to improve the Canadian school food environment. Potential interventions could include limiting students' access to off-campus food outlets during school hours and increasing the availability of healthier choices through school meal programs with nutrition standards for foods being offered.

Unfortunately, it is not possible to examine whether the same differences across lunch-time food source groups were present among Canadian children in 2015 since the CCHS-2015 Nutrition did not include a 'location of food preparation' variable as in the CCHS 2.2 (75). There has been limited research in Canada examining how food source relates to dietary outcomes in children, which reflects a priority for future research.

5.1.3 Differences in school hour and school day dietary quality from 2004 to 2015

Studies examining temporal trends in children's dietary intake patterns are scarce in Canada. The last study in this thesis characterised the quality of Canadian children's diet on school days in 2004 and 2015. The dietary quality of Canadian children during school hours improved modestly from 2004 to 2015, from 51 to 57 points (p-value < 0.001). Findings also suggest while some aspects of the diet improved, others remained unchanged and even worsened from 2004 to 2015. On the positive side, Canadian children increased their intake of vegetables and fruit and decreased the proportion of energy coming from other foods (both during school hours and for the whole school day). However, there were no improvements for other dietary components. For example, there were no increases in whole day milk intake and no reduction in school hour or school day sodium intake. Some dietary sub-scores decreased from 2004 to 2015 (e.g. whole grains) during school hours and for the whole school day. Moreover, for both 2004 and 2015, many dietary components (whole fruit, dark green and orange vegetables, whole grains, and milk products) were relatively low in relation to national dietary standards. The modest improvement observed over an 11-year period suggest that more effective strategies are needed to improve the dietary quality of Canadian children.

5.2 Strengths and limitations

Key strengths of these studies include the use of large, nationally representative dietary surveys and the use of 24-hour dietary recall to capture dietary intake patterns on school days. Nationally representative 24-hour dietary recall data are rarely collected in Canada – prior to the CCHS 2.2, the last dietary survey went back to 1970 (74). An advantage of this method is that the respondent is asked for detailed information (e.g. quantify consumed) of foods and beverages consumed (as opposed to frequency of consumption) (83). In addition, contextual data such as meal occasion, time and place of consumption can be collected.

There are important limitations to the three studies presented here that deserve consideration. The data drawn upon are cross-sectional, making causal inference impossible. For example, it is not possible to know whether the changes observed in school hour dietary quality are due to the recent adoption of school nutrition policies and guidelines adopted by the various provinces over the last decade. There are issues around the generalizability of the CCHS. Although the survey is representative of the Canadian population in terms of age, sex, geography and SES, the target population in the CCHS 2.2 and CCHS 2015 Nutrition did not include individuals who lived in the Territories, on reserves or other First Nation settlements (74,75). These analyses likely included some days or time periods when some children were not physically in school (for example, spring break), as the CCHS 2.2 did not include a question asking respondents where food was consumed. However, I limited the potential to include such days by eliminating any reporting days which occurred on a Canadian national holiday or possible school break.

I used an adaptation of the C-HEI (42) to assess the quality of foods and beverages consumed by Canadian children during school hours. However, this index (and its categorical scale for “poor”, “require improvement” and “good” diet quality ratings) has not been validated against specific health outcomes among children or compared to nutritional criteria for school meals (to my knowledge, no such standards currently exist in Canada). The scaling of the scoring criteria in one-third assumes that to obtain a perfect score, individuals would need to eat perfectly balanced meals (including all dietary components) for each eating occasion. That is, to get a perfect School-HEI score, usual intake of foods consumed during school hours should meet each of the 11 nutrition criteria in the index (e.g. ~1/2 dark green and orange vegetable serving,

~1 whole grain serving, etc.). However, this way of assigning scores may not may not be realistic or reflect cultural norms around the composition of foods consumed for breakfast, lunch and dinner.

Under-reporting of energy is a major issue in dietary surveys, and studies conducted among children suggest substantial under-reporting (80,123). In 2004, Garriguet found that average under-reporting of energy was approximately 10% for the whole sample (160). Moreover, some studies have suggested increases in energy under-reporting among children over time (161,162) which could in part due to increasing prevalence of children with high BMI. An increase in energy under-reporting from 2004 to 2015 could complicate findings presented in chapter 4. A study assessing the prevalence of energy misreporting from 2004 to 2015 suggests that while the prevalence of plausible energy reporters did not change, the proportion of energy under-reporters increased while the prevalence of over-reporters decreased from 2004 to 2015 (157). Recent analyses comparing reported energy intake from the 2004 and 2015 CCHS suggest that reported energy intake decreased substantially in almost all age groups (158). Within Canadian children, the percentage of decreases in energy reported ranged from 9% to 18% (highest among male adolescents). This suggests that energy intake was under-reported to a greater extent in 2015 (compared to 2004). Greater energy under-reporting in 2015 could mean that intakes of nutrients (e.g. sodium) and foods (e.g. SSBs) would also be under-reported (although controlling for energy intake difference should help when attempting to compare nutrient intake between survey years).

Dietary recall methods can be affected by social desirability bias, a type of systematic error when subjects selectively misreport certain foods due to their norms and beliefs about what they should eat (85). It is reasonable to believe that both the recall and social desirability biases would be similarly distributed during school and non-school hours for older children who completed the recall without any parental assistance. Yet for children aged 6-11 years who completed the recall with parental assistance, the presence of a parent could have been a selective confounder. The parent would know what was in a home-packed lunch, but the child might have been reluctant to report that he/she had not eaten part of the lunch. When examining differences in diet quality across lunch-time food source, the issue of misreporting would not likely pose a problem unless the social desirability bias differed across lunch-time food source groups. When comparing dietary intakes between survey cycles (chapter 4), it is possible that nutrition education programs would have heightened children's awareness of health risks of minimally nutritious foods (e.g. SSBs), which could have encouraged respondents to underreport 'junk' foods while over reporting more healthful foods to a greater extent in 2015 (compared to in 2004 where less social stigma was perhaps associated with the consumption of 'junk' foods) (161). So, it is possible that social desirability bias increased, which could exaggerate the improvement in School-HEI scores from 2004 to 2015.

There are methodologic differences between the two surveys which could have implications when examining differences in dietary intakes from 2004 to 2015. For example, lower response rates could increase the potential for non-response bias. This lack of response, or poor compliance, could result in a non-response bias if non-respondents have characteristics (e.g. lower SES, older children) that differ from those who responded. For example, if more adolescents declined to participate in the survey in 2015, then this could result in an overestimation of the mean School-HEI scores for Canadian children.

Finally, there are some limitations to the analytical methods used in these studies. First, I did not use an approach to exclude implausible respondents (163). While Garriguet proposed an approach to identify implausible respondents in the CCHS 2.2 by comparing estimated energy requirements to reported energy intakes using physical and sedentary activity coefficients, it was not possible to use this method among children below age 12 since these questions were not asked among younger respondents in 2004 (160,163). Moreover in the CCHS 2015, the detailed questions which would have allowed an estimation of physical activity levels were not asked for participants under 18 years (75). To my knowledge there is no known cutoff with which to identify implausible school-hour intake, as students who skip lunch or report low school-hour intake may indeed be valid reporters regardless of energy needs. I opted to drop extreme energy reporters (24-hour recall where either very little or very large amounts of calories were reported on a school day) and those children who consumed 0 kcal during school hours. However, it is possible that individuals might have fasted while at school and remain ‘plausible’ energy reporters. Under-reporting is also not a consistent occurrence across individuals or across nutrients, making it difficult to assess (74,160). By including implausible reporters in these analyses, I increased the risk of biasing HEI estimates downwards (assuming that these implausible reporters tended to under-report energy intake). Second, nutrient intake data are known to be non-normally distributed and therefore, nutrients are often power transformed to comply with assumption of normality and homoscedasticity. For example, I used multivariable linear regression models when comparing nutrients intakes between school and non-school hours (chapter 2) and between 2004 and 2015 (chapter 4). When conducting ordinary least square regression, the dependent variables do not need to be normally distributed by themselves – only the prediction errors (i.e. residuals) need to be normally distributed (164). Due to my large sample size and energy adjustment within my regression models, I believe that the normality of the dependent variables was not a concern for these analyses.

5.3 Significance and contribution of the research

Diet is an important risk factor for chronic disease prevention in Canada (165). Examining children's dietary patterns in the school context at the national level provides insights to inform the design of effective strategies to improve their diet and ultimately, their health.

The first study pointed to nutritional quality differences between school hour and non-school hours in Canada (relatively lower intakes of milk products and higher intakes of minimally nutritious foods during school hours compared to non-school hours). Since many Canadian children and adolescents do not meet the national dietary guidelines for milk products (8) and more than 10% of Canadian youth (9-17 years) have inadequate intakes of vitamin A, D, calcium and magnesium (10), the school context provides an opportunity to correct for these shortfalls. School-based interventions focused on increasing intakes of milk products (e.g. subsidised school milk programs) while reducing intakes of minimally nutritious foods (e.g. bans on the sale of SSBs) have the potential of improving children's overall dietary quality. Improving students' intake of milk products at school appears to be particularly relevant since there has been no improvement in Canadian children's consumption of milk products from 2004 to 2015 (see chapter 4).

If schools are going to tackle food and nutrition issues, it is also important to ask whether certain sub-groups of children are more nutritionally vulnerable, or for example, at what grade or age interventions should be targeted. Prior to this work, no national-level analysis had examined whether dietary inequities were present among sub-groups of children in the school hour context. As part of the first and third study, I examined whether any sociodemographic factors were associated with differences in school hour dietary quality among children sub-groups. From 2004 to 2015, there was no reduction in the gaps in dietary quality between younger and older children. Much of the school-based health promotion interventions have been geared towards the elementary school-aged children population (166). Future school-based interventions should aim not only at younger but also older age groups who often experience a decline in diet quality when transitioning into adolescence (167,168).

The second study examined the associations between school hour and school day diet quality and lunch-time food source in a large, nationally representative sample – which was novel in the Canadian context. Although home-packed lunches are exempt from school nutrition policies, they appeared to be (at least in 2004) more nutritious than lunches obtained from off-campus and school locations among adolescents. Moreover, among adolescents, the nutritional quality of foods obtained from school was similar to that of foods obtained off-campus. These findings reflect the absence of a national school lunch program and/or inadequate access to nutritious options at school for Canadian children and underscore the need for more effective actions to change school food environments in Canada to promote more healthful dietary behaviours. Since most Canadian children bring home-packed lunches to school, adolescents should be encouraged to prepare healthy home-packed lunches. Schools also need to provide supportive environments to consume healthy foods (for example, giving children sufficient time to eat, providing access to fridges and microwaves). Nutrition education programs could provide students with the opportunity to develop the food skills to prepare healthy meals (e.g. in-school cooking classes).

The third study suggests modest improvements in school hour dietary quality over time among Canadian children, highlighting the need for more effective strategies to improve children's dietary quality on school days. I found that the improvement in School-HEI scores from 2004 to 2015 was largely driven by less energy from minimally nutritious foods and higher intakes of vegetables and fruit. In the past decade, many school jurisdictions have taken action to reduce the sale of less healthful foods on school grounds (69). Considerable resources have been aimed at limiting the consumption of minimally nutritious beverages (e.g. SSBs) by provincial governments (e.g. Sip Smart BC (169), Going the Healthy Route at School in Québec (170)). Some governments such as BC and Manitoba have implemented school fruit and vegetable programs (171). It is not possible to quantify the true impact of these interventions because of the cross-sectional design of the studies conducted in this thesis. Nevertheless, the modest improvement seen over an eleven-year period suggests that more effective efforts are needed to help Canadian children meet national dietary standards.

5.4 Future research directions

Based on the results of the three studies presented, there are several opportunities for future research. The findings that Canadian children have room to improve their overall dietary quality on school days (both in 2004 and 2015) calls for additional action to address the barriers in consuming nutritious foods while at school.

The cross-sectional nature of this work limits the ability to determine the potential drivers behind children's dietary practices during school hours as well as our understanding of the potential impact of school-based nutrition interventions on children's diet. My findings suggest that school-based interventions targeting milk products could have the potential of increasing overall dietary quality. Critical knowledge gaps remain, including more in-depth analyses of beverage intake consumption patterns of Canadian children at school. For example, it would be interesting to examine whether children who consumed milk regularly at school have overall better dietary quality and are at a lower risk of inadequate intakes of nutrients such as calcium, vitamin D and magnesium (key nutrients of concerns among Canadian children). Future intervention research could also evaluate whether students who are provided free or subsidised milk at school 'compensate' by reducing their consumption of milk products outside of school hours. Answering these questions could help determine whether large scale school-based milk programs merit consideration for future funding or evaluation.

In Canada, school meal programs are often run by charity-based organisations (e.g. School Breakfast Club of Canada, the School Lunch Association in Newfoundland and LB (172)) and administered at the school board, or even the individual school level. There is no national database or registry documenting their reach or their impact on students' dietary outcomes. This contrasts with the U.S. which has conducted several national-level studies to examine the impact of school meal participation status on student's dietary quality (via the School Nutrition Dietary Studies since the early 1990's) (53). Some academics and advocacy groups are lobbying for a national, standardized school meal program to improve population-level diet quality among children (24,27,102,173,174). Understanding the reach and impact of current school meal programs in Canada could help provide foundational knowledge to inform debates around whether Canada should invest into a universal school meal program for its children.

In Denmark, the OPUS school meal study, a randomised controlled trial assessing the impact of serving school meals based on the New Nordic Diet suggests an improvement in children's diet as a result of introducing a universal school meal program (126). Within the Canadian context, limited research has explored the potential for school meal programs to ameliorate students' dietary outcomes (142,175,176), reflecting a priority for future research. To my knowledge, there has been no work testing the impact of free or subsidized lunches on Canadian children's dietary quality and no studies have compared the nutritional intakes of students who receive school meals with those who bring home-packed lunches to school. Finally, little research has explored whether school-based interventions (e.g. school bans on SSB sales) result in compensatory behaviours in other contexts (increases in SSBs consumption at home). Such research would be helpful to design effective school-based interventions to improve Canadian children's overall dietary quality.

Few studies have targeted home-packed lunches as a means of improving dietary outcomes of children on school days (177,178). Since most Canadian children bring a home-packed lunch to school, it makes sense for nutrition education to target meal preparation and eating behaviours at home. In the U.K., the *SMART lunch bag* randomized control trial consisted of providing households with supportive material (e.g. lunch bags, wall chart ideas for lunch items) with the overall aim of encouraging households to provide foods from five main food groups (starches, protein, dairy, vegetables and fruit). However, this trial did not provide food to families. Parents in the *SMART lunch box* intervention group increased the amount of fruit and vegetables and dairy food provided to children, but the magnitude of the difference was small and aside from vitamin A and folate, no other changes in the other dietary outcome measures were observed. In the U.S., the *Lunch is in the Bag* 5-week intervention trial aimed at preschoolers (3-5 years) increased the prevalence of parents packing fruit (+5.5%, SE 2.4), vegetables (+21.3%, SE 4.7) and whole grains (+12.1%, SE 5.4) while decreasing the prevalence of salty snacks (-12.8 %, SE = 5.0%) and sweets (-6.6%, SE 4.7) for a 6-week follow-up period (178). This latter intervention included 'boosters' which acted as prompts to remind parents of healthy lunch-packing behaviours several months after the intervention (178) which could explain why this intervention appeared more successful than the earlier trial conducted in the U.K. (177). To my knowledge, no nutrition education interventions aimed at improving the healthfulness of home-packed lunches have been conducted in the Canadian context (even though many Canadian children bring a home-packed lunch to school), providing an opportunity for future research.

5.5 Conclusions

There is increased interest in Canada in developing policies to improve children's eating habits and reduce their long-term risk of chronic diseases (7,9,179). The studies presented in this thesis provide empirical evidence to inform the development of future strategies to improve Canadian children's dietary quality on school days. The modest improvement observed from 2004 to 2015 suggests the need for more effective efforts to improve Canadian children's eating habits. To promote population-level changes in Canadian children's dietary quality, future strategies will need to be tailored to children's eating behaviours in various contexts (e.g. schools, home, restaurants). School-based strategies aimed at increasing intakes of vegetables, whole fruit, dairy products and whole grains have the potential of improving Canadian children's dietary quality on school days.

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Appendices

Appendix A : A Systematic Review of Methods to Assess Children's Diets in the School Context

Acknowledgement: A version of Appendix A has been published. Tugault-Lafleur C.N., Black J.L., Barr S.I. A systematic review of methods to assess children's diets in the school context. Advances in Nutrition. 2017;8:63–79.

A.1 Summary

To evaluate the impact of school-based nutrition interventions, accurate and reliable methods are needed to assess what children eat at school. The primary objective of this study was to systematically review methodological evidence on the relative accuracy and reliability of dietary assessment methods used in the school context. The secondary objective was to assess the frequency of methods and analytical approaches used in studies reporting in-school dietary outcomes. Three health databases were searched for full-text English-language studies. Twenty-two methodological studies were reviewed. For school meal recalls, the majority of studies (*n*=8/12) reported poor accuracy when accuracy was measured using frequencies of misreported foods. However, when energy report rates were used as a measure of accuracy, studies suggested that children were able to accurately report energy intake as a group. Results regarding the accuracy of Food Frequency Questionnaires (FFQs) and Food Records (FRs) were promising but limited to a single study each. Meal Observations (MOs) offered consistently good inter-rater

reliability across all studies reviewed (*n*=11). Studies reporting in-school dietary outcomes (*n*=47) used a broad range of methods, but the most frequently used methods included weighed FRs (*n*=12), school meal recalls (*n*=10), MOs by trained raters (*n*=8) and estimated FRs (*n*=7). The range of dietary components was greater among studies relying on school meal recalls and FRs compared to studies using FFQs. Overall, few studies have measured the accuracy of dietary assessment methods in the school context. Understanding the methodological characteristics associated with dietary instruments is vital for improving the quality of the evidence used to inform and evaluate the impact of school-based nutrition policies and programs.

A.2 Introduction

Given growing concerns about nutrition-related chronic diseases among children (64,180), there is now strong international interest in evaluating and improving children's diets within school settings (181,182). Schools are a proposed site for public health action to improve children's diet quality because schools reach a large number of children, can facilitate nutrition education and health promotion programs, and can influence dietary behaviours (18,21,183). For example, school meal and snack programs have been promoted as a means to reduce food insecurity for children living in poverty (176,184,185) and to improve diet quality at the population level (53,102,126). In Canada, some jurisdictions have also implemented food policies such as school food and beverage sales guidelines aiming to improve nutrition environments and promote healthier dietary choices (186,187). Given that implementing school meal programs and policies require substantial investments to implement and sustain (125,188), evidence is needed to assess whether and how they impact children's overall diet quality, which in turn, requires an accurate assessment of both dietary intakes in the school setting and during the remainder of the school day.

Evaluating the impact of school-based nutrition interventions requires both valid and reliable instruments. Validity broadly refers to the ability of a method to measure *true* intake and to reflect the aspect of the diet it is proposed to measure (143,189) while reliability refers to the ability of an instrument to produce *consistent* results (143,189). There are several types of both validity and reliability that must be considered when developing approaches for measuring diets in the school context. In the nutritional methodological literature, one of the most frequently discussed types of validity is criterion validity, which involves comparing a tool's assessment of dietary intakes with results obtained using a reference instrument. While there is no agreed-upon gold standard in nutrition assessment, a reference instrument is thought to hold a greater degree of demonstrated validity, even if it is not an exact measure of the underlying concept (189). Test-retest reliability (sometimes referred to as reproducibility (189)) refers to an instrument's ability to produce consistent results with repeated measurements. Inter-rater reliability examines the extent to which different 'raters' (or observers) provide similar estimates while intra-rater reliability refers to how consistent results are for repeated ratings by a given rater.

Approaches to measure dietary intakes within school settings can be broadly categorized as self-reported approaches and observational techniques. Self-reported instruments include meal-specific recalls, estimated food records (FRs) (or food diaries), food frequency questionnaires (FFQs) and diet screeners. In contrast, observational methods all involve an observer or rater evaluating dietary consumption of study participants in real time. Observational techniques include direct meal observations, weighed food records, digital photography (DP) methods and the School Food Checklist (SFC). The SFC is a one-page form listing 29 food and beverage items commonly found in students' lunches. Meal observers filling in the SFC also indicate the approximate portion size consumed for each food or beverage; total energy is estimated from the lunch meal (190). 24-hour dietary recall methods and diet records are often used in large, population-based dietary surveys, as they are typically less labour intensive and thus less expensive to conduct compared to observational tools (143). However, validation studies have confirmed important measurement errors inherent to self-reported instruments (80,191,192). Understanding the extent and type of measurement error associated with self-reported tools is crucial for appropriately interpreting study results (193).

While several reviews have examined the validity of dietary assessment instruments for use among children (80,123,194,195) no comprehensive review has focused specifically on eating contexts such as schools, and the validity of adapting current dietary assessment tools to evaluate diet quality in these contexts. Schools present both unique methodological challenges and opportunities for collecting dietary data. For example, parents are not present to assist in reporting food intakes and foods may come from different sources (home, school vending operations and off-campus locations). On the other hand, dietary intakes can be observed more easily since consumption typically occurs in large groups at set times. To appropriately measure the impact of school-based nutrition interventions (such as school lunch programs or regulations regarding the sales of 'unhealthy' foods and beverages on school grounds), researchers and practitioners need to know which tools are most appropriate, including their strengths, limitations, type(s) of measurement error, and which outcomes can be assessed most effectively using a given instrument.

This review therefore aims to fill current gaps by: 1) describing the strengths, limitations, and sources of measurement errors of dietary instruments commonly used to evaluate in-school dietary intakes; 2) assessing methodological evidence on the criterion validity and inter-reliability of each instrument; 3) examining whether the use of various diet quality indicators differs across dietary instruments; and 4) describing key gaps and proposing next steps for measuring diet quality in the school context.

A.3 Methods

The review process was informed by the Preferred Reporting Items for Systematic reviews and Meta-analyses (PRISMA) 2015 framework (196).

Eligibility and exclusion criteria

The search strategy aimed to identify papers that developed, validated, or applied dietary assessment instruments to characterise in-school dietary intakes. Participants were school-age children (6-17 years) who participated in experimental or observational studies that measured food and beverage consumption in the school context such as lunches or snacks consumed at school. Studies were excluded if they focused on childcare/daycare settings, included only preschool-age children, took place in low-income countries, did not specify whether dietary intakes were consumed at school or elsewhere, or only included measures of food availability or sales but not actual intake. Commentary and editorial papers were also excluded.

Information and search strategy

Three health databases (MEDLINE Complete, CINAHL Complete, and PubMed) were searched for full-text English-language publications published in 2015 or prior using keywords ("school meal*[6]" OR "school diet*" OR "school intake*" OR "school dietary intake*" OR "school nutrient* intake*" OR "school food*" OR "school lunch*" OR "packed lunch*" OR "bagged lunch*" OR “school snack*” OR “school breakfast*”) AND (children OR youth OR adolescent* OR student*) AND (tool* OR measure* OR assessment* OR instrument* OR indicator* OR index). Reference lists were further screened to identify additional studies.

Study selection and classification

Articles were assessed for eligibility independently by the first author in consultation with co-authors. Studies were classified into two groups based on their main purpose: 1) methodological studies evaluating criterion validity and/or reliability of dietary instruments (e.g. school meal recalls) used in the school context compared to a reference instrument (e.g. weighed food records); and 2) studies whose primary outcome(s) were measures of in-school dietary intakes and/or overall diet quality.

Approach for evaluating relative accuracy and reliability

Studies were first categorized based on whether they used a self-reported or observational tool. Key characteristics of each study including the study reference, context, sample characteristics, test and reference instrument used, statistical approach, and study results measuring validity and/or reliability were extracted into summary tables by the first author and checked for accuracy and completion by co-authors.

Table A-1 describes the key measures for evaluating criterion validity and reliability and the scoring criteria to appraise each methodological study. Common approaches used in the

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[6] The * symbol was used at the end of key search terms to any additional characters for a key word search (for e.g. “school meal” and “school meal**s**”).

literature included omission, intrusion and match rates used to assess misreporting for the types of foods reported (regardless if amounts were accurate) whereas arithmetic and absolute differences were used to assess validity in terms of amounts[7] reported for matched foods. There are currently no established cut-offs classifying dietary instruments as having 'acceptable' or 'poor' validity. To facilitate the interpretation and comparison in findings across methodological studies, new scoring criteria and cut-offs were used. These cut-offs were based on previous standards used in the methodological literature (88). Statistical assessments of criterion validity also included two-sample t-tests to compare means, correlation coefficients comparing amounts from the test and reference measures and energy report rates. The scoring criteria for these measures also align with a previous review on dietary assessment methodologies for use in children (123) and cut-offs for energy report rates were based on previous approaches (80,123). Cut-points for defining 'poor', 'acceptable' and 'good' test-retest reliability and inter- and intra-rater reliability were derived from methodological literature on reliability (197,198).

Types of diet quality indicators used in relation to dietary instruments

Using the second group of studies, study reference, context, sample characteristics, type of dietary instrument used, dietary outcome(s) variables and key findings were extracted into summary tables for each type of dietary instrument identified. For each study, we examined whether authors captured diet quality using single, multiple dietary components (e.g. absolute amounts of micronutrients and/or foods, proportion of energy from macronutrients) or whether studies used more complex analytical methods (e.g. use of a composite diet quality index). We

[7] When assessing the precision of a self-report method (meal recalls) compared to visual estimation from trained raters, precision was assessed up to 0.1 servings.

examined the frequency of instrument use across diet quality indicators to examine whether the use of specific instruments was associated with more frequent measures of in-school diet quality.

Table A- 1 Measures used for evaluating the relative accuracy and reliability of dietary instruments used for assessing dietary intakes in school settings

	Definitions	**Cut-offs for assessing relative accuracy and reliability**	
Measures of relative accuracy		**Poor/Failing**	**Acceptable**
Omission rate	A measure of reporting error that reflects the rate of foods reported relative to all foods observed. Calculated as the sum of weighted values* for omitted foods / (sum of weighted values for matched foods + sum of weighted values for omitted foods). Ranges from 0 to 100%.	>15%	≤ 15%
Intrusion rate	A measure of reporting error that reflects the rate of foods reported but not observed. Calculated as the sum of weighted values* for intrusion† foods / (sum of weighted values for matched foods + sum of weighted values for intrusion foods). Ranges from 0 to 100%.	>15%	≤15%
Match rate	The ratio of foods reported to be consumed over foods that were consumed. Ranges from 0 to 100%.	< 85%	≥85%
Arithmetic difference‡	The difference (expressed in servings) between observed and reported amounts for matched foods, but under- and over- reports can offset one another. These differences for each meal item are multiplied by a statistical weight[1] and then summed up for each meal for each child. The sign of the arithmetic difference provides an indication as to whether on average, children tend to over- or under- report foods and beverages consumed.	< -0.5 or > 0.5 servings/meal	≥ -0.5 to ≤ 0.5 servings /meal
Absolute difference‡	The difference (expressed in servings) between observed and reported amounts for matched foods, but under- and over- reports do not cancel each other. These differences for each meal item are multiplied by a statistical weight* and then summed up for each child. This represents the average number of servings misreported in each meal for a group of children.	>1 servings /meal	≤ 1 servings /meal
Two-sample t-test	A statistical test used to assess the difference between two means (obtained from the reference and test instrument).	Significant difference	No significant difference
Energy report rate	The percent of reported energy consumed by the total observed energy consumed. The closer to 100%, the more valid the instrument.	<85% or >115%	85-115%
Correlation coefficient	Measures the agreement between individual values between a test and reference method§	$r < 0.6$	$r \geq 0.6$

Measures of reliability¶		Poor/Failing	Acceptable
Cohen's Kappa coefficient	Statistical measure of the amount of agreement between two measures of the same concept (can be used to assess test-retest or inter-rater reliability).	<0.6	0.6-0.8: acceptable >0.8: good
Intra-class Correlation Coefficient	A statistical test that measures intra-rater reliability (how similar the ratings are for a given observer over time).	<0.6	0.6-0.8: acceptable >0.8: good
Percent agreement between raters	A statistical test to measure inter-rater reliability (how different observers rate the same observation).	<60%	60-80%: acceptable >80%: good

[*] Subjective weights are used when adding each meal component to generate an omission or intrusion rate for the whole meal: meal entrée=2, condiments=0.33 and other meal items=1 (87,89,199). [†] Intrusion foods are foods that were not observed by raters/observers but reported by children (also sometimes referred to as 'phantom' foods). [‡] A limitation of arithmetic and absolute difference measures is that that they are serving-based, but serving sizes vary greatly across different types of foods. A 0.1 serving difference in reporting of a food with low energy density (such as lettuce) or a food typically consumed in small portions (such as ketchup) have a very different impact on the accuracy of total reported intake compared to 0.1 servings of a food that is energy dense (such as pizza or a chocolate bar). [§] Correlation coefficients only provide an indirect measure of accuracy. A correlation coefficient measures the agreement between individual values for two methods. For example, the individual values for protein intakes obtained by a 24-hour dietary recall and a food frequency questionnaire designed to measure usual daily protein intake could be highly correlated but the absolute difference in individual values estimated via each method could substantially differ. [¶] Cut-offs for defining 'poor', 'acceptable' and 'good' test-retest reliability and inter- and intra-rater reliability were derived from methodological literature on reliability (197,198).

A.4 Results

Figure A-1 outlines the article identification and selection process. A total of 436 unique references were identified, of which 59 were selected for qualitative synthesis. An additional 10 papers were identified after screening reference lists from reviewed studies in the primary search (n=69 studies in the final review). Twenty-two studies were classified as methodological studies and 47 included at least one outcome measure describing in-school dietary intakes. No study fell into both categories; hence all 69 papers were considered unique records.

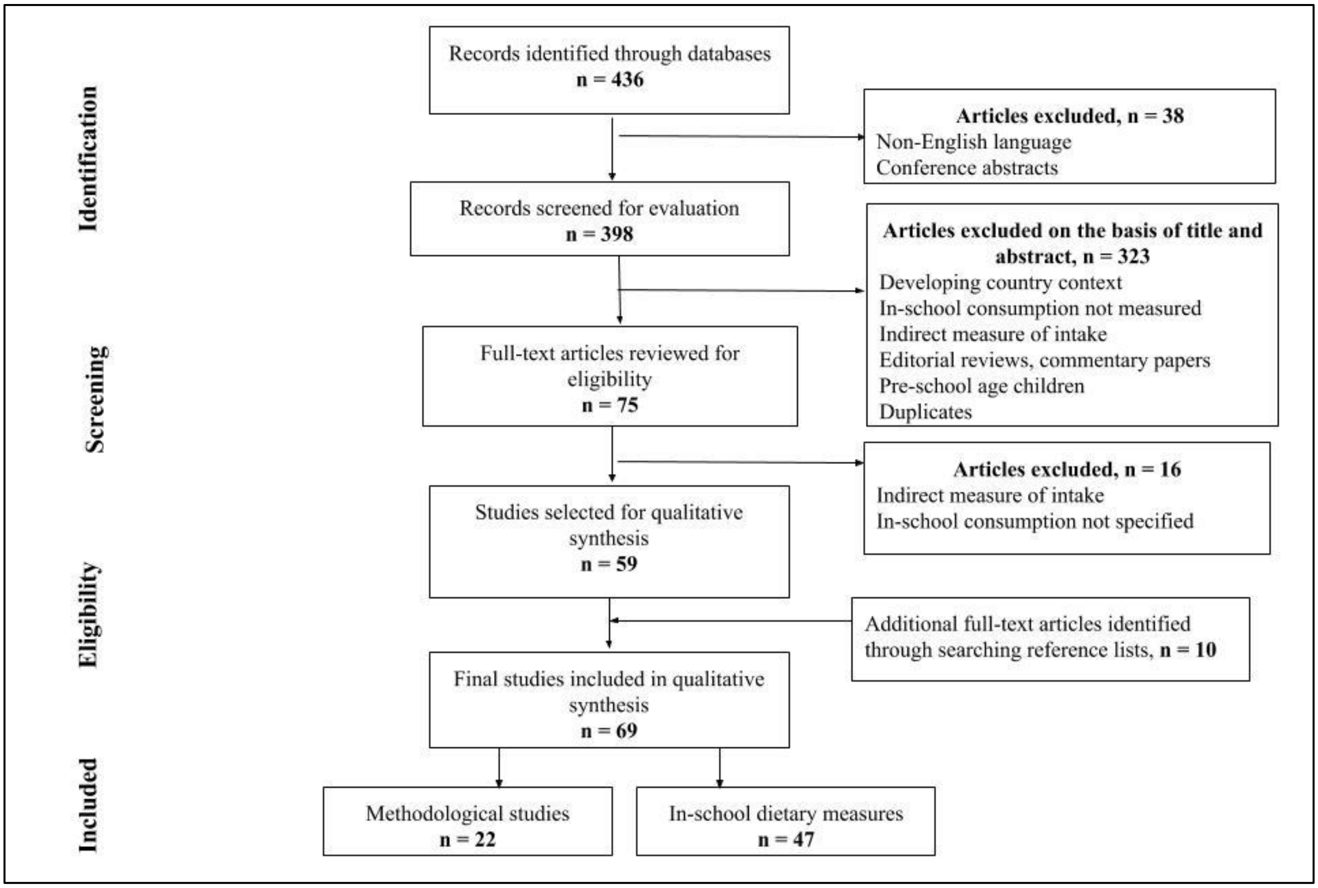

Figure A-1 PRISMA flow diagram of the study selection process. PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses (196).

Table A-2 provides descriptive information on each of the dietary assessment instruments used in the school context, outlining key strengths, limitations, sources of measurement error and an overall summary grade for validity and reliability. Table A-3 synthesizes key details of methodological studies sorted by instrument type.

Methodological evidence on the relative accuracy and reliability of dietary assessment tools

School meal recalls (n=15 studies). Adapted from the 24-hour dietary recall method, school meal recalls rely on children’s memories and reporting of all foods and beverages consumed at school (breakfast and/or lunches) often using specific prompting methods to elicit detailed information on the types and amounts of foods consumed. This method poses minimal burden on children and is designed to collect detailed, contextual information about consumption patterns (e.g. where was the food consumed and with whom). The main drawbacks of the 24-hour dietary recall are the high labor costs associated with interviewer administration of the recall. However, technological advances making this instrument both web-based and self-administered (e.g. the Automated Self-Administered 24-hour dietary recall or 'ASA24') have made this approach more cost-effective (200). The ASA24 is a fully automated, web-based, self-administered 24-hour dietary recall that provides a complete system for probing, coding and calculating nutrient and food group intakes (200). The ASA24 has been available at no cost to extramural investigators, clinicians and educators since 2009, is updated on a regular basis, and modified versions currently exist for use with children (ASA24-KIDS) and Canadian participants (200).

Table A-2 Key characteristics of dietary instruments to measure in-school diet quality among children (n = 22 studies)

Dietary instrument	Strengths	Limitations	Evidence of relative accuracy*	Evidence of reliability†
Self-report methods				
School meal recalls	Opportunity to probe for detailed dietary information and portion sizes, low burden on subjects	Costly if interviewer-administered; relies on memory; subject to misreporting, social desirability bias	Poor accuracy for individual foods reported (n = 8/12 studies); acceptable accuracy when reporting amounts consumed (n = 4/5 studies), acceptable energy report rates (n = 2/3 studies)	N/A
Estimated food records (by study subjects)	Detailed dietary information (quantities and types of food), self-administered, does not rely on memory	Higher burden on subjects, prone to reactivity and social desirability bias	Acceptable accuracy with daily monitoring; poor when children only monitored on a weekly basis (n = 1 study)	N/A
Food frequency questionnaires	Can provide estimates of usual intakes, self-administered (so lower costs)	Finite food list, lower precision for amounts consumed; difficult to capture contextual information (e.g. time and place of consumption); cognitively challenging for younger age groups; subject to misreporting, social desirability bias	Acceptable accuracy for measuring select beverages and snack foods (n = 1 study)	N/A
Observational methods				
In-person meal observations	Precise information about amounts and types of foods; lowest burden on subjects, more 'objective' method	Costly; labor-intensive; potentially intrusive	Acceptable (n = 1 study)	Good (n = 11 studies)

Dietary instrument	Strengths	Limitations	Evidence of relative accuracy*	Evidence of reliability†
Weighted food records (by research staff)	Precise information about amounts and types of foods; lowest burden on subjects, more ‘objective’ method	Most costly method; labor-intensive; not well suited for environments where students bring home-packed lunches	No evidence‡	No evidence
Digital photography methods	Low burden on participants; quick to administer, can be self-administered (so lower cost), more ‘objective’ method	Costly (labor-intensive for dietary data entry); difficult to capture hidden, wasted, spilled or traded foods; can be challenging to interpret data from photos	Acceptable (*n* = 2 studies)	Acceptable (*n* = 2 studies)
School Food Checklist	Only validated to measure energy intake for a group; quick to administer (~3 min per child), more ‘objective’ method	Finite food list; labor-intensive; potentially intrusive; not validated to assess the quality of intake (only energy)	Unknown	Acceptable (*n* = 2 studies)

*A measure of accuracy was expressed using categorical ratings (poor/failing *vs*. acceptable) defined with cut-offs shown in Table 1. † Inter-rater and intra-rater reliability is applicable to observational tools only. ‡ There is no gold standard in dietary assessment methodology but weighed food records by trained raters/observers are regarded as the closest to a gold standard. We found no methodological study testing the relative accuracy of the weighed food record. The ‘plate waste method’ (a form of weighed food record in which weights of foods remaining on the plate at the end of the meal are subtracted from the amounts served) is an adaptation of the weighed food record.

Table A-3 Summary of methodological studies evaluating dietary instruments for measuring in-school consumption (*n*=22 studies)

Study, Country	Dietary instrument	Reference method	Sample characteristics	Results[*]	Key Findings[†]
School meal specific recalls[§] (*n* = 15 studies)					
Baxter et al. 2002 (87), U.S.	Breakfast and lunch recall (school meals), same day (evening), no parental assistance	MOs	104 children, (10 years)	Omission rate: 41% Intrusion rate: 24% Absolute difference: 0.24 svgs. Arithmetic difference: −0.08 svgs. 89% agreement across raters for within ¼ of a serving for reference method	Poor accuracy for types of foods reported. However, children were able to report amounts consumed for matched foods with acceptable accurately. Good inter-rater reliability for in-person meal observations
Baxter et al. 2003 (88), U.S.	Breakfast and lunch recalls (school meals), same day (evening) via person and telephone, no parental assistance, multiple pass protocol	MOs	69 children, (10 years)	For in-person and via telephone recalls, respectively: Omission rates: 34% & 32% Intrusion rates: 19% &16% Absolute difference: 0.28 & 0.19 svgs. Arithmetic difference: -0.09 & 0 svgs. 93% agreement across raters for within ¼ of a serving for the reference method	Poor accuracy for types of foods reported, regardless of telephone vs. in-person interview. However, children were able to report amounts consumed for matched foods with acceptable accuracy. Good inter-rater reliability for the reference method.
Baxter et al. 2003 (89), U.S.	Breakfast and lunch recall (school meals), next morning, no parental assistance, multiple pass protocol (4 passes)	MOs	121 children (10 years)	For reverse and forward recalls, respectively: Omission rates: 57% & 56% Intrusion rates: 32% & 39% Absolute difference: 0.23 & 0.24 svgs. Arithmetic difference: -0.08 & -0.08 servings. 90% agreement across raters for within ¼ of a serving for the reference method.	Poor accuracy for foods reported, regardless of the recall order. However, children were accurate at reporting amounts for matched foods. Good inter-rater reliability for the reference method.

Study, Country	Dietary instrument	Reference method	Sample characteristics	Results[*]	Key Findings[†]
Baxter et al. 2009 (201), U.S.	Breakfast and lunch recall (school meals), same and next day (different retention intervals), no parental assistance	MOs	374 children (10 years)	For lunch recalls (rates for different time retention periods, ranges): Omission rates: 28%-55% Intrusion rates: 16%- 49% Energy report rates: 78%-88% Reported good inter-rater reliability for meal observations but percent agreement not reported by authors	Poor accuracy for types of foods reported (both on same day and next day). Poor accuracy for energy reported when recall occurred on the next day but acceptable accuracy when recall occurred on the same day.
Baxter et al. 2010 (91), U.S.	Breakfast and lunch recall (school meals), different retention intervals, no parental assistance	MOs	374 children (10 years)	Energy report rates: 85% Protein report rates: 105% Carbohydrates report rates: 86% Fat report rates: 97% 94-97% agreement across raters for the reference method	Acceptable accuracy for energy report, protein, carbohydrates and fat report rates; report rates varied by nutrient. Children tended to under-report energy and under-report carbohydrates. Fat and protein were accurately reported. Good inter-rater reliability for reference method.
Baxter et al. 2000 (199), U.S.	Lunch recalls (school meals), morning of the next day, no parental assistance, with and without prompting	MOs	96 children, (mean 7.2 and 10.1 years)	*Next day, no prompting:* Total inaccuracy[§]: 2.7 svgs. (grade 1) Total inaccuracy[§]: 1.7 svgs. (grade 4) *Next day, with prompting,* Total inaccuracy[§]: 2.6 svgs. (grade 1) Total inaccuracy[§]: 1.8 svgs. (grade 4)	Accuracy described as poor for both grades, but accuracy measures were higher for grade 4 compared to grade 1 students.
Baxter et al. 1997 (86), U.S.	Lunch recall (school meals), same day and next day, no parental assistance	MOs	260 children, (10 years)	*Rates for same day and next day, respectively:* Omission rates: 16%, 32% Intrusion rates: 5%, 13%	Poor accuracy for types of foods reported but omission and intrusion rates improved when recall was conducted on same day as the lunch

Study, Country	Dietary instrument	Reference method	Sample characteristics	Results*	Key Findings†
				Absolute difference: 0.10 & 0.14 svgs. Arithmetic difference: -0.02 & -0.01 svgs.	meal. Good accuracy for amounts consumed.
Biltoft-Jensen et al. 2013 (202), Denmark	Lunch recall (school meals), same day (evening), web-based software (WebDASC), parental assistance	Weighed FRs and DP method	81 children, (8-11 years)	Omission rate: 3% Intrusion rate: 14%	Acceptable accuracy for types of foods reported
Biltoft-Jensen et al. 2015 (203), Denmark	Lunch recall (school meals), same day (evening), web-based software (WebDASC), parental assistance	Weighed FRs and DP method	193 children (8-11 years)	Omission rates: 9% Intrusion rate: 6%	Acceptable accuracy for types of foods reported
Guinn et al. 2010 (92), U.S.	School meal recall, same day and previous day, no parental assistance	MOs	327 children (10 years)	Mean energy report rate: 88%. Report rates for energy decreased with increasing points on the social desirability scale and BMI percentiles categories. >90% inter-rater agreement for the reference method	Acceptable accuracy for energy report rates. Accuracy was inversely associated with social desirability bias and BMI. Good inter-rater reliability for the reference method.
Hunsberger et al. 2013 (204), Sweden	School meal recall, previous day, RD administered using a web-based dietary recall software	Weighed FRs	25 children (6-8 years)	Overall match rate: 90% (range: 67-100%). Difference in child-reported energy and observed energy: 7 kcals (SD=50) (p-value=0.49); strong correlation (r=0.92, p-value<0.001) between children's recall and reference method.	Acceptable accuracy for reporting individual foods and for estimating energy intake of the group

Study, Country	Dietary instrument	Reference method	Sample characteristics	Results*	Key Findings†
Lyng et al. 2013 (205), Denmark	Lunch recall (home-packed lunches), same day (PM), no parental assistance	DP method	114 children (11 years)	For girls and boys, respectively: Match rates: 78% & 74% Omission rates: 22% & 26% Intrusion rates: 18% & 24%	Poor accuracy for reported food items
Medin et al. 2015 (206), Norway	Lunch recall (school meals), web-based self-administered recall, same day, with parental assistance	MOs	117 children (8-9 years)	Match rate: 73% Omission rate: 27% Mean intrusion rate: 19% Higher parental education associated with better accuracy (77% vs. 52% match rate) (*P-value*=0.008). 92% agreement across raters for the reference method.	Poor accuracy for reported foods. Good inter-rater reliability.
Paxton et al. 2011 (90), U.S.	Lunch recall (school meals), paper and pencil questionnaire, same day, no parental assistance	MOs	18 children (8-10 years)	6% mean omission rate 10% mean intrusion rate Absolute difference: 0.06 svgs. Arithmetic difference: 0.01 svgs. 85% agreement between raters for the reference method.	Acceptable accuracy for both reported food items and for amounts of foods reported. Good inter-rater reliability for reference method.
Warren et al. 2003 (207), U.K.	Lunch recalls (school meals and home-packed lunches), same day (2h post meal), no parental assistance	MOs	303 children, 5-7 years	Home-packed and school lunches, respectively: Match rates: 70% & 58% Intrusion rates: 22% & 8% Prompting significantly increased match rates which increased from 66% to 80% for the whole sample.	Poor accuracy for reported food items, regardless of lunch type. Non-directive prompts increased recall accuracy.

Study, Country	Dietary instrument	Reference method	Sample characteristics	Results[*]	Key Findings[†]
				Inter-rater reliability not reported for the reference method.	
Estimated FRs (*n* =1 study)					
Domel et al. 1994 (208), U.S.	Estimated lunch-time FRs, no parental assistance	MOs	24 students (9-10 years)	Using a daily monitoring approach (students were prompted by data collectors to complete their FRs), Pearson's *r* ranged from 0.16-0.85 for different meal components (mean *r* = 0.66). However, using the weekly monitoring approach, Pearson *r*'s dropped: range -0.21-0.69 (mean *r* = 0.25). 90% agreement between raters for the reference method.	Overall school meal accuracy was acceptable only for children who were monitored on a daily basis to complete their FRs (but not among children on the weekly monitoring group). Accuracy varied also considerably depending on the meal component. Good inter-rater reliability for the reference method
FFQs (*n* =1 study)					
Neuhouser et al. 2008 (209), U.S.	19-item Beverage and Snack FFQ (recall period: past week)	Estimated 4-day FRs (administered one week before FFQ)	46 children, (mean age 12.7 years)	Pearson *r* = 0.71, 0.70 and 0.69 for beverages, snacks and total fruit and vegetables, respectively. Test-retest reliability *r* > 0.7 for 19 items	Acceptable accuracy Acceptable test-retest reliability
In-person meal observations (*n* =1 study)					
Richter et al. 2012 (210), Canada	In-person meal observation (by nutrition students)	Weighed FRs	32 children (elementary, no age provided)	Raters accurately identified 86% of pre-measured lunches (within ¼ of a serving) and over- or under-reported amounts for the other meal items in 14% of the lunches. Majority of ICCs >0.8	Acceptable accuracy Good inter-rater reliability

Study, Country	Dietary instrument	Reference method	Sample characteristics	Results[*]	Key Findings[†]
DP methods (*n* =2 studies)					
Sabinsky et al 2013 (211), Denmark	DP for home-packed lunches	Weighed FRs	191 children (7-13 years)	Spearman *r* range: 0.89-0.97 for amounts of meal items. No statistical difference between amounts of fish, fat, starch, whole grains, and overall lunch meal quality index scores (Meal IQ) between the test and reference instrument. Bland–Altman analyses suggest negligible bias (mean bias for fruit: -4.27g; LOA -29.4 to +20.8g) (mean bias for vegetables -6.19g; LOA -34.5 to + 22.2g). Kappa coefficients: 0.59-0.82	Acceptable accuracy. Bland-Altman plots suggest a tendency for the DP method to underestimate fruit and vegetable consumption. Acceptable inter-rater reliability.
Taylor et al. 2014 (212), U.S.	DP assessing only fruit and vegetable intake from home-packed lunches	Weighed FRs	958 children (8-10 years)	Pearson *r* range: 0.59-0.98 for amounts of meal items, all r above 0.8 except for leafy greens (r=0.59) Mean fruit and vegetable consumption using photography (97 g) was within 1.0 g of reference method and not significantly different from reference method (*P-value*=0.56). LOA for individual-tray fruit and vegetable consumption were –32.9.0 to 31.3 g. 96% percent agreement across raters; mean ICC was 0.92.	Acceptable accuracy. DP was accurate at estimating amounts eaten at the group level. There was no evidence of bias from Bland-Altman analyses. Good inter-rater reliability.

Study, Country	Dietary instrument	Reference method	Sample characteristics	Results*	Key Findings†
SFC (*n*=2 studies)					
Kremer et al. 2006 (190), Australia	SFC	Weighed FRs	106 children (5-12 years)	Relative accuracy for energy measured using mean difference between test and reference instrument: Mean difference 15 kJ (95% CI: -107 kJ to +138 kJ) (*P-value*>0.05). Kappa coefficient: 0.51	The SFC provides acceptable accuracy to measure energy intake for the group. Inter-rater reliability was poor.
Mitchell et al. 2009 (213), Australia	SFC, home-packed lunches, SFC + meal observations and SFC + DP method	No reference measure¶	176 children (5-8 years)	ICCs range for different lunch items *Using the SCF with meal observations*: ICCs=0.78–1 (intra-rater reliability) ICCs = 0.50–0.95 (inter-rater reliability) *Using the SCF with DP*: ICCs=0.57–0.92 (intra-rater reliability) ICCs= 0.32-0.92 (inter-rater reliability) (majority ICCs >0.7 except for leftovers where ICC=0.32)	The SFC has good intra-rater reliability; acceptable inter-rater reliability. Accuracy measures were higher when the SFC was used with in-person MOs rather than DP methods.

Digital Photography, DP. Food Frequency Questionnaires, FFQs. Food Records, FRs. Intraclass Correlation Coefficients, ICCs. Limits of Agreements, LOA. Meal Observations, MOs. School Food Checklist, SFC. * Results presented are group means unless specified otherwise. † To provide an overall rating for relative accuracy and reliability (where relevant), we used cut-off points for measures of relative accuracy. Those measures of accuracy and reliability are presented in Table 1. ‡ Unless specified, the school meal recall method was interviewer-administered. § Total inaccuracy combines both the type of error from misreporting meal items with measures of accuracy (199). Total inaccuracy is calculated as: (absolute difference between amounts reported and observed eaten for each match × statistical weight) + (each omitted amount × statistical weight) + (each intruded amount × statistical weight) summed over all items for a given meal for each child. There is no upper limit for total inaccuracy and this measure of reporting can be sensitive to the number and types of meal components. For example, a meal with multiple small entrees may result in greater total inaccuracy values compared to a meal with only one entrée. Thus, total inaccuracy is not appropriate to compare the accuracy of different instrument as these measures may vary depending on the meal context. Hence, this indicator was not selected as a criterion for comparing accuracy between types of instruments. [¶] The study goal was to test intra- and inter-rater reliability for estimating energy intake from lunches using the SFC.

Methodological studies using an adaptation of the 24-hour dietary recall method for assessing intakes from meals consumed at school are outlined in Table A-3 (n=15 studies). All studies were conducted with elementary school children, the majority of whom were age 9-10 years. The validity of school meal recalls was compared to an observational method, either in-person meal observations (n=11), digital photography methods (n=3) or weighed food records (n=1). The validity of children's descriptions of reported foods varied across studies, reflecting the influence of interview conditions on children's ability to recall their lunch meal. Omission rates ranged from 0% (202) to 57% (89) and intrusion rates ranged from 5% (86) to 49% (214). When the school meal recall was conducted the same day as the lunch meal (afternoon or evening), 8 of the 11 studies reporting omission, intrusion and/or match rates reported acceptable criterion validity with the reference instrument (86,90,201–203,205–207). Two studies which conducted school meal recalls the same day (in the evening, without parental assistance) reported poor criterion validity using the same measures of reporting error (87,88). Overall, 11 of the 15 methodological studies testing the validity of school meal recalls reported acceptable criterion validity – regardless of the measure of criterion validity used and the interview conditions.

The recall retention period[8] emerged as an important determinant of school meal recall validity in all studies reviewed. This is not surprising given that a recent review found that 24-hour dietary recall methods can vary greatly in accuracy depending upon interview conditions including retention period, type of prompting and use (or not) of parental

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[8] The retention period is the length of time elapsed between the eating occasion and the time when a child is asked to report dietary intake.

assistance (81). Among the studies reviewed, a shorter retention interval (recall conducted on the afternoon or evening on the same day of lunch consumption) was consistently associated with better recall validity. Findings related to the impact of prompting methods on recall validity for school meals were mixed. One study reported improved omission and intrusion rates with prompting (207) while another reported less reporting error (lower intrusion and omission rates), but only in the older age group (199).

The five studies reporting absolute and arithmetic differences (between amounts reported and amounts observed to be consumed by observers) suggest that children were able to correctly report amounts consumed, with arithmetic differences often being ≤0.1 servings per meal for foods reported at lunch (86–90). In all but the Paxton study (90), arithmetic differences in amounts were slightly negative, suggesting that children tended to slightly under-report (rather than over-report) amounts consumed. When pooling the energy report rate as a measure of validity across studies using this measure (91,92,201), the average energy report rate was 85%. Another study also confirmed that as a group, energy reported by children from school meal recalls did not significantly differ from estimates using weighed food records (204). These findings suggest that as a group, children are reasonably able to report energy consumed – yet studies using energy report rates indicate that children (similarly to adults) tend to under-report energy consumed.

Two studies evaluated the validity of reported meal items (fruit and vegetables, fish) with biological biomarkers. In Denmark, the school meal recall method was validated for assessing usual intake of fruit and vegetables (202) as well as fish (203) consumed at lunch in a sample of 81 children age 8-11 years. Dietary intake was assessed using a web-based dietary lunch meal recall for five consecutive school days in conjunction with the digital photography (DP) method to optimize the validity of the recall. In the first study, reported fruit and vegetable intakes were correlated with plasma carotenoids concentrations (mean $r = 0.49$, $p<0.01$, adjusted for sex, BMI and energy intake) (202). In their second study, fish consumption was significantly and moderately correlated with whole blood eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) concentrations (mean $r = 0.30$, $p<0.001$, adjusted for sex, grade, household education, BMI and fish oil supplement) (203).

Limitations of the school meal recall method include the reliance on children's memory and the high labour costs associated with interviewer-administered recalls (Table 2). However, three studies demonstrated acceptable criterion validity using cost-saving methods such as self-reported paper and pencil school meal recall questionnaires (90) and school meal recalls using a 24h dietary recall software (202,203). A web-based self-administered school meal recall instrument could potentially generate a valid estimate of the mean dietary intakes during school hours for a group at relatively low cost. Provided that the target recall period is minimised (i.e. the recall occurs in the afternoon or evening after lunch consumption), the overall evidence suggested that as a group, children age 9 to 10 years appear to be able to accurately report the majority of meal items (≥70% of items consumed), are fairly competent energy reporters (although like adults, they also tend to under-report energy), and can generally estimate amounts within ¼ of a serving.

Estimated lunch-time food records (n=1 study). The food record is a self-administered instrument where children are asked to record all foods consumed during the lunch period. Since they are self-administered, estimated food records are less expensive to conduct than interview-administered dietary recall methods or observational instruments. Estimated food records can provide detailed information about foods consumed without relying on children's memory

(Table 2). However, this tool is thought to hold more reactive bias[9] since the acts of recording and eating occurs at the same time.

One study drawing from a small, low socioeconomic status (SES) sample (n=24 children, age 9-10 years) tested the criterion validity of estimated food records at lunch-time (test instrument) compared with in-person meal observations for a two week period (reference instrument) (208). Students were reminded to fill out their food records either on a daily or a weekly basis by research assistants during school visits. Children were prompted for any missing items either on a daily or weekly basis. Criterion validity was measured using Pearson's correlation coefficients for different meal components. Among students who were monitored daily, criterion validity was acceptable for most of meal items ($r > 0.6$, $p<0.001$ for 6 out of 8 meal items). However, among students who were monitored on a weekly basis, validity dropped significantly ($r >0.6$ for only 2 out of the 8 meal items). These findings suggest that children can reasonably report foods consumed at lunch-time using food records if there is regular daily monitoring. However, this was the only methodological study using food records, thus there is a clear need for more studies with larger sample sizes to establish the estimated food record as a valid instrument. Unlike other contexts, food diaries completed at school cannot be modified by parents who are not present to observe dietary intake during school hours.

Food Frequency Questionnaires (n=1 study). Designed to evaluate usual dietary consumption, FFQs typically include a finite list of food groupings and/or categories and ask respondents to report usual frequency of consumption of each food category over a specific time (e.g. one

[9] Reactivity bias is a type of systematic error occurring when the respondent changes his/her eating behavior because of the act of recording their food intake.

month or shorter among children due to the difficulty associated with estimating usual intakes over time). FFQs hold the benefit of being a self-report instrument which is low cost and is designed to assess habitual or usual dietary intakes (Table 2). However, FFQs and diet screeners can be prone to systematic error (or bias)[10] due to difficulty in estimating intake over longer periods of time.

Only one methodological study assessed the validity of a 19 item FFQ (a beverage and snacks questionnaire or screener) developed to measure both in-school and out-of-school snack and beverage consumption patterns in U.S. middle-school children (209) (Table 3). This screener, which queries intake over a 1-week period, was administered on two occasions to assess test-retest reliability, separated by 4 to 6 weeks. During the week prior to the second screener administration, participants completed a 4-day food record. Criterion validity was assessed using correlation coefficients between the test instrument (diet screener) and average intakes from the 4-day food record. The majority of 19 questionnaire items were significantly associated with the reference measure (for in-school beverages, mean r=0.71; snacks and sweets, mean r=0.70; total fruit and vegetables, mean r=0.69, p-values<0.05). However, there were several limitations to this study. First, the test instrument was not compared to a more 'objective' or observational reference instrument (both the screener and the food records were prone to reporting error). Second, interpreting the test-retest reliability of the screener is challenging given that it captured different time periods for which dietary patterns could be reasonably be different due to intra-individual variability

[10] Systematic error (or bias) is a type of measurement error in which measurements consistently depart from the true value in the same direction. Unlike random error which can be reduced by taking multiple repeated measurements, systematic error is not reduced when multiple repeated observations are averaged.

in dietary intakes in a 4-6-week period. Finally, it is possible that the act of recording foods using a food diary may have helped children respond more accurately subsequently to the screener when administered a second time. Therefore, the validity of using the screener to measure in-school dietary patterns remains unclear, especially in younger children who might experience more difficulty remembering past consumption patterns (78,123) for specific time reference periods (school hours on school days). Lastly, FFQs and diet screeners have not been validated to measure amounts consumed during school hours, only types of foods and beverages consumed.

Meal observations by trained raters (n=11 studies). Meal observation is a method in which trained raters visually estimate amounts of foods consumed at lunch-time from children in group settings. Unlike self-report tools, meal observations by trained raters avoid the misreporting errors associated with recall of past dietary consumption. Like the school meal recall and food record, meal observations provide detailed information on the types and amounts of food and beverages consumed, but this method can also be labour-intensive requiring extensive training on visual estimation of food consumption and is potentially intrusive to children (Table 2).

Meal observation was the most commonly used reference method among methodological studies reviewed. Only one study assessed the criterion validity of the meal observation method by comparing visually estimated amounts from trained raters (dietetics students) to pre-measured home-packed lunches (210). The criterion validity of the method was deemed acceptable, with raters able to accurately estimate amounts consumed for 86% of the lunches (n=32 lunches) (Table 3). In contrast, the inter-rater reliability of this observational tool has been more extensively investigated and measures of inter-rater reliability were reported in 11 studies (Table 3). Inter-rater reliability was consistently good or very good, with percent agreements for amounts consumed across raters ranging from 85% to 97% (87–92,201,206,208). Intra-rater reliability was also good and Intra-class Correlation Coefficients (ICCs) reported in one study were all above 0.8 (210). Collectively, these findings support the meal observation as both a valid and reliable method for estimating types and amounts of food consumed in school settings.

Digital photography methods (n=2 studies). Digital photography (DP) captures food intake through cameras before and after consumption. Trained staff take digital images of the lunch meal following a standardised protocol (e.g. taking pictures before and after consumption from different camera angles to capture depth) and research staff (typically dietitians) use these images to estimate consumption (215,216). DP offers similar strengths as in-person meal observations but is potentially lower in costs as more lunch meals can be captured by a single photographer (Table 2). However, data entry can still be labour-intensive and requires trained staff to translate photos to estimated intakes. This method can omit foods that are spilled, traded, wasted or not easily visible (for example, margarine spread on bread, milk in opaque containers). Finally, the criterion validity may vary greatly depending on whether children consume school meals (of known portions and nutrient composition) versus home-packed lunches, or whether children take photos themselves (e.g. using cameras from mobile phones) as opposed to trained research staff.

A limited number of studies suggest that DP can be a valid method to assess the content of school meals (Table 3). In Denmark, the criterion validity of DP to measure the content of students' packed lunches from home was evaluated against weighed food records using correlation coefficients, two-sample t-tests for differences in means, and Bland-Altman plots (211). Correlation coefficients were strong and positive (ranging from 0.89 to 0.97) and no statistically significant differences were found in mean amounts for different lunch meal components estimated using the DP and the reference method. Bland–Altman analyses suggested a tendency to slightly under-estimate fruit (mean bias -4.27 g; Limits of Agreement (LOA): -29.4 to +20.8 g) and vegetables (mean bias -6.19 g; LOA -34.5 to + 22.2 g). When measuring meal quality using the Meal IQ (a composite diet quality index for the lunch meal with scores ranging from 0 to 28, and 28 being a perfect score), the Bland-Altman plots suggested no evidence of bias (0.07; LOA -2.26 to 2.40). In another study conducted in the U.S., the accuracy of the DP method was tested using weighed food records (212). Criterion validity was measured using correlation coefficients, two-sample t-tests for differences in group means, and Bland-Altman plots. All 11 meal items had a correlation coefficient above 0.7 (range 0.76-0.98) except for leafy greens (r=0.59) and lasagna (r=0.62). The group mean for fruit and vegetable intake was within 1 gram of the reference method and there were no statistical differences in group means for other meal components and no evidence of bias in Bland-Altman analyses. Both of these studies suggest the potential of the DP method to provide a valid method for estimating dietary intakes (in terms of the types of food consumed and also the amounts consumed) in the context of home-packed lunches (211) as well as school meals (212).

The School Food Checklist (n=2 studies). The SFC was designed to facilitate data collection for meal observations conducted in Australian elementary schools (Table 2) (190). The SFC is a one-page form listing 29 food and beverage items commonly found in Australian students' lunches (e.g., bread, spreads, cheese, packaged snacks, yogurt, milk, water, soda). Trained observers monitor children at meal time, typically one observer per 4-5 students. Portion sizes are estimated using predefined standard portion sizes (e.g. 1 tbsp of peanut butter, 1 slice of bread). The mean difference in estimated energy intake between the weighed food record and the

SFC was 15 kJ (95% CI, -107 kJ to 138 kJ). However, the limits of agreement (±2 standard deviations) were large (± 1270 kJ). The SFC overestimated the energy from breads and fruit drinks and under-estimated energy from fat spreads, crackers, granola bars and fruit. Findings suggested the SFC with meal observations by trained raters demonstrated moderate inter-rater reliability, with a mean Kappa coefficient of 0.51 (190). In a more recent study comparing the intra- and inter- rater reliability of the SFC when used with in-person meal observation and the DP method, ICCs for intra-rater reliability ranged from 0.32 to 0.95 for different meal components (213). ICCs for inter-rater reliability were high (ICC>0.7) apart from left-overs (ICC=0.34). There are many limitations to this instrument, the most important one being that it does not 'stand-alone' and still requires either DP or in-person meal observers to measure intake. Moreover, the SFC has a finite food list and may miss other foods not listed in the SFC.

Frequency of instrument use and dietary outcomes assessed in school contexts

Table A-4 lists the frequency of dietary assessment instruments used in studies examining dietary outcomes in the school context. Detailed information from each study is provided in the supplemental tables[11].

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[11] Supplemental Tables 1–7 are available from the "Online Supporting Material" link in the online posting of the article and from the same link in the online table of content at http://advances.nutrition.org.

Table A-4 Frequency of dietary instruments used, and types of dietary outcomes used to assess dietary intakes in the school context (n = 47 studies)

	Meal recalls	**Estimated FRs**	**FFQs**	**Weighed FRs**	**MOs**	**DP**	**SFC**
All studies (n = 47)*	10	7	5	12	8	5	2
Studies using specific analytical methods to measure in-school dietary intakes							
Multiple dietary components*, n=44 studies	8	8	4	12	8	4	2
Dietary components†, n (range)	17 (1-58)	28 (19-64)	11 (7-19)	17 (1-34)	13 (1-27)	8 (1-26)	13 (13)
Macronutrients, amounts and/or densities, n=22 studies	2	7	0	9	3	1	0
Energy density, n= 3 studies	1	1	0	1	0	0	0
Micronutrients, amounts and/or densities, n=19 studies	1	6	0	8	3	1	0
Fruit and/or vegetable intake exclusively, n=5 studies	1	0	0	2	1	1	0
Food groups‡, n=32 studies	5	6	3	8	5	3	2
Composite diet quality index, n=3 studies	1	0	1	0	0	1	0

Digital Photography, DP. Food Frequency Questionnaires, FFQs. Food Records, FRs. Meal observations, MOs. School Food Checklist, SFC. *Some studies used more than one instrument, so the row total does not match the number of studies reviewed. Two studies used 2 instruments to assess overall diet quality in the school context. † Values are mean (range) number of dietary components among studies. ‡ These studies included a wide range of food group outcomes. Outcomes were expressed as the proportion of children consuming specific types of food groups and/or amount in servings of specific food groups. Some studies also reported on either frequency of intake of absolute intake of food groups considered ‘minimally nutritious’ such as sugar-sweetened beverages, low-nutrient energy dense foods, ‘fast foods’, desserts/pastries/confections, minimally nutritious packaged snacks.

Overall, observational instruments (n=27/47 studies) were slightly more common than self-report instruments (n=22/47 studies), with 2 studies using more than one method. The most common instruments were weighed food records (n=12 studies) (39,58,220,221,61,127–130,217–219), followed by school meal recalls (n=10 studies) (16,29,32,40,56,57,222–224), in-person meal observations (n=8 studies) (17,60,138,225–229), estimated food records (n=7 studies) (37,38,97,131,156,230,231), FFQs (n= 5 studies) (30,31,94,232,233), DP methods (n=5 studies) (59,93,98,99,234), and the SFC (n=2 studies) (59,228).

Ninety-four percent of studies (n=44/47) used multiple, single dietary components to describe in-school diet quality. The number of components varied greatly, ranging from a single food group or nutrient to 64 dietary components (mean=18, SD=14). The mean number of dietary components was higher for instruments eliciting more detailed information about types of foods and amounts consumed. For example, the mean number of dietary components was 28 for estimated food records. In contrast, the mean number of dietary components was 11 for FFQs and included only food-based outcomes. There was no clear pattern between the type of dietary assessment instrument and type of diet quality indicator used. However, studies using FFQs and the SFC reported only food-based (and not nutrient-based) outcomes. Five studies solely measured fruit and vegetables intake (99,218,221,224,225).

Only 3/47 studies reviewed developed or applied a composite measure to evaluate the overall quality of the lunch meal in the school context (57,93,94). A composite diet quality index (The Meal Index of dietary Quality or 'Meal IQ') was developed, validated and applied to measure the quality of foods in home-packed lunches for Danish children 7-13 years (93). Seven dietary components (fat, saturated fat, snacks, whole grains, fish, fruit, and vegetables intake) were used to provide a composite score (ranging from 0 to 28 points) to reflect adequacy, balance and moderation. This composite measure is based on the Danish dietary guidelines for school-age children and was validated by correlating composite index scores with energy and nutrient densities. Meal IQ scores were associated with lower energy density ($r=-0.61$), lower intakes of added sugars ($r= -0.22$) and higher intakes of fiber ($r= 0.54$) and vitamins C, E, K, B6, and folic acid (*r* ranging from 0.32-0.47) ($p<0.001$). However, Meal IQ scores were not associated with vitamin A, vitamin D, calcium and iron ($r \leq 0.2$ and $p\geq 0.05$) – all key nutrients of public health importance for children (117).

In Finland, researchers used a simpler measure of meal-based diet quality based on the 'balance' dimension of diet quality (94). Usual dietary patterns were assessed using a web-based questionnaire which included a 37-item FFQ using the school week as reference period. Children were classified as 'balanced' or 'unbalanced' eaters based on whether they reported consuming three meal components (main dish, salad and bread) from school lunches on most school days in a week. The school lunch was 'balanced' in 47% of the children in their sample. Daily, 'balanced' eaters were more likely to consume fruit and dairy products and less likely to consume salty packaged foods and sugar-sweetened beverages for snacks (p-value < 0.05). On a weekly basis, 'balanced' eaters consumed foods such as pizzas, meat pies, and sugar-sweetened beverages less frequently ($p<0.05$).

In the U.S., the 2005 Healthy Eating Index (HEI-2005) is a validated composite diet quality index which reflects dimensions of adequacy, balance and moderation (115). The U.S. HEI-2005 was used to evaluate diet quality during school hours and to examine temporal variations in diet quality between school days and weekend days (57). Using a single 24-hour dietary recall data from a large, nationally-representative dietary survey, the scoring standards of the HEI-2005 (which expressed ideal amounts per 1,000 kcal consumed) were applied to derive HEI total scores and sub-scores during and outside of school hours on school days and on weekend days. Although the U.S. HEI was originally developed to assess diet quality based on a whole day, it can potentially be applied to a portion of the school day because its scoring standards are expressed on an energy density basis.

A.5 Discussion

Lessons learned about school-based dietary instruments

Assessing dietary intakes in school has a unique set of challenges and opportunities and is methodologically difficult, from the perspectives of both data collection and data analysis. A study's goals and specific dietary outcomes of interest should be taken into consideration when choosing the appropriate dietary instrument, as each tool offers trade-offs between the ability of the instrument to provide details on quantity of foods and nutrients consumed, costs and ease of administration (largely affected by whether the tool is self-administered or not), and measurement error – which in turn, affects the tool's validity and reliability. School lunch recalls, food diaries and meal observations can each offer rich details about the types of foods and amounts consumed. The main limitation of the school meal recall method is that it provides detailed information on short-term consumption patterns (e.g., intake at a single school meal) and does not reflect usual consumption patterns (235). However, in many instances researchers are interested in estimating the distribution of usual intakes for the group. This can be accomplished by incorporating a second recall within a subset of the population to remove the intra-individual variability (random error or day-to-day variability) in dietary intakes (235).

Although subject to misreporting, validation studies conducted on the school meal recall method suggest children can reasonably report energy intake at the group level (i.e., within the range of 85 – 115%). However, these studies also indicate that children (similarly to adults) tend to under-report energy obtained from lunches eaten at school. Evidence also suggests that children can vary in terms of their ability to report foods consumed in one meal (as shown by variable omission and intrusion rates) which reflects the influence of the interviewing conditions on the validity of this method. However, for matched foods, children can accurately report amounts consumed. Because school meal recalls are designed to assess not only types of foods consumed but also amounts, the dietary data generated from meal recalls is more ‘flexible’ in terms of being operationalized into various outcome measures for diet quality. For example, dietary data from meal recalls can be compared against specific meal-based standards (181,236). Dietary data from school meal recalls has also been used to examine overall diet quality using an *a priori* diet quality index (the U.S. HEI-2005) between National School Lunch Program (NSLP) and non-NSLP participants (57).

Until recently, food records, FFQs and diet screeners were more cost-effective than dietary recalls since the former were self-administered. However, web-based dietary recalls now exist for use in the school environments (202,204,237). FFQs have the added advantage of being designed to measure usual dietary exposure. However, dietary data from FFQs are subject to bias or systematic error (238). Unlike random error driven by day-to-day variability in dietary intakes, bias or systematic error is difficult to correct or account for (239). Random error can, however, be reduced by repeated administrations of the school meal recall method or multiple days of estimated food records. The validity of using an FFQ for assessing usual dietary intake patterns at school was only explored in one study (209). Given that FFQs are not well suited to measure food and nutrient quantities consumed and the limited methodological evidence testing FFQ validity in the school context, dietary data from FFQs are ill suited to be compared against specific nutrient and food-based intake standards such as those established by the NSLP. More research on the validity of FFQs for assessing in-school dietary intakes (preferably using observational instruments as reference instruments) is needed for future application of FFQ-based approaches to examine population-level dietary intake in the school context.

While food records present some benefits similar to school meal recalls in terms of details about the types and amounts of foods consumed whilst being low cost instruments, evidence regarding the validity of their use for school contexts remains limited. In this review, only one study assessed the validity of this method (208). There may be considerable variation in the validity of using food records to assess dietary intakes in the school context depending upon the study conditions and characteristics of the population. Overall, the methodological evidence on food records and FFQs or diet screeners is limited. More studies in larger, diverse samples are recommended before recommending these tools for capturing in-school dietary intake.

Across all studies reviewed, observational instruments such as weighed food records and meal observations were regarded as gold standards. Observational instruments are being more objective since they are not subject to reporting error. The ease of applying observational instruments may vary depending upon specific conditions within the school context. For example, lunch source (where most children obtain their lunch food from) appears to play a decisive role when deciding on a dietary assessment instrument. It is not surprising that weighed food records were commonly used in U.S. studies, where a substantial proportion of children participate in the NSLP (184). The plate waste method, which is a form of weighed food record in which amounts of unconsumed food are subtracted from the amounts served, can be an effective, non-obtrusive way of estimating consumption (240,241). This works well in school contexts where most children obtain their meals from school vending operations where standardised menus are in place. However, in school contexts such as Canada (which does not have national school lunch program and where students commonly bring a home-packed lunch) (29), the plate waste method is not well suited since nutritional information on meals offered and served is not easy to obtain.

Lessons learned on dietary outcome measures to evaluate diet quality at school

This review found that measures to evaluate in-school diet quality are heterogeneous. Although dietary pattern analyses (multiple dietary components operationalized as a single exposure) have gained popularity to estimate whole day diet quality (242–244), studies most commonly used multiple single dietary components to capture in-school diet quality. Developing a valid analytical measure of overall diet quality is complex and no consensus exists on the ‘best’ diet quality indicator. Moreover, most of diet quality indicators are based on national dietary guidelines which change over time and differ across countries. Using multiple, single components to assess overall diet quality is also easier when there are food-based standards available to provide a nutritional ‘benchmark’ for evaluation.

In the U.S., federal agencies such as the U.S. Department of Agriculture and the Institute of Medicine have established nutritional standards for school meals offered through the NSLP. The 2012 US national school meal guidelines stipulate that school lunches must include a minimum of ½ cup of whole fruit, ¾ cup of vegetables, 1 oz of grain without added sugars, 1 oz of meat/meat alternate and 1 cup fluid milk (117). In the U.S., the HEI-2005 (115) (and its more recent update the HEI-2010 (245)) can both be used to assess overall diet quality for school meals since their components are scaled for energy intake. In Canada, there are no national food-based dietary guidelines for school meals and considerable variability across provinces in school-meal guidelines and policies (102,246), which make assessing school meal diet quality as a whole difficult. In Canada, several adaptations of the HEI have been developed (42,95,96). However, none are scalable at the meal level since the scoring system for each index component is based on dietary intakes for the entire day. A composite diet quality index to assess the quality of meals and snacks consumed in the school context could provide a simple and easy to interpret measure of diet quality.

A.6 Summary and directions for future research

This review suggests that future school-based studies would be best served by applying either school meal recalls (if using a self-report measure) or observational tools when collecting dietary intakes in school settings. If school meal recalls are used, the quality of measures can be improved by implementing recalls on the same day to optimize the accuracy of dietary intakes. Within self-report tools, school meal recalls demonstrated the highest and most consistent criterion validity and have been more extensively tested for validity. Among observational tools reviewed, meal observations by trained raters appear to offer the best criterion validity and good inter-rater reliability. Digital photography offers promising opportunities, but this method is also limited in that it can be difficult to capture hidden foods. Technological advances to improve the validity and reduce costs of conducting school meal recalls, in-person meal observations and digital photography methods are warranted. Finally, researchers should ensure the tool chosen for their study fits their stated goals and is appropriate for their specific study context. A tool deemed to be 'valid' in one study may be inappropriate in another context where the sample, school context or research questions substantially differ. Understanding the advantages, limitations, type of measurement error and dietary outcomes associated with dietary assessment methods is vital for improving the quality of the evidence used to inform and evaluate the impact of school-based nutrition policies and programs.

Assessing diet quality is complex and there is no consensus on a best approach. Indeed, studies reviewed included a wide range of different dietary components to capture overall diet quality. The HEI-2010 has potential for assessing overall diet quality in the U.S. school context. However, no single composite measure of diet quality has been developed and validated specifically for the school context. Such an index could be used to monitor secular trends and to measure the impacts of school-based nutrition interventions aimed at improving the quality of meals and snacks consumed in schools.

Appendix B Dietary intakes from lunch only by Canadian school-aged children estimated from survey-weighted multivariable linear models

Table A-5 Dietary intakes from lunch only by Canadian children by lunch-time food source

	Home	School	Off-campus
Energy, kcal	592 (10)[a]	629 (44)[ab]	695 (25)[b]
Carbohydrate, g	81.4 (1.1)[a]	73.9 (2.5)[b]	79.7 (2.7)[ab]
Fibre, g	4.2 (0.1) [a]	3.5 (0.1)[b]	3.5 (0.1)[b]
Total sugar, g	34.9 (0.7)	32.1 (2.3)	33.4 (2.7)
Total fat, g	22.1 (0.4)[a]	27.5 (1.7)[b]	24.4 (0.9)[ab]
Saturated fat	7.4 (0.2)	8.3 (0.4)	8.2 (0.4)
MUFAs, g	8.7 (0.2)[a]	11.8 (0.9)[b]	10.3 (0.4)[b]
PUFAs, g	3.9 (0.1)	4.8 (0.4)	4.0 (0.3)
Linoleic FAs, g	3.28 (0.12)	3.48 (0.25)	3.25 (0.23)
Linolenic FAs, g	0.52 (0.02)	0.80 (0.14)	0.58 (0.05)
Cholesterol, mg	56 (2)	65 (5)	55 (3)
Protein, g	21.5 (0.4)	24.5 (1.4)	22.4 (1.0)
Vitamin A, RAE	137 (4)	141 (11)	111 (10)
Vitamin D, µg	0.99 (0.04)[a]	1.32 (0.13)[a]	0.69 (0.07)[b]
Vitamin C, mg	48.0 (1.6)[a]	43.1 (6.8)[ab]	30.2 (2.5)[b]
Thiamin, mg	0.51 (0.01)[a]	0.47 (0.04)[ab]	0.42 (0.02)[b]
Riboflavin, mg	0.54 (0.01)	0.53 (0.03)	0.49 (0.03)
Niacin, mg	10.10 (0.19)	10.53 (0.53)	10.59 (0.45)
B6, mg	0.39 (0.01)	0.44 (0.05)	0.37 (0.02)
B12, mcg	0.92 (0.03)	1.02 (0.10)	0.78 (0.08)
DFE	135.2 (2.7)	124.1 (10.6)	141.4 (7.5)
Calcium, mg	248.7 (6.8)	277.9 (20.5)	253.9 (13.7)
Phosphorus, mg	340.0 (6.1)	366.7 (15.9)	334.5 (13.0)
Magnesium, mg	69.8 (1.0)[a]	65.5 (2.9)[a]	56.0 (1.6)[b]
Iron, mg	3.9 (0.1)[a]	3.5 (0.2)[ab]	3.5 (0.1)[b]
Zinc, mg	2.8 (0.1)	3.0 (0.2)	2.7 (0.1)
Sodium, mg	1063 (23)	978 (49)	1000 (47)
Potassium, mg	666 (11)[a]	778 (40)[b]	645 (20)[a]
Grain products, svgs.	2.16 (0.05)[a]	1.54 (0.15)[b]	1.81 (0.12)[b]
Vegetables and fruit, svgs.	1.18 (0.04)	1.25 (0.18)	0.98 (0.08)
Milk and alternatives, svgs.	0.48 (0.02)	0.62 (0.07)	0.51 (0.04)
Meat and alternatives, svgs.	0.62 (0.02)	0.71 (0.11)	0.54 (0.05)
‘Other’ foods, kcal	121 (4)[a]	149 (15)[ab]	177 (14)[b]

Values are survey-weighed energy-adjusted average dietary intakes from lunch (SEs). Significant differences in the relative dietary contributions from nutrient and food groups intakes were tested using multivariate linear models with lunch type (main independent variable) while controlling for sex, age group and energy intake or the relative differences in energy contributions to TDIs. Means sharing a group letter are not significantly different at the 5% level.

Comparisons across means are Bonferroni-adjusted. Children who skipped lunch or did not report any energy for the entire school hour period were excluded from these analyses, yielding an analytical sample of 4,589 children.

Appendix C Provincial school and nutrition guidelines and policies in Canada

Province	Name of school nutrition guideline and (if present) policy	Date of implementation	Mandatory policy banning the sale of specific foods and beverages
Newfoundland and Labrador	Newfoundland and Labrador School Food Guidelines	2006	No
Prince Edward Island	Prince Edward Island School Nutrition Policy	2005	Yes
Nova Scotia	Food and Nutrition Policy for Nova Scotia Public Schools	2007	Yes
New Brunswick	New Brunswick Policy 711: Healthier Eating and Nutrition in School	2005	Yes
Quebec	Going the Healthy Route at School	2008	Yes
Ontario	Ontario School Food and Beverage Policy; PPM 150: School Food and Beverage Policy	2010	Yes
Manitoba	Moving Forward with School Nutrition Guidelines	2014	No
Saskatchewan	Nourishing Minds: Eat Well, Learn Well, Live Well	2012	No
Alberta	Alberta Nutrition Guidelines for Children and Youth	2012	No
British Columbia	Guidelines for Food and Beverage Sales in BC Schools	2008	Yes

Source: Author's compilation.