Comparing common summary measures of the quality of diets in Canadian children

by

Seyedehatefeh Panahimoghadam

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Abstract

Background: Despite some improvements, many Canadian children still fail to meet dietary guidelines, lacking sufficient intake of fruit and vegetables while consuming high-fat, high-sugar foods, and excessive sodium. Establishing healthy dietary habits in childhood reduces the risk of obesity and chronic diseases in adulthood, improves academic performance and overall quality of life, and substantially reduces healthcare costs. Employing an optimal index enables accurate diet quality assessment and guides future interventions to improve children's overall diet and health status. Previous studies were mainly conducted outside of Canada, evaluating indices different from those commonly employed within the country. They mostly focused on evaluating diet quality indices among adults and applied methods that had several limitations.

Objective: This thesis aimed to compare the properties of common summary measures of diet quality in Canada, including Healthy Eating Index-Canada 2015 (HEI-C 2015), Diet Quality Index-International (DQI-I), and Healthy Eating Food Index 2019 (HEFI-2019) among school-age Canadian children. The specific objectives of this thesis were examining and comparing: 1) score variations of HEI-C 2015, DQI-I, and HEFI-2019; 2) the level of agreement across the diet quality indices; 3) the ability of the diet quality indices to differentiate between groups with known diet quality differences; and 4) the capacity of diet quality indices to assess diet quality independent of diet quantity based on the diet quality of Canadian children.

Methods: To achieve these objectives, dietary information obtained from 1,699 grade 4-6 students through validated web-based 24-hour diet recall surveys conducted in 2016, 2018, and 2020/2021 as part of the APPLE Schools program was used. The agreement between the indices was evaluated through weighted Cohen's Kappa. Univariable and multivariable linear regression models were applied to estimate the potential difference in conclusions resulting from each index's application.

Results: The study presented in this thesis revealed wider ranges (and coefficients of variation [CVs]) for HEI-C 2015 (11.7-95.3 [25.7]) and HEFI-2019 scores (8.6-90.1 [30.1]) compared to DQI-I scores (19.9-83.9 [18.1]). Overall, only fair agreement was revealed between HEI-C 2015 and HEFI-2019 (Weighted Cohen's Kappa coefficient [Kw]=0.38; 95% confidence Interval [CI]: 0.35, 0.42), and between HEFI-2019 and DQI-I (Kw=0.29; 95%CI: 0.25, 0.33), while moderate agreement was found between HEI-C 2015 and DQI-I (Kw=0.55; 95%CI: 0.52, 0.59). Regardless of the index used, girls demonstrated better diet quality than boys, with DQI-I being the most effective index in differentiating between sexes' diet quality. Grade levels could not discriminate between students' diets using any of the three indices. All three indices indicated lower diet quality among students in materially deprived neighbourhoods, with HEI-C 2015 showing the strongest association. Conversely, higher DQI-I scores were associated with more socially deprived areas. Students in smaller geographic regions exhibited slightly better diet quality, with HEI-C 2015 indicating the most robust association. When comparing the abilities of indices to identify diet quality independent of diet quantity, higher energy consumption was associated with higher DQI-I and lower HEFI-2019 scores.

Conclusions: The results of this thesis underscore the importance of selecting the most optimal diet quality index for Canadian school-age children to ensure a precise interpretation of their diet quality. Researchers, practitioners, and policymakers must agree on a suitable diet quality index for Canadian children due to its importance in dietary research and interventions, and dietary guidelines development. HEFI-2019 is the most recent Canadian diet quality index, aligning with the latest Canadian Food Guide (CFG-2019). The index displayed notable strengths in this study,

such as large score variability and the ability to differentiate between the diet quality of children residing in areas with different material deprivation levels. However, its scoring standards need to be more age-specific, and its dependence on energy intake should be addressed in future research endeavours.

Preface

This thesis is an original work by Seyedehatefeh Panahimoghadam. The research project, of which this thesis is a part, received research ethics approval from the Health Research Ethics Board of the University of Alberta (Pro00061528). The school boards that participated in the study approved all study procedures.

Chapter 3 of this thesis is currently under review in a peer-reviewed journal as: Panahimoghadam S, Tran T, Dabravolskaj J, Veugelers PJ., Maximova K. Comparing common summary measures of the quality of diets of Canadian children: A call for consensus. Dr. Veugelers and Dr. Maximova conceived the idea and supervised Panahimoghadam developing an analysis plan, executing all analyses, interpreting the findings, and drafting the manuscript. Dr. Veugelers, Dr. Maximova, Dabravolskaj J, and Tran T reviewed draft versions and provided valuable feedback, which was incorporated into the final version.

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List of Abbreviations

AHA	American Heart Association
AHEI	Alternative Healthy Eating Index
AI	Adequate Intake
BMI	Body Mass Index
CCHS	Canadian Community Health Survey
CFG	Canada's Food Guide
CI	Confidence Interval
CV	Coefficient of Variation
CVD	Cardiovascular Disease
DASH	Dietary Approaches to Stop Hypertension
DiPaC	Dietary Pattern Calculator
DQI-I	Diet Quality Index-International
DRI	Dietary Reference Intake
FAO	Food and Agriculture Organization
FFQ	Food Frequency Questionnaire
FVS	Food Variety Score
HEFI-2019	Healthy Eating Food Index 2019
HEI	Healthy Eating Index
HEIC	Canadian Healthy Eating Index
HEI-C	Healthy Eating Index-C
HEI-C 2010/2015	Healthy Eating Index-Canada 2010/2015
MetS	Metabolic Syndrome
NFD	Nutritional Functional Diversity Indicator
NHANES	National Health and Nutrition Examination Survey
NRF	Nutrient Rich Foods
RA	Reference Amount
RC-DQI	Revised Children's Diet Quality Index
RDA	Recommended Dietary Allowance
SD	Standard Deviation
SES	Socioeconomic Status
T2D	Type 2 Diabetes
USDA	United States Department of Agriculture
WHO	World Health Organization

Chapter 1: Introduction

1.1. Introduction to Diet Quality

1.1.1. Diet Quality Definition

Diet quality is determined by the diversity across key food groups and the extent of adherence to dietary guidelines,[1] reflecting realistic dietary intakes where the combined interaction of foods and nutrients is considered rather than focusing solely on individual nutrients or food groups.[2] High-quality diets depict this approach by providing optimal intake of a group of macro and micronutrients to meet energy and physiological needs, reducing the risk of diet-related non-communicable diseases.[1] Various factors, such as cultural influences, socioeconomic status (SES), individual and familial food preferences, and dietary guidelines tailored to age, gender, and cultural context, influence diet quality.[3]

1.1.2. School-Age Children's Diet Quality Worldwide and in Canada

Compared to children between the ages of 4 and 8, Canadian children between the ages of 9 and 13 have lower overall diet quality, drinking almost twice as many high-calorie beverages and consuming more sugary, and fatty meals consisting of trans and saturated fats.[4, 5] Likewise, they exhibit a lower diet quality compared to older children and adults.[6] A systematic review examining dietary data from 185 countries from 1990 to 2018 found no distinctions between children and adults in alternative healthy eating indices (AHEI) scores. However, upon the study's closer examination, children tended to score lower in fruit, non-starchy vegetables, and sugar-sweetened beverages while scoring higher in polyunsaturated fatty acids and sodium compared to adults.[2]

A study in the US revealed that the proportion of children with intermediate-quality diets, defined as 40% to 79.9% adherence to the American Heart Association (AHA) dietary targets, doubled during the 20th century. Nevertheless, based on the study's results, fewer than half of children in the US were identified as having intermediate-quality diets. Optimal diet quality, characterized by a minimum of 80% adherence to the AHA dietary targets, was still scarce, with less than 1% meeting the required dietary standards.[7] Similarly, despite some improvements noted in the dietary habits of Canadian children, particularly regarding reduced consumption of sugar-sweetened beverages, a significant proportion still fail to meet dietary guidelines, with about two-thirds not achieving the recommended daily intake of fruit and vegetables.[8, 9] Moreover, children in Canada aged 4 to 18 typically derive about one-third of their daily calorie intake from "other foods," characterized by high-fat and sugary meals. Excessive consumption of high-sodium foods is another issue among Canadian children, as 72% of 4-13-year-olds consume more sodium than recommended.[4, 10]

1.1.3. Diet Quality and Health-Related Outcomes

Poor diet leads to several health issues, with malnutrition at the top of the list. According to the World Health Organization (WHO), malnutrition encompasses deficiencies, excesses, or imbalances in energy and/or nutrient intake, mainly resulting in impaired growth, deficiencies or excesses of vitamins and minerals.[11] Poor diet quality is also known to increase children's vulnerability to childhood overweight and obesity, along with weight-related health issues, consequently elevating the risk of obesity and its associated health consequences in adulthood.[12, 13] Obesity rates among children and adolescents in Canada have nearly tripled in the past three decades and are increasing at an accelerating pace.[14] Based on Statistics Canada reports, in 2019, 17.4% of Canadian children aged 5 - 17 years were overweight, and 10.1% were obese.[15] This is higher than the equivalent rates in 2004, with 18% of children and adolescents in Canada aged 2 to 17 years were overweight, and 8% were Obese.[16] From an economic standpoint, the annual healthcare and disability costs attributed to obesity have been estimated at CAD$7.881 billion and CAD$3.686 billion, respectively, in Canada.[17]

On the other hand, children who follow a healthier diet tend to have higher health-related quality of life (HRQoL).[18] To be more specific, children with higher consumption of fruit and vegetables indicate higher levels of HRQoL, including social and physical functioning and psychological health, compared to those who consumed fewer fruit and vegetables. By contrast, higher consumption of high-fat, high-sugar, and high-salt food is associated with poor HRQoL.[18] It is also evident that children with higher diet variety are less likely to be diagnosed with internalizing disorders diagnoses, which include typical symptoms of depression and anxiety.[19] Additionally, several studies show that adhering to dietary recommendations, including diverse food groups and limited sugar intake, improves academic performance in students.[20, 21, 22] Diets of better quality are also linked to healthier body weights and a lower incidence of metabolic syndrome (MetS) in childhood and also associated to improved blood pressure, type 2 diabetes (T2D), and premenopausal breast cancer, as well as enhanced intelligence quotient in children's future health outcomes.[1, 23]

Based on a Canadian study using the 2015 Canadian Community Health Survey (CCHS)-Nutrition, it was estimated that not meeting food recommendations for five healthful (whole grains, nuts and seeds, fruit, vegetables, and milk) and three harmful foods (red meat, sugar-sweetened beverages, and processed meat) contributed to a total economic burden of $15.8 billion, with direct healthcare costs (hospital, physician, drug) amounting to $5.9 billion and indirect costs (those associated with mortality, long-term disability, and short-term disability) constituting $9.9 billion of the burden in 2018.[24]

Having said that, however, a significant portion of disease burden on individuals and public health that is linked to poor diet can be prevented or postponed.[25] A study conducted in the US in 2021 using dietary data from the National Health and Nutrition Examination Survey (NHANES) 2011–2012 predicted that improvements in diet quality, beginning in 2019 and continuing over the following three decades, could lead to a noteworthy decrease in diabetes, heart disease, and stroke prevalence. These improvements were estimated to result in substantial healthcare cost savings of $59.6 billion, focusing solely on health-related changes within the US population over 30 years.[26]

Hence, addressing Canadians' poor-quality diets is crucial for maximizing positive health impacts and minimizing healthcare costs. Developing a healthy diet in childhood is even more critical for Canada's public health as the negative effects of poor diet often persist into adulthood, impacting long-term health outcomes.[27, 28] Nevertheless, establishing the defining characteristics of a healthy diet through an appropriate index is the preliminary step before addressing contributing factors to the population's diet quality, mainly because results from such an index can guide future research and dietary interventions.

1.1.4. Factors Associated to Diet Quality

Globally, women tend to have a healthier diet quality compared to men, particularly in high-income countries, with higher consumption of specific dietary components such as fruit, non-starchy vegetables, and whole grains.[2, 29] Similarly, Canadian women are more inclined to report consuming fruit and vegetables five or more times daily and generally exhibit a higher overall diet quality compared to men.[5, 6, 30] This also applies to Canadian children. Although some studies find little to no difference in diet quality between girls and boys,[31, 32] Canadian girls generally demonstrate a higher diet quality, consuming, on average, more fruit and vegetables and less sodium compared to boys.[5, 6, 9, 10] Of note, younger children have diets of higher quality than older children, characterized by higher intake of fruit and vegetables, protein foods, and dairy products along with reduced consumption of sugar-sweetened beverages and fries.[32, 33, 34] This is also evident among Canadian children.[5, 6]

Studies show mixed results regarding the influence of SES on children's diets: while some literature does not provide strong evidence for SES-based differences in diet quality,[32, 35] others suggest that children from higher SES backgrounds tend to have healthier diets, consuming less energy-dense foods and more fruit, vegetables, and dairy products compared to those from lower SES households.[36, 37, 38] More specifically, children of educated parents are less likely to follow high-fat and high-sugar diets,[39] showing a higher tendency to dairy and vegetables intake while demonstrating a reduced likelihood to consume sugar-sweetened beverages.[37, 40] Likewise, higher household income is linked to increased fruit and vegetables consumption and improved overall diet quality.[41, 42]

Additionally, the association between SES and children's diet quality varies in different countries. The results of a multinational cross-sectional study of school-age children from 12 countries revealed that in Canada, Australia, Finland, the US, Brazil, Colombia, and China, lower SES was linked to higher scores of unhealthy dietary patterns in children. However, the inverse association was not shown over the five remaining countries (Portugal, United Kingdom, South Africa, India, and Kenya).[36]When it comes to reviewing the effects of area of residence on diet, research indicates that people residing in urban areas generally consume more fruit and whole grains but less sugar-sweetened beverages, red/processed meat and legumes/nuts compared to rural residents.[2] Similarly, studies focusing on children, particularly those in Canada, demonstrate differences in diet quality among urban or rural residents; however, they do not follow a consistent pattern.[35, 42, 43]

1.2. Introduction to Assessment of Diet Quality

1.2.1. Diet Quality Evaluation Approaches

Traditional approaches in nutritional epidemiology have focused on the relationship between individual nutrients or food groups and specific diseases. This approach in dietary assessment faces limitations due to overlooking nutrient interactions, challenges in assessing intercorrelated nutrients, and potential confounding by the whole diet. Additionally, interventions targeting overall diet show greater effectiveness in improving chronic diseases compared to single nutrient approaches due to considering the complexity and multidimensionality of diet.[44]

There are three main approaches to overall diet analysis: hypothesis-based approach, exploratory approach, and hybrid method combining elements of both.[45, 46] The hypothesis-based approach relies on existing knowledge about specific dietary components and their health associations. This technique involves allocating points to predetermined dietary components using a scoring system called dietary index, which assesses adherence to national dietary guidelines or are based on healthy diet such as the Dietary Approaches to Stop Hypertension (DASH)[47] or the Mediterranean diet.[48] By contrast, the exploratory approaches derive dietary patterns without any preconceived hypothesis and involve creating subgroups within a population by grouping individuals together based on similarities in their dietary intakes.[45] Hybrid methods incorporate prior knowledge of variables relevant to the pathophysiological effects of dietary intake. However, they use an exploratory approach for grouping food items, making them hybrid by design.[46]

1.2.2. The Optimal Approach to Evaluate Diet Quality

Both hypothesis-based and exploratory analyses revealed merits and demerits in methodology and results. The hypothesis-based method offers advantages in basing guidelines on scientific evidence, describing dietary characteristics, and showing significant associations with disease outcomes, providing an easy-to-understand metric for assessing diet quality.[49] However, their subjective construction, limited focus on selected aspects of diet, and inability to capture overall diet pose disadvantages. Additionally, their inability to provide specific information on multiple foods can lead to unclear interpretations, especially for individuals with intermediate scores who may have varying nutritional compositions and dietary intakes.[49]

The exploratory dietary assessment method offers advantages in describing population-wide variations in dietary intake and assessing overall diet quality, providing interpretable patterns that can be directly incorporated into statistical models for health outcomes.[49] Moreover, certain major diets derived from these methods demonstrate reproducibility across different populations.[49] However, they suffer from subjectivity in selecting food groups, determining the number of components or factors, and pattern interpretations within these methods[49] that can impact the formation of diets and their associations with various characteristics such as socioeconomic status, anthropometric measurements, and lifestyle factors.[50]

Exploratory methods including factor analysis and principal component analysis pose challenges in interpretation due to each component or factor representing a linear combination of all food groups. This limitation restricts their ability to explain the entire variance, potentially disregarding crucial information.[49] Dietary patterns derived from factor analysis typically account for a small portion of the total variance, particularly when using 24-hour dietary recalls rather than food frequency questionnaires (FFQs).[50] Furthermore, these methods struggle to accurately identify which dietary patterns predict disease risk and may overlook interactions between diet and various lifestyle characteristics simultaneously.[49] Thus, overall, regardless of its subjective nature and inability to capture overall diets, the hypothesis-based approach stands out for its strengths in basing guidelines on scientific evidence and describing overall dietary characteristics.

1.2.3. Diet Quality Indices Worldwide and in Canada

Various diet quality indices have been developed and validated based on epidemiological research and have been used to assess children's diet quality and their adherence to various countries dietary recommendations over the world. These indices work based on different dietary assessment methods: for instance, Brazilian Healthy Eating Index, and Chinese Children Dietary Index rely on 24-hour dietary recall;[51, 52] The Canadian adapted version of the Youth Healthy Eating Index, Australian Child & Adolescent Recommended Food Score, Healthy Nutrition Score for children & Youth in Germany, and Food Index in Greece are based on FFQ;[53, 54, 55, 56] Finnish Children Healthy Eating Index, and Dietary Index for a Child's Eating in New Zealand rely on food records/diaries as diet assessment methods.[57, 58]

The Healthy Eating Index (HEI), initially developed by the United States Department of Agriculture (USDA) in 1995,[59] represents one of the earliest endeavors to measure compliance with national dietary recommendations. The index has undergone successive updates to mirror the evolving versions of the Dietary Guidelines for Americans, with iterations like HEI-2010, HEI-2015, and HEI-2020.[60, 61, 62] In addition to the Brazilian[51] and Chinese Healthy Eating Index,[63] the index was adapted for use in Canada in several years 1995, 2005, 2010, and 2015.[6, 64, 65, 66, 67] Diet Quality Index-International (DQI-I) has been widely employed in several studies both in Canada and globally.[68] Healthy Eating Food Index 2019 (HEFI-2019), developed in 2021, assesses how closely Canadians aged two and above adhere to the latest Canada's food guide (CFG-2019).[69]

1.3. Knowledge Gaps and Objectives of Thesis

Previous research predominantly focused on evaluating the variation in scores, the capacity to differentiate between groups, and the associations with health outcomes of diet quality indices, primarily concentrating on adults, using indices that have not been used or rarely used in Canada.[5, 29, 70, 71, 72, 73, 74, 75, 76] There is a notable gap in evaluating commonly used indices among Canadian school-aged children, a population particularly susceptible to poor diet quality and its long-term health consequences. The methods of the studies also had some aspects that could potentially be revised and improved to obtain more reliable and interpretable results.

Using an optimal and population-tailored index for assessing Canadian school-age children's diet quality can help provide an accurate assessment of their diet quality and targeted interventions to address their specific dietary deficiencies or excesses. This leads to more effective strategies for improving Canadian children's dietary habits and preventing diet-related diseases. Additionally, using such an index facilitates monitoring dietary trends over time and allocating resources for maximum impacts.

Thus, the objective of this thesis is to compare the properties of common summary measures of diet quality, including Healthy Eating Index-Canada 2015 (HEI-C 2015), DQI-I, and HEFI-2019, and determine the potential variations in conclusions regarding the application of each of these indices to the diet quality of Canadian children,

The specific thesis objectives are to:

1) Examine the variation in scores for HEI-C 2015, DQI-I, and HEFI-2019 based on the diet quality of Canadian children.

2) Investigate the level of agreement across HEI-C 2015, DQI-I, and HEFI-2019 based on the diet quality of Canadian children.

3) Compare the ability of the HEI-C 2015, DQI-I, and HEFI-2019 to differentiate between groups with known differences (e.g., sex, grade, material and social deprivation and area of residence) based on the diet quality of Canadian children.

4) Evaluate the capacity of the HEI-C 2015, DQI-I, and HEFI-2019 to assess diet quality independent of diet quantity based on the diet quality of Canadian children.

1.4. Structure of the Thesis

This thesis adheres to a "paper-based" thesis format, comprising four chapters. The first chapter provides an overview of the literature on diet quality, covering its determinants, health outcomes, and assessment approaches, with a specific focus on Canadian children. This chapter underscores the importance of utilizing an appropriate diet quality index tailored to this population, as well as the thesis objectives. The second chapter comprehensively reviews relevant methods and comparable literature, including their approaches and challenges. This second chapter aims to reveal the advantages, disadvantages, and knowledge gaps through previous studies. The third chapter incorporates the main study of this thesis, titled "Comparing common summary measures of the quality of diets of Canadian children: A call for consensus." Lastly, the fourth chapter presents a summary of the research findings, their interpretations, the strengths and limitations of thesis, public health implications, recommendations for future studies and conclusions.

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Chapter 2

2.1. Measurement Methods

2.1.1. Measuring Dietary Intake

Over the past two decades, FFQs[1, 2], 24-hour diet recalls,[3, 4] and food records/diaries[5, 6] have been widely used as the main diet quality assessment tools for assessing diet quality among children all over the world. The dietary intake assessment method can affect the diet quality results. A cross-sectional study assessed 204 older adults in Worcester County, Massachusetts, USA using both FFQ and 24-hour diet recall. The results revealed that diet quality scores measured by AHEI were significantly higher when they used FFQ compared with 24-hour diet recall and only 9% of men and 7% of women were classified as eating unhealthy based on the FFQ, versus 47% of men and 38% of women based on 24- hour diet recall.[7]

The main aim of FFQ is to capture usual food and beverages intake, typically measuring dietary intakes from the past month to the past year, and they are often self-administered.[8] However, these estimations have been shown to have the potential to introduce notable measurement bias, particularly concerning energy and nutrient intakes, which can be tracked by established recovery biomarkers.[9, 10] Therefore, relying on FFQ data to estimate mean intake among populations is not recommended.[8] Unlike 24-hour diet recall, which is an open-ended questionnaire, FFQ has a finite list of foods and beverages, making it susceptible to systematic errors.[11] The other source of bias for FFQ is that it is complicated for children to retrieve a long period of time diet in the past due to their limited concepts of time and memory.[12, 13] Children may lack comprehension of composite foods included in such questionnaires[14] and the length of FFQ leads them to get bored and fatigued, potentially affecting their reports.[15] Moreover, querying portion sizes not suited to children may lead to systematic overestimation of intake.[15]

24-hour dietary recall captures a more detailed accounting of all food and beverages consumed in the past 24 hours. For estimating average usual intake, a single recall within a group suffices, but to estimate the distribution of usual intakes (i.e., prevalence below/above a threshold), repeated recalls from at least a subsample are necessary to account for day-to-day intake variation.[8] Traditionally, 24-hour diet recalls were administered by interviewers. Employing multiple-pass methods like the Automated Multiple-Pass Method (AMPM) enhances the measure accuracy, offers automated coding, and reduces manual work.[16] These methods involve steps such as a quick list, probing for possible forgotten foods, organizing foods by eating time and occasion, probing preparation details and final prob for any consumed food or beverages that have already been missed to recall.[17] Portion sizes are usually reported using aids like measuring cups or pictures.[17] The tool is prone to social desirability biases, and if it is interviewer-administered, it is more time and cost-intensive as well as being susceptible to interviewer bias. While recalls capture dietary intake with less bias than FFQ, they face challenges such as short-term memory errors and portion size estimation inaccuracies.[8]

Food records/diaries, like 24-hour diet recalls, aim to provide a detailed account of all foods, beverages, and possibly supplements, typically for a period of one, three, or seven days. Unlike recall and FFQ, which assess dietary intake retrospectively, food records involve respondents tracking their consumption in real time. Similarly to 24-hour diet recall, records offer insights into meal patterns, snacking behaviour, and contextual factors surrounding consumption. However, data from records can be influenced by reactivity, where individuals may alter their eating behaviours due to monitoring. Like 24-hour diet recall, food records are susceptible to portion size inaccuracies and social desirability biases.[8] Food records can be particularly challenging for children and adolescents, as recording their dietary intakes several times a day over multiple days may irritate and bore them, resulting in compliance issues.[8]

Overall, when selecting a dietary assessment method for children, regardless of the pros and cons of different tools, it's crucial to prioritize a balance between quality and feasibility, considering factors like accuracy, reliability, and validity. Additionally, it's important to consider practical aspects such as participants' characteristics, burden, and cost to minimize error and bias.[18]

2.1.2. Measuring Diet Quality

Canadian studies on children's diet quality during the last two decades have mainly used various adaptations of HEI tailored for Canadian population such as Healthy Eating Index-C (HEI-C),[19] Canadian Healthy Eating Index 2009 (HEIC-2009),[20] Healthy Eating Index-Canada 2010 (HEI-C-2010),[21] HEI-C-2015[22] and School-HEI.[23, 24, 25] Apart from HEI-C,[19] which aligns with the 1993 Canada's Food Guide to Healthy Eating and 1990 Canadian Nutrient Recommendations, all other indices evaluate dietary adherence according to the guidelines provided in the 2007 CFG-2007.[20, 21, 22, 24]

HEI-C-2015 was adapted in 2019[22] to measure the extent to which Canadian adults adhere to age-specific dietary recommendations outlined in CFG-2007 comprised 12 components with an overall score of 0 (worst) to 100 (best) representing an individual's overall diet quality. More than half of score allocated to the adequacy of diet based on evaluating 8 components (0-60 points) related to healthy food consumption: total fruit and vegetables intake, whole fruit, greens and beans, whole grains, dairy intake, total protein foods, seafood & plant proteins and fatty acids. Moderation is calculated based on 4 resting components (0-40 points) related to unhealthy food consumption: refined grains, sodium, added sugars and saturated fats.[22] The widespread utilization and persistent development of the HEI underscore its significance as an established measure for investigating the link between diet quality and chronic health issues across diverse populations. Higher HEI-2015 scores have been observed to be associated with decreased all-cause mortality and a lower risk of chronic diseases such as cardiovascular disease (CVD), type 2 diabetes (T2D), and various types of cancer.[26, 27, 28, 29]

DQI-I, initially developed for international applications, was also widely used in Canadian studies on children's diet quality.[30, 31, 32, 33, 34] School-DQI was developed based on the DQI-I structure to assess children's diet quality during school time.[35] Both HEI-C and DQI-I utilize both food group and nutrient intake criteria in their scoring systems. However, DQI-I assesses a broader range of components related to a high-quality diet, including variety, adequacy, moderation, and overall balance, whereas HEI-C focuses primarily on adequacy and moderation.[20, 36]

DQI-I scores range from 0 to 100, with higher scores indicating a healthier diet. The four components of the index are described as follows: variety (score range: 0-20), which gauges the diversity of food and protein sources; adequacy (score range: 0-40), which evaluates the intake of essential foods and nutrients such as fruit, vegetables, grain, fiber, protein, iron, calcium, and vitamin C; moderation (score range: 0-30), which assesses the consumption of total fat, saturated fat, cholesterol, sodium, and empty calorie foods; and overall balance (score range: 0-10), which considers the proportion of energy derived from macronutrients and the ratio of saturated fatty acids.[36]

Healthy Eating Food Index 2019 (HEFI-2019), a newly developed diet quality index,[37] evaluates adherence to healthy eating recommendations outlined in CFG-2019 among Canadians aged two years and older. However, the index does not evaluate adherence to CFG-2019's recommendations regarding healthy eating habits. This index evaluates diet quality by incorporating consumed beverages besides food intake, distinguishing it from previous indices utilized in Canadian children's dietary assessments.[37] The HEFI-2019 scores range from 0 to 80, with higher scores indicating better diet quality. It evaluates intake based on five foods (score range: 0-40), which assesses the consumption of fruit and vegetables, whole-grain foods, grain foods ratio, protein foods, plant-based protein foods; four nutrients (score range: 0-30), considering fatty acids ratio, saturated fats, free sugars, and sodium intake and beverage intake (score range: 0-10), which measures consumed beverages.[37]

Unlike HEI-C-2015 and DQI-I, HEFI-2019 does not classify components under the known elements of a healthy diet (i.e., variety, adequacy, moderation, and overall balance). Additionally, it replaces daily consumed food servings with reference amounts (RA) per total consumed foods. Similar to DQI-I, but unlike HEI-C-2015, HEFI-2019 does not include milk and dairy products as individual components; rather, they are considered as a protein foods subgroup.[37] A study by Barrasard et al. in 2023 on 4,093 older adults from the 2015 Canadian Community Health Survey (CCHS)-Nutrition surprisingly found that higher HEFI-2019 scores were associated with increased prevalence of inadequate intakes of calcium (2.3%; 95% Confidence Interval [CI]: -3.0, 7.5), which milk and dairy products being its primary sources.[38] Recently, it was observed that higher HEFI-2019 scores were linked to a decreased risk of CVD in middle-aged and older adults.[39]

2.1.3. Measuring Demographic and Socioeconomic Factors

Demographics and SES as described in chapter 1 are pivotal contributing factors to diet quality. Demographic factors like sex and age or school grade, as were assessed in this thesis, are widely included in studies assessing children's diet quality.[25, 40, 41, 42, 43, 44] Some studies also consider race/ethnicity,[25, 40, 45] and immigration status.[46] Since previous studies employed different methods to evaluate SES, it is important to review the methods of these studies to determine the most suitable and applicable method for this thesis. In studies of children, SES has generally been evaluated through individual-based SES criteria,[43, 47] area-based SES measures,[41, 42] or a combination of both approaches.[48]

Various factors are considered in studies assessing individual-based SES. A multinational cross-sectional study involving 6,808 9–11-year-olds across 12 countries identified combined annual household income and self-reported highest level of parental education as primary indicators of SES.[49] Other studies also included variables such as highest parent occupation level,[47] occupation level of each parent separately, [43] household size[50] and household food security status to evaluate SES.[25, 40]

In assessing parental education, studies typically used the highest attained education level of either parent.[43, 47, 51] Household income was determined by monthly net income divided by household size,[47] comparing income to a specific low-income line in a reference year,[43, 51] or considering both the federal poverty level and household size.[40] One study utilized the family affluence scale, which includes questions about household possessions, indirectly assessing household income.[48]

In many population-based studies, similar to this thesis, data on individual-based SES is not available. When such information is requested, participants may refuse to answer or overestimate their SES. Thus, to overcome this issue, researchers commonly substitute individual-based SES with population-based SES.[52] Area-based SES, which was used in this thesis, is commonly assessed using area material and social deprivation indices. The material deprivation index is associated with factors such as the population's unemployment rate, education level, and average household income, and the social deprivation index is linked to the population's marital status, proportion of individuals living alone and rates of single-parent households.[53] Recent studies on Canadian children's diet quality and this thesis utilized the results from school-area deprivation indices[41, 42] based on 2016 Canadian census data, indicating higher deprivation in higher quintiles.[54] Material and social deprivation index 2021 is the most updated version of the index, built based on the 2021 Canadian census.[55] The Canadian Index of Multiple Deprivation was also recently developed using microdata from the 2021 Canadian census of population, covering all regions, provinces, and territories in Canada. The index encompasses four main components: residential instability, ethno-cultural composition, economic dependency, and situational vulnerability.[56] Some studies also considered neighbourhood environment, including factors like access to fresh produce and recreational services, as part of area-based SES assessment.[48, 57]

Additionally, the region of residence is considered a potential confounding factor in studies measuring children's diet quality.[24, 35] Statistics Canada categorizes regions as rural (with <1,000 residents), small population centers (1,000–29,999), medium population centers (30,000–99,999), and large urban population centers (≥100,000).[58] Alternatively, in the Institute National De Sante Publique Du Quebec method, which was used in this thesis, regions were classifieds into 1) Montreal, Toronto, and Vancouver census metropolitan areas; 2) other census metropolitan areas with over 100,000 residents; 3) census agglomerations with 10,000 to 100,000 residents; and 4) small towns and rural communities with less than 10,000 residents.[54]

2.2. Comparing Common Summary Measures of the Quality of Diets

During the last decade, many studies have compared several diet quality indices using different methods. These studies can be classified based on several criteria. Based on the objectives of the studies, they can be categorized into two main groups. The first includes studies that evaluated the psychometric properties of a newly developed index or an updated version of an established index by comparing it to a valid index capturing the same concept or the older version of the index.[26, 59, 60, 61, 62, 63] These studies typically examined the variability of the scores of the indices among participants, their abilities to indicate diet quality differences between groups with known different diet quality, their association with other diet quality indices, and the abilities of the indices to measure diet quality independent of diet quantity.[26, 59] The second includes studies that aimed to identify the most optimal diet quality index for a specific purpose among the existing diet quality indices. These studies typically involved comparisons of different diet quality indices in relation to SES or nutrient adequacy of a population.[50, 64] Many studies in this category focused on finding an appropriate diet quality index capable of predicting one or more health-related outcomes such as CVD, MetS, cancer, T2D, osteoporosis, mortality, etc.[45, 65, 66, 67]

However, it is worth noting that the classification mentioned above may not adequately clarify the methodologies of the studies. Therefore, regardless of the objectives of the studies, forthcoming paragraphs will explain their methods and the statistical analyses employed to compare diet quality indices. This will provide a more comprehensive review of existing literature, identifying their strengths and limitations to determine the most appropriate methods to apply in this thesis.

When reviewing dietary intake assessment methods in previous studies, the study conducted by Bullock et al. stands out as they compared the ability of different dietary indices [HEI-2015, DASH, the Main Meal Quality Index (MMQI), and the Nutrient Rich Foods (NRF) Index] to evaluate the nutrition quality of individual meals in 2022, using meal data from the Physical Activity Calorie Expenditure Food Labeling study and analyzed 8,070 meal photos from

379 participants from the US.[68] They employed Spearman's correlation coefficients to compare the total scores of each indices and revealed that the strongest correlations were between DASH and MMQI (r=0.68) and between DASH and NRF (r=0.63), while the weakest correlations were between DASH and HEI-2015 (r=0.26) and NRF and HEI-2015 (r=0.29).[68] One issue with this study is that the data might not accurately capture the exact meal compositions or cover the range of choices made by participants, as meal details were assessed via photographs, and specific nutritional information for cafeteria offerings was lacking. There is also a concern about employing Spearman's correlation coefficients to compare the total scores of the indices. This is mainly because correlation and agreement are distinct concepts; correlation denotes a relationship between different variables, while agreement assesses the consistency between measurements of one variable.[69] That is to say, two highly correlated sets of observations may lack agreement, while if two sets of values agree, they will likely exhibit high correlation.[69] In addition, the researchers focused on only a single eating occasion, overlooking the fundamental aim of dietary indices, which is to provide a comprehensive evaluation of dietary intake in relation to established guidelines. This, in addition, raises concerns about the generalizability of their findings.[70]

Ebrahimi et al., in their 2020 study, used household-level instead of individual-level dietary data. They assessed the suitability of HEI-2015 and DQI-I by investigating their relationships with nutrient adequacy, and nutrient intake levels among the 6,935 Iranian households with at least two days of 24-hour diet recalls, using the cut-off points presented in World Health Organization/Food and Agriculture Organization 2002 (WHO/FAO).[50] They employed logistic regression analysis to assess the relationship between diet quality indices and nutrient adequacy, finding that households scoring higher on HEI-2015 and DQI-I were more inclined to meet WHO/FAO recommendations for calcium, vitamin C, and protein, while only the

DQI-I higher scores were associated with increased likelihood of households achieving adequate iron intake levels.[50] The main limitation with this study could be using household-level dietary data. Although relying on household-level dietary data eases the financial burdens of dietary assessment in low- and middle-income countries,[71] it may pose challenges to accurately determine how food is distributed and consumed within the household, affecting the precision of dietary intake assessment at the individual level.

Rather than evaluating the indices in terms of their abilities to assess overall diet quality, in their 2013 study, Kranz et al. compared five comparable components of the HEI-2005 and Revised Children's Diet Quality Index (RC-DQI), including fruit, vegetables, total grains, whole grains and dairy among 5,936 children aged 2-18 using an average intake of two 24-hour diet recalls from the 2003-2006 the National Health and Nutrition Examination Survey (NHANES).[64] When examining the distribution of indices' total scores, the authors observed that while all children scored between one and 24 points for RC-DQI, only 12% scored zero (minimum) and 88% scored between one and 24 (intermediate) points for HEI-2005, indicating the higher ability of RC-DQI to result in a larger distribution of scores compared to HEI-2005. They also estimated the correlations between the indices' identical components, observing a range of coefficients (r^2) from 0.17 for total grain to 0.55 for fruit.[64] The comparison between indices' components could be more interpretable if the authors complemented their method by estimating the agreement between the components as the correlation coefficients may occasionally be insufficient and could lead to misinterpretation when evaluating agreement, as they solely assess the direction of relationship between two sets of observations.[72]

The following two studies effectively demonstrated the fundamental strategies used to assess diet quality indices, which are also applied in this thesis. In their 2022 study, Brassard et al.

evaluated HEFI-2019 through several steps using dietary data of 20,103 participants aged two years and older from the 2015 CCHS-Nutrition.[59] All participants completed at least one 24-hour dietary recall, with 37% completing two recalls. Firstly, the researchers estimated the variation of the index's scores, finding an average HEFI-2019 score of 43.1 points (95% CI: 42.7, 43.6), with the range of 22.1 to 62.9 points across percentiles. In the second step, they estimated the mean HEFI-2019 scores for specific groups with known differences in diet quality based on factors like sex, age, and smoking status. Receiving better scores in fruit and vegetables, and beverages components led females to score 3.1 points higher on average than males in HEFI-2019. They also found that older adults aged 50-70 had a 6.5-point higher score than younger adults aged 19-30. Similarly, non-smokers scored 7.2 points higher than Smokers. Thirdly, they examined if there was a strong correlation between HEFI-2019 and HEI-2015 scores, using the first 24-hour diet recall of each respondent through Pearson correlation and linear regression, finding a strong linear association between the HEFI-2019 and HEI-2015 scores in assessing overall diet quality (r=0.79; r2=0.62). Next, they searched to evaluate the extent to which HEFI-2019 scores were independent of total energy intake, finding a Pearson correlation coefficient of -0.13 (95% CI: -0.20, -0.06).[59]

Reedy et al. examined the psychometric properties of HEI-2015 in 2018, using datasets from NHANES 2011-2012 (sample size [n]=7,935) and the American Association of Retired Persons Diet and Health Study (NIH-AARP) [n=422,928].[26] They follow almost the same approach as Brassard et al. study. Their results indicated an average total HEI-2015 score of 56.6, ranging from 32.6 to 81.2 across percentiles. They also assessed consistency between HEI-2015 and HEI-2010 scores, revealing a correlation coefficient of 0.96 between the indices' total scores. According to their results, women exhibited higher scores in total fruit, whole fruit, total vegetables, and whole grains and higher mean HEI-2015 total scores than men (59.7 vs. 57.2

points). Likewise, significant variations were observed across age groups, with the older adults aged 60 to 80 years attaining higher mean scores compared to the younger adults aged 20 to 30 years (62.8 vs. 55.0 points). Similarly, nonsmokers displayed significantly higher mean total scores (59.7) compared to current smokers (53.3). To answer whether HEI-2015 can assess diet quality independent of diet quantity, they calculated the correlations between total HEI-2015 score and energy, finding a very low and not statistically significant correlation between energy and the HEI-2015 total score (r=0.06).[26] Despite the meticulous methodologies utilized in the two studies mentioned above, using a correlation coefficient to evaluate consistency between indices' scores could not be able to provide sufficient information on the indices' agreements. As explained earlier in this chapter, such a method is suggested to be complemented by measuring the agreement between indices.

Apart from the correlation coefficients, various other methods were utilized to measure the consistency between indices. In their 2023 study, Jessri et al. developed the Dietary Pattern Calculator (DiPaC), a digital diet quality screener, offering personalized evaluation and feedback on the healthiness of adults' dietary patterns aged 18 years and older.[62] They used dietary data from 13,958 Canadian adults, with at least 30% providing two 24-hour diet recalls from the 2015 CCHS-Nutrition. The screener asks about dietary intake over the past 30 days, ranking participants' diet quality by comparing them with the recent dietary guidelines. For part of the validation processes, they compared the screener with DASH scores, finding that 52% of individuals classified in the healthiest quartiles (3 or 4) of the DASH score were also categorized in the same quartiles using DiPaC. Similar to the two aforementioned studies, they assessed the index's scores independence of energy intake, finding a low Pearson correlation between the total DiPaC score and energy intake, suggesting that DiPaC is independent of diet quantity.[62] The authors assessed agreement between DiPaC and DASH scores by estimating the proportion of individuals classified similarly by the indices. While the method offers more insight into the consistency of the indices' scores compared to correlation coefficients, it does not account for the agreement due to chance.

Cohen's Kappa statistics, employed in this thesis, offer a more precise evaluation of agreement between indices by accounting for chance agreement.[73] The statistics values range from -1 to 1: perfect agreement at 1, agreement by chance at 0, and worse-than-chance agreement with values less than 0; however, negative values are unlikely in practice.[73] Agreement magnitude is categorized as follows: ≤0 as no agreement, 0.01-0.20 as poor to slight, 0.21-0.40 as fair, 0.41-0.60 as moderate, 0.61-0.80 as substantial, and 0.81-1 as almost perfect.[73]

Maso et al., in 2023 employed the same approach to measure their studied indices agreement level; the authors studied on 7,948 Italian subjects from 1991 to 2008 to compare the Nutritional Functional Diversity Indicator (NFD) with the Food Variety Score (FVS) in order to analyze their variances in measuring diet diversity, using a reproducible and validated FFQ as the dietary intake assessment tool.[63] The study employed unweighted and weighted Cohen’s kappa statistics to assess the agreement between NFD and FVS. Of note, the magnitude of kappa is affected by factors such as the choice of weighting and the number of categories in the measurement scale.[73] with scale categories over two, there is a greater potential for disagreement, leading to lower unweighted kappa values because unweighted kappa treats all disagreements equally, making it unsuitable for ordinal scales, while weighted kappa considers the severity of disagreements.[74] Maso et al. revealed moderate to substantial agreement between NFD and FVS, with an unweighted Cohen’s kappa of 0.62 and a weighted Cohen’s kappa coefficient of 0.77.[63] Two weighted schemes have been introduced in literature: Linear-weighted kappa, which used in Maso et al. study, measures mean distance changes between raters' classifications, while quadratic-weighted kappa focuses on changes in the center of inertia.[75] While there is an idea advocating Linear-weighted kappa due to its emphasis on location parameters and the less favourable mathematical properties of the quadratic-weighted kappa, Quadratic weights are widely favoured due to their practical interpretability,[75] which was employed in this thesis. Although Cohen's kappa statistics is an optimal method to evaluate the agreement between indices in many samples, it is essential to consider that its magnitude, except for the number of categories, is influenced by the size of the sample, and how subjects are distributed among those categories.[76] Employing the traditional Cohen's Kappa coefficients seems to be one possible issue with Maso et al. study, as the number of individuals in each quartile shared between the study's indices indicated large discrepancies due to the method's limitations.

Bland-Altman is another method employed in studies comparing diet quality indices[45, 60, 61] which assesses the agreement between two continuous measurements or one method against a reference standard, providing insight into the magnitude and direction of disagreement between two measurements. This method plots differences between the two measurements against their means, visualizing any systematic bias (mean difference) and the limits of agreement (mean difference ± 1.96 standard deviations [SDs]). The ideal agreement is a zero difference, with the average difference and its limits ideally near zero.[77] The Bland-Altman method has been criticized for its assumption of normal distribution for measurement differences. Additionally, Insufficient sample sizes can lead to misleadingly low biases and narrower agreement limits. Some studies proposed regression analysis as an alternative, particularly for calibrating measurements or detecting bias, while Bland-Altman is preferred typically for evaluating method substitution in clinical contexts.[78]

Bland-Altman was employed in Aloy dos Santos et al. study in 2024. They assessed the criterion validity of their newly developed diet quality self-assessment tool, titled "Wheel of Cardiovascular Health Diet," by examining the agreement between 330 Brazilian adults' self-perception of diet quality by the new tool and the HEI-2020 using the Bland-Altman plots.[61] The result showed a mean difference of -10% (95% CI: -35.3, 15.3) between the two measures. They also used linear regression models to predict HEI-2020 average score changes based on their new tool, revealing that a 10-point increase in self-perception in the Wheel of Cardiovascular Health Diet corresponded to a 2.9% variability in diet quality by the HEI-2020 (95% CI: 2.08, 3.70), adjusting for potential confounding factors (age, sex, sedentary lifestyle, smoking, Body Mass Index [BMI], and total energy intake). Additionally, they used logistic regression to assess the same association between the indices categories. The results indicated that patients with self-perception above 70% had 2.32 times (95% CI: 1.33, 4.02) the chance of having a high-quality diet, according to the HEI-2020. They also used the logistic regression model to predict HEI-2020 average score changes based on each 10-point increase in self-perceived diet quality, finding an association with 1.63 times (95% CI: 1.31, 2.02) higher chance of having a high-quality diet based on HEI-2020 after adjusting for the study's confounders.[61] One possible limitation of this study is its low generalizability as the samples were selected from two randomized clinical trials and the individuals who reported adequate consumption may have made recent alterations in their diet.

Several studies aim to identify a suitable diet quality index capable of predicting various health-related outcomes, such as CVD, MetS, cancer, T2D, osteoporosis, mortality, etc.[45, 67, 79, 80] Ghadiri et al. 2023 study is one of these studies that compared HEI-2015 and DQI-I in their association with bone mineral density among 131 postmenopausal women with and 131 without osteoporosis.[67] A validated FFQ was used to assess dietary intake. In addition to the use of regression models to examine how changes in the average score of one index correspond to the average score of another index, like the methods' application in the Aloy dos Santos et al. study,[61] they estimate how much the mean scores of different indices could vary based on specified independent variables as used in the analysis presented in this thesis. These independent variables could be disease risk factors and/or relevant potential confounding factors based on the study objectives. Here, Ghadiri et al. used unadjusted and adjusted multivariable logistic regression to investigate the association between HEI-2015 and DQI-I and the likelihood of femoral and lumbar abnormalities. In their study, factors such as BMI, age, income, physical activity, education level, and intake of vitamin D and calcium supplements were accounted for to control their effects in the adjusted model. They revealed that individuals in the last tertile of HEI and DQI-I were more likely to have higher femoral and lumbar bone mineral density in both unadjusted and adjusted models. However, the odds ratio (OR) for femoral bone mineral density associated with HEI-2015 was notably higher than that for DQI-I in the unadjusted ([0.38; 95% CI: 0.20, 0.71] vs. [0.23; 95% CI: 0.12, 0.45]) and adjusted ([0.40; 95% CI: 0.20, 0.78] vs. [0.29; 95% CI: 0.14, 0.58]) models.[67]

Given several methodological limitations observed in previous studies, this thesis aims to address these issues by employing modified methodologies to make novel contributions to the field. Previous studies introduced different methods to evaluate and compare different indices. These methods were taken through various statistical analysis approaches based on the studies' objectives. Among the aforementioned methods, some approaches were more appropriate to be followed in this thesis considering the study's population and the employed indices features, which are as follows: 1. Measuring variation of indices' scores to distinguish between individuals with different diet qualities; 2. Measuring the independence of the indices scores to diet quantity; 3. Measuring the ability of the indices to effectively differentiate the variation across different population groupings with known diet differences (e.g., sex, age, and SES); and 4. Measuring the agreement between the diet quality indices. Another feature of an optimal diet quality index was its ability to effectively predict health-related outcomes, as mentioned above. However, this thesis did not aim to assess this aspect of diet quality indices due to restricted access to health-related data.

The previous studies on diet quality indices assessments were mostly conducted in other countries like Brazil, Italy, the US, etc,[26, 61, 63] which compared indices frequently used in their populations, while a limited number of studies were conducted in Canada.[59, 62] The Canadian studies' main objective was to evaluate the properties of newly developed indices and compare them with established indices to assess the criterion validity of the new measures as a small fraction of their studies. Thus, to my knowledge, there is no Canadian study that comprehensively compares diet quality indices in relation to their different abilities to evaluate Canadians diet quality. Apart from that, the methods used in previous studies to measure dietary intake, the criteria for optimal diet quality indices, and the statistical methods used to measure consistency and agreement between indices were inconsistent and required some modifications. Furthermore, among previous studies, only one study compared diet quality indices specifically on 2–18-year-old children and adolescents.[64] Nonetheless, this study compared only a few comparable components in indices, and their methods for evaluating agreement between indices could be fundamentally improved. Among Canadian studies, only one study included children as part of the larger study's samples,[59] while the indices were compared as a small part of the study's main objective. Finally, it is very important to include the widely used indices, which could differ in different societies and might be the main reason for the inconsistency among diet quality indices employed in previous studies. As a result, this thesis aims to compare the diet quality indices frequently used in studies on Canadian children's diet quality.

2.3. References

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Chapter3: Comparing common summary measures of the quality of diets of Canadian children: A call for consensus.

3.1. Introduction

Canadian children consume diets of poor quality:[1] in fact, most children do not meet dietary recommendations for fruit and vegetables and sodium intake,[2,3] and a substantial portion of their energy intake comes from foods high in fat and sugar.[1] While it is well established that a good diet quality is essential for growth and physical development, it is also proven to be associated with better health outcomes, including healthier body weights, improved blood pressure, reduced risk of MetS, better mental health outcomes and enhanced intelligence quotient.[6, 7] Emerging evidence also points to the importance of high-quality diets for mental health, well-being and academic performance.[4, 5] An accurate measure of diet quality is essential to study the impact of diet quality on health outcomes and assess the effectiveness of dietary interventions. The three indices that are most commonly used to assess the diet quality of Canadian children are DQI-I,[8, 11, 12] HEI-C,[10,13,14] and the more recently developed HEFI-2019.[15] While all three indices aim to summarize the overall diet quality, they vary in terms of dietary criteria and scoring systems,[16] which hinder the interpretation of dietary guidelines to improve diet quality.

An optimal diet quality index should have a wide variation of scores to distinguish between individuals with different diet qualities. Additionally, a diet quality index should be independent of diet quantity and be able to effectively differentiate the variation across different population groupings (e.g., sex, age, and SES).[17] Indeed, while some studies find little to no difference in diet quality between girls and boys,[8, 18] Statistics Canada reports that Canadian girls consume on average more fruit and vegetables and less sodium, compared to boys.[2, 3] Likewise, younger children have diets of higher quality than older children.[18, 19] Children from families of higher SES have healthier dietary patterns, characterized by lower consumption of energy-dense food and higher consumption of fruit, vegetables, and dairy products, compared to their peers from lower SES households.[20, 21, 22]

In the absence of an existing comparison of the commonly used diet quality indices, this study describes the properties of the HEI-C 2015, DQI-I, and HEFI-2019, and assesses the agreement across these indices and the extent to which the application of each of these indices may lead to different conclusions related to diet quality of Canadian children.

3.2. Methods

3.2.1. Procedures

In the spring of 2016 and 2018, and in the winter 2020/spring 2021, we surveyed 1887 grade 4-6 students from 23 APPLE Schools in a repeated cross-sectional study. APPLE Schools is an innovative school-based health promotion program that was introduced in 2008 and is currently active in 100 schools in socioeconomically disadvantaged communities across multiple provinces and territories in Canada. The APPLE Schools program focuses on improving well-being through health promotion activities targeting healthy eating, physical activity, and mental health and benefits over 33,000 children annually.[23] Data collection took place within the school premises during regular school hours. Students were provided with unique usernames and passwords and used their Chromebooks to access the online survey portal. Students self-reported their sex (girl vs. boy), grade level (4, 5, 6), and dietary intake in the past 24 hours. A total of 441, 473, and 973 students from rural and remote Northern communities in Canada completed the survey, with participation rates of 66%, 67%, and 78% in 2016, 2018, and 2020/2021, respectively.

3.2.2. Measures

Students reported food and beverages they consumed in the past 24 hours using the web-based Food Behaviour Questionnaire, previously validated in a sample of 201 grade 6-8 students.[24] The questionnaire employs the multiple-pass approach in which children select a food item by searching for it in the search bar or choosing it from the presented icons. Once a food was selected, students reported their consumption by selecting one of six pre-programmed portion sizes (0.5, 1, 1.5, 2, 2.5, or 3 servings).

Healthy Eating Index-Canada 2015

HEI, initially developed by the USDA in 1995,[25] reflects the recommendations outlined in the Dietary Guidelines for Americans and focuses on promoting healthy eating patterns by assessing two key elements of the diet: adequacy and moderation. HEI scores range from 0 (the least healthy diet) to 100 (the healthiest diet). High HEI scores have been shown to be associated with a reduced risk of chronic diseases.[26,27] HEI was adapted for use in Canada in 1995, 2005, 2010, and 2015.[28,29,30,31,32] In 2019, HEI-C 2015 was adapted to measure the extent to which Canadian adults adhere to age-specific recommendations outlined in the CFG-2007.[32] In this study, HEI-C 2015 was calculated based on the CFG-2007 recommendations for 6-11-year-old children (Appendix A).

Diet Quality Index-International

An international index, DQI-I,[33] developed in 2003, gives a certain flexibility regarding the components of a healthy diet that are included in the index calculation. Hence, it enables the comparison of dietary patterns across countries. By incorporating both foods and nutrients, DQI-I allows capturing various diets across different countries. DQI-I measures the four key elements of a high-quality diet: variety, adequacy, moderation, and overall balance. DQI-I scores range from 0 to 100, with higher scores indicating a healthier diet (Appendix B).[33]

Healthy Eating Food Index-2019

HEFI-2019, developed in 2022, assesses the adherence to healthy eating recommendations outlined in the CFG-2019 among Canadians aged two years and older.[15] The index measures the intake of five foods and four nutrients, with one component measuring the beverages intake. HEFI-2019 scores range from 0 to 80, with higher scores indicating better diet quality (Appendix C).[15] To facilitate comparisons with DQI-I and HEI-C-2015, in this study, the HEFI-2019 scores have been adjusted to range from 0 to 100 by multiplying the original scores by 1.25.

School-level characteristics

The region of residence and area-based material and social deprivation were defined based on schools' postal codes linked to the 2016 Canada census data.[34] As classified by the Institute National De Sante Publique Du Quebec, the region of residence included four main geographic areas based on their population: 1) Montreal, Toronto, and Vancouver census metropolitan areas; 2) other census metropolitan areas with over 100,000 residents; 3) census agglomerations with 10,000 to 100,000 residents; and 4) small towns and rural communities with less than 10,000 residents. Schools were categorized into two groups: those located in areas with 10,000 or more residents vs. less than 10,000 residents. Higher quintiles of material and social deprivation indices indicate higher deprivation. To ensure that we had enough schools in each group of materially and socially deprived areas, we combined 1-3 and 4-5 quintiles of the material deprivation index and 1-2 vs. 3-5 quintiles of the social deprivation index.

3.2.3. Data Analysis

We calculated means, SDs, ranges, and coefficients of variation (CV) for each diet quality index. The percent agreement and weighted Cohen's Kappa coefficients were used to assess the level of agreement between the three indices. As cut-off points for differentiating good vs. poor diet quality have not been previously proposed for HEI-C 2015 and HEFI-2019, the HEI-C 2015, DQI-I, and HEFI-2019 scores were categorized into quartiles. The weighted Cohen's Kappa coefficients were calculated since more than two categories were being compared.[35] We used quadratic weighting to account for the severity of disagreements and penalize them accordingly.

To assess the extent to which the use of these three indices would lead to different conclusions, initially we fitted univariable multilevel models. Since the inter-school variance appeared small (less then 2%) we applied linear regression. We ran separate univariable linear regression models for the total score of each index (continuous variable) with sex, grade levels, energy intake, material and social deprivation quintiles, and regions of residence as independent variables. We also ran separate multivariable linear regression models for the total score of each index, adjusting for covariates. We excluded students that had missing data on sex and/or grade level (n=14 [2016], 2 [2018], and 0 [2020/21]). We also excluded students with unplausible values of energy intake (i.e., <500 kcal or >5000 kcal) (n=91 [2016], 17 [2018], and 64 [2020/21]) since extremely low- or high-calorie intakes may not accurately reflect the children's usual daily dietary intakes.[24] All statistical analyses were conducted using Stata/MP 17.0.[36] A p-value <0.05 was considered statistically significant.

3.3. Results

A total of 336 (2016), 454 (2018), and 909 (2020/21) students were included in the analytic sample. Students' and schools' characteristics are shown in Table 1. There were 874 (51.4%) girls, with 520 (30.6%) students in grade 4, 630 (37.1%) in grade 5, and 549 (32.3%) in grade 6. Of 23 participating schools, 14 (60.9%) were located in regions with more than 10,000 residents.

HEI-C 2015 and DQI-I had almost comparable average scores and similar decreasing trends between 2016 to 2020/2021: from 54.7 (SD=13.9) to 49.5 (12.9), and from 55.6 (9.7) to 53.2 (9.9), respectively. The equivalent values were markedly lower for HEFI-2019 in all years: 45.0 (14.0) in 2016, 44.7 (13.1) in 2018, and 45 (13.6) in 2020/2021 (Table 1). Regardless of the survey year considered, DQI-I scores showed notably less variation, ranging from 19.9 to 83.9 (CV=18.1%), compared to HEI-C 2015 that ranged from 11.7 to 95.3 (CV=25.7%) and HEFI-2019 from 8.6 to 90.1 (CV=30.1%).

The percent agreement and weighted Kappa scores varied across the survey years but were statistically significant for all comparisons (Table 2). In a combined sample of students who participated in any of the survey cycles, the percent agreement between HEI-C 2015 and DQI-I was 0.88 (95% CI: 0.87, 0.89), between HEI-C 2015 and HEFI-2019 – 0.83 (95% CI: 0.82, 0.84), and between DQI-I and HEFI-2019 – 0.80 (95% CI: 0.79, 0.81). For this combined sample, weighted Cohen's Kappa coefficient for agreement between HEI-C 2015 and DQI-I was 0.55 (95% CI: 0.52, 0.59), between HEI-C 2015 and HEFI-2019 – 0.38 (95% CI: 0.35, 0.42), and between DQI-I and HEFI-2019 – 0.29 (95% CI: 0.25, 0.33). These values of weighted Cohen's Kappa coefficients translate into fair to moderate agreement.[37]

Compared to girls, boys reported diets of lower quality, with the difference being particularly pronounced when using DQI-I, both in unadjusted (β=-1.37, 95% CI: -2.31, -0.43) and adjusted (β=-1.44, 95% CI: -2.38, -0.50) models (Table 3). There were no statistically significant differences in indices across grade levels (Table 3). Energy intake was positively associated with DQI-I (β=0.09, 95% CI: 0.04, 0.14) and negatively associated with HEFI-2019 (β=-0.19, 95% CI: -0.25, -0.12). After adjusting for covariates, students attending schools in more materially deprived areas appeared to have worse diet quality, irrespective of the index used, than their counterparts attending schools in less materially deprived areas. However, higher social deprivation was associated with higher diet quality, as measured by HEI-C 2015 (β=1.24, 95% CI: -0.09, 2.57) and DQI-I (β=1.03, 95% CI: 0.05, 2.02) after adjusting for covariates. Differences with respect to the region of residence were statistically significant for HEI-C 2015 (β=1.84, 95% CI: 0.54, 3.14) but not for DQI-I and HEFI-2019.

3.4. Discussion

This study compared the properties of three commonly used diet quality indices (i.e., DQI-I, HEI-C 2015, HEFI-2019) in a sample of 1,699 grade 4-6 students in 23 elementary schools in Canada. These indices have different properties (e.g., dietary components, range of values, CVs) and have only fair to moderate agreement; therefore, when applied to the same sample, these indices can yield distinct conclusions about children's diet quality. Notably, higher energy consumption was associated with higher DQI-I and lower HEFI-2019 scores.

HEFI-2019 and HEI-C 2015 scores appear to have more variation than DQI-I scores, assigning more varied weights to different intake amounts, which leads the indices to better distinguish between individuals with various diet qualities compared to DQI-I. In the overall sample of students who participated in any of the survey cycles, we found only a fair agreement between HEI-C 2015 and HEFI-2019 and between HEFI-2019 and DQI-I, while a moderate agreement was found between HEI-C 2015 and DQI-I. The latter finding could be due to HEI-C 2015 and DQI-I incorporating similar dietary components (i.e., adequacy and moderation). In a study by Brassard et al. (2022), the Pearson correlation coefficient for the comparison of HEI-2015 and HEFI-2019 was 0.79,[15] while in our sample, it was as low as 0.6 (data not shown), which may be attributed to us using HEI-2015 adapted for the Canadian population.[25]

Consistent with the reports from Statistics Canada,[2,3] girls had better diet quality regardless of the index used, with DQI-I being the most robust in distinguishing diet quality between sexes. This could be because DQI-I, unlike HEI-C 2015 and HEFI-2019, includes unique nutrients and dietary components (cholesterol, vitamin C, and macronutrient ratio). Our comparisons across grade levels (as a proxy for age groups within the 9 to 12 years age range) revealed no statistically significant differences using any of the three indices. We could not find similar age groupings in studies highlighting diet differences among children, as they typically studied a wider age range.[1, 14, 18]

Existing literature shows that children from lower SES families consume less fruit and vegetables and fibre and more added sugar and energy drinks,[38,39] which is supported by our findings. While three indices detected poorer diet quality among students from more materially deprived neighbourhoods, HEI-C 2015 and HEFI-2019 showed more robust results. This could be due to some of HEI-C 2015 dietary components (i.e., fruit and vegetables, whole grain and added sugar) and HEFI-2019 dietary components (i.e., free sugar, healthy beverages, and fatty acid ratio) that obtained significantly lower scores among students residing in more materially deprived areas. In contrast, consumption of DQI-I equivalents dietary components (i.e., fruit, vegetables, and empty calory food groups) was not significantly different among students from high and low materially deprived regions. However, an opposite picture emerged for social deprivation, with a robust association with DQI-I. This could be possibly due to higher consumption of some additional dietary components in DQI-I (i.e., fibre, calcium, and vitamin C) compared to HEI-C

2015 and HEFI-2019 by students from more socially deprived areas. Studies that reported on the association between social deprivation and diet yielded inconsistent findings,[40, 41] possibly because of differences in methods used to assess children's diets and social deprivation levels, covariates adjusted for, and population characteristics.

Students residing in less populous areas reported slightly higher diet quality. Among the studied indices, HEI-C 2015 was the most robust in detecting differences in diets between regions, possibly attributed to HEI-C 2015 distinct components for fruit and vegetables and a separate component for milk and dairy intake. This finding aligns somewhat with the findings of Tugault-Lafleur et al., which observed a slightly higher, though not statistically significant, diet quality among rural students compared to their urban counterparts in a sample of 4,728 students aged 6 to 17, utilizing the school-HEI.[14] Conversely, the results of Gaudin et al.'s study, involving 3,956 Canadian students aged 6 to 18 and employing DQI-I, contradicted the findings of our study.[12] This could be due to differences in sample sizes, time of measurement (school time vs. whole day), the classification method employed for areas of residence, and lack of participants from metropolitan areas in the current study.

Similar to a study by Brassard et al.,[15] we found that higher calorie intake was correlated with lower HEFI-2019 scores. As the authors suggested, this necessitates considering energy intake when examining trends in diet quality over time or differences among groups using the HEFI-2019. The index scores' dependence on diet quantity could result from the HEFI-2019 components with inverse correlation coefficients with energy intake, such as the beverages with the largest inverse correlation with energy intake (Appendix K). One reason for this may be the scoring method based on dividing low-calorie plain water (including carbonated and unsweetened beverages) by total beverages containing a higher amount of energy.[15]

To the best of our knowledge, this is the first study to compare established and commonly used diet quality indices among Canadian school-aged children. Data were collected through 24-hour diet recall with a sample size large enough to include a sufficient variation in diet quality. However, there are a few limitations to consider. Collecting 24-hour dietary recall at a single time point may not capture participants' usual dietary intakes; yet collecting data from multiple 24-hour dietary recalls is not feasible in school-based studies, given the burden on participants and school administrations. Additionally, self-reported measures carry the possibility of introducing measurement biases due to their reliance on individuals' memory abilities. However, the burden of memory may be less for 24-hour dietary recall than that of the FFQ, which requires recall over a longer period.[42] Self-reported measures can also be influenced by social desirability. Nevertheless, using a web-based 24-hour diet recall in this study helped mitigate this bias to some extent compared to traditional paper-based 24-hour dietary recall.[43] These approaches could enhance the internal validity of the study. Furthermore, adjusting the models for covariates supports internal validity.

Lastly, this study focused on Canadian school-aged children from smaller regions with populations under 100,000 due to limited data availability from larger cities such as Montreal, Toronto, and Vancouver. This may impact the ability to generalize the findings to metropolitan populations. In addition, cross-sectional studies cannot assess causality, which applies to this study as well. However, since the primary objective of this study did not rely on establishing causal relationships, assessing causality was not included in the study's objectives. Consequently, this limitation is unlikely to affect the validity of the findings. Therefore, the results of this study could be generalizable to all Canadian school-age children residing in non-metropolitan areas.

This study shows that the choice of the diet quality index affects the interpretation of the results and practical considerations. Therefore, researchers, practitioners, and policymakers must seek consensus on which index to use and under which circumstances. Of the three indices we examined, HEFI-2019 is the most recent one; it reflects the adherence to the dietary recommendation outlined in the CFG-2019 and our current understanding of diet quality and how it should be measured. However, we recommend HEFI-2019 to be revised to address its dependency on diet quantity. Overlooking the HEFI-2019 scores' dependence on diet quantity would result in inaccurate diet quality measurement, confusing policymakers, and misguiding interventions. This could ultimately lead to misallocated resources and increased costs with minimal health benefits.

Table 3.1. Characteristics of students attending APPLE Schools in 2016, 2018, and 2020/2021, along with characteristics of the schools

	Variable	**Group**	**2016 (n=336)**	**2018 (n=454)**	**2020/2021 (n=909)**	**Total (n=1699)**
Students' characteristics			**N (%)**			
	Sex	Girls	181 (53.9)	225 (49.6)	468 (51.5)	874 (51.4)
		Boys	155 (46.1)	229 (50.4)	441 (48.5)	825 (48.6)
	Grade	4	93 (27.7)	141 (31.1)	286 (31.5)	520 (30.6)
		5	119 (35.4)	175 (38.6)	336 (37.0)	630 (37.1)
		6	124 (36.9)	138 (30.4)	287 (31.6)	549 (32.3)
			Mean (SD)			
	Diet quality indices' scores	HEI-C 2015	54.7 (13.9)	52.4 (12.9)	49.5 (12.9)	51.3 (13.2)
		DQI-I	55.6 (9.7)	55.0 (9.4)	53.2 (9.9)	54.1 (9.8)
		HEFI-2019[a]	45.0 (14.0)	44.7 (13.1)	45.0 (13.6)	44.9 (13.5)
			Range (CV%)			
		HEI-C 2015	19.3-93.4 (25.4)	14.6-95.3 (24.6)	11.7-89.3 (26.1)	11.7-95.3 (25.7)
		DQI-I	28.0-80.8 (17.4)	26.1-80.6 (17.1)	19.9-83.9 (18.6)	19.9-83.9 (18.1)
		HEFI-2019[a]	8.6-84.0 (31.1)	13.5-82.7 (29.3)	10.5-90.1 (30.2)	8.6-90.1 (30.1)
Schools' characteristics			**N (%)**			
	Material deprivation index's quintile	1 (least deprived)	3 (13.0)			
		2	5 (21.7)			
		3	4 (17.4)			
		4	5 (21.7)			
		5 (most deprived)	6 (26.1)			
	Social deprivation index's quintile	1 (least deprived)	5 (21.7)			
		2	6 (26.1)			
		3	5 (21.7)			
		4	4 (17.4)			
		5 (most deprived)	3 (13.0)			
	Region of residence	Over 10,000 residents	14 (60.9)			
		Under 10,000 residents	9 (39.1)			

Abbreviations: CV, coefficient of variation; SD, standard deviation; HEI-C 2015, Healthy Eating Index-Canada 2015; DQI-I, Diet Quality Index-International; HEFI-2019, Healthy Eating Food Index 2019.

[a] HEFI-2019 scores have been recalibrated from a maximum of 80 to a maximum of 100 by multiplying the scores by 1.25.

Table 3.2. Percent agreement and weighted Cohen's Kappa coefficient (95% CI) between HEI-C 2015, DQI-I, and HEFI-2019, based on dietary intakes of Canadian children (n=1,699)

Year	Index	HEI-C 2015		DQI-I	
		Percent agreement (95% CI)	**Cohen's kappa coefficient (95% CI)**	**Percent agreement (95% CI)**	**Cohen's kappa coefficient (95% CI)**
2016	DQI-I	0.89 (0.88, 0.91)	0.62 (0.55, 0.69)		
	HEFI-2019[a]	0.83 (0.81, 0.86)	0.42 (0.34, 0.49)	0.81 (0.78, 0.84)	0.33 (0.25, 0.41)
2018	DQI-I	0.88 (0.86, 0.89)	0.55 (0.49, 0.61)		
	HEFI-2019[a]	0.82 (0.80, 0.84)	0.36 (0.30, 0.42)	0.79 (0.76, 0.81)	0.25 (0.18, 0.32)
2020/2021	DQI-I	0.87 (0.86, 0.89)	0.55 (0.50, 0.60)		
	HEFI-2019[a]	0.83 (0.82, 0.85)	0.41 (0.36, 0.45)	0.80 (0.78, 0.82)	0.29 (0.24, 0.34)
	DQI-I	0.88 (0.87, 0.89)	0.55 (0.52, 0.59)		
Total	HEFI-2019[a]	0.83 (0.82, 0.84)	0.38 (0.35, 0.42)	0.80 (0.79, 0.81)	0.29 (0.25, 0.33)

Abbreviations: CI, confidence interval; HEI-C 2015, Healthy Eating Index-Canada 2015; DQI-I, Diet Quality Index-International; HEFI-2019, Healthy Eating Food Index 2019.

[a] HEFI-2019 scores have been recalibrated from a maximum of 80 to a maximum of 100 by multiplying the scores by 1.25.

p-value for all kappa coefficients <0.01.

Table 3.3. Association of schools' and children's characteristics and their energy intake with diet quality by HEI-C 2015, DQI-I, and HEFI-2019, using linear regression models. The final multivariable models included all explanatory variables considered.

Variable	Group	N	HEI-C 2015		DQI-I		HEFI-2019[a]	
			Unadjusted β (95% CI)	**Adjusted β (95% CI)**	**Unadjusted β (95% CI)**	**Adjusted β (95% CI)**	**Unadjusted β (95% CI)**	**Adjusted β (95% CI)**
Sex	Girls	874	Ref	Ref	Ref	Ref	Ref	Ref
	Boys	825	-0.81 (-2.09, 0.47)	-0.69 (-1.96, 0.58)	-1.37 (-2.31, -0.43)*	-1.44 (-2.38, -0.50)*	-0.84 (-2.14, 0.46)	-0.47 (-1.76, 0.82)
Grade	4	520	Ref	Ref	Ref	Ref	Ref	Ref
	5	630	-0.49 (-2.04, 1.07)	-0.22 (-1.78, 1.34)	0.50 (-0.65, 1.65)	0.52 (-0.63, 1.67)	-0.22 (-1.81, 1.36)	0.20 (-1.38, 1.79)
	6	549	1.42 (-0.18, 3.03)	1.44 (-0.18, 3.05)	0.77 (-0.41, 1.96)	0.64 (-0.55, 1.83)	1.22 (-0.41, 2.86)	1.61 (-0.03, 3.25)
Energy intake (per 100 kilocalories)		1699	0.07 (-0.006, 0.13)	0.04 (-0.03, 0.1)	0.10 (0.06, 0.15)*	0.09 (0.04, 0.14)*	-0.16 (-0.23, -0.10)*	-0.19 (-0.25, -0.12)*
Material deprivation index[b]	Low	1221	Ref	Ref	Ref	Ref	Ref	Ref
	High	443	-3.22 (-4.65, -1.78)*	-3.05 (-4.52, -1.58)*	-1.18 (-2.25, -0.11)*	-0.87 (-1.96, 0.22)	-2.03 (-3.50, -0.56)	-2.54 (-4.03, -1.04)*
Social deprivation index[c]	Low	721	Ref	Ref	Ref	Ref	Ref	Ref
	High	943	1.41 (0.12, 2.70)*	1.24 (-0.09, 2.57)	1.20 (0.25, 2.15)*	1.03 (0.05, 2.02)*	-0.24 (-1.55, 1.08)	0.27 (-1.08, 1.62)
Region of residence	>10,000 residents	864	Ref	Ref	Ref	Ref	Ref	Ref
	<10,000 residents	800	1.58 (0.30, 2.86)*	1.84 (0.54, 3.14)*	0.95 (0.007, 1.89)*	0.90 (-0.06, 1.86)	0.79 (-0.51, 2.09)	1.25 (-0.06, 2.57)

Abbreviations: CI, confidence interval; HEI-C 2015, Healthy Eating Index-Canada 2015; DQI-I, Diet Quality Index-International; HEFI-2019, Healthy Eating Food Index 2019.

[a] HEFI-2019 scores have been recalibrated from a maximum of 80 to a maximum of 100 by multiplying the scores by 1.25.

[b] Low, combined 1-3 quantiles; high, combined 4-5 quintiles of the material deprivation index.

[c] Low, combined 1-2 quantiles; high, combined 3-5 quintiles of the social deprivation index.

*p-value<0.05

3.5. References

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Chapter 4: Discussion

4.1. Summary

In this thesis, I compared three population-based diet quality indices, HEI-C 2015, DQI-I, and HEFI-2019, aiming to explore potential variations in conclusions regarding applying each of these indices to the diet quality in a sample of Canadian school-age children. Dietary intake data from Canadian children, collected through a web-based 24-hour diet recall implemented in APPLE Schools over three years, was analyzed.

In this thesis, HEFI-2019 scores showed the widest range of variability, contrasting with the narrowest variability observed in DQI-I scores. The scores of HEI-C 2015, DQI-I, and HEFI-2019 were divided into quartiles, as there were no pre-defined cut-off points for HEI-C 2015 and HEFI-2019. Weighted Cohen's Kappa coefficients were employed, providing adjustment for chance agreement and facilitating easy interpretation. The agreement between HEI-C 2015 and HEFI-2019 scores, as well as between HEFI-2019 and DQI-I scores, was found to be fair, while moderate agreement was observed between HEI-C 2015 and DQI-I scores, suggesting that the choice of index could lead to different conclusions regarding children's diet quality.

Girls consistently exhibited superior diet quality to boys across all indices, with DQI-I displaying the greatest mean score difference. However, no significant association between grade level and diet quality was observed for any of the indices, likely due to the study's focus on grade 4-6 students who generally adhere to similar dietary patterns. This thesis employed area-based material and social deprivation indices to assess the capacity of the diet quality indices to distinguish between the diet quality of children from areas with diverse SES backgrounds. Canadian children with higher levels of material deprivation consistently demonstrated poorer dietary quality across all indices, which is especially evident in HEI-C 2015 and HEFI-2019 assessments. In contrast, children with higher levels of social deprivation tended to have marginally higher diet quality scores, notably significant when using DQI-I. Although the latter result was surprising, it was supported by one study emphasizing the role of single parents in compensating for the absence of another parent.[1]

Students residing in areas with smaller populations showed moderately better diet quality, with only HEI-C 2015 showing a statistically significant association after controlling for other variables. Finally, despite no significant association between HEI-C 2015 and energy intake, higher energy consumption corresponded to increased DQI-I scores but reduced HEFI-2019 scores, highlighting careful considerations in interpreting the results of the diet quality indices.

4.2. Interpretation

4.2.1. The HEI-C 2015, DQI-I and HEFI-2019 Scores Variability

The greater variability in HEFI-2019, and to a lesser extent in HEI-C 2015 scores compared to DQI-I scores[2, 3, 4] allows HEFI-2019, and to a smaller extent HEI-C 2015 to differentiate between individuals with various diet qualities more effectively compared to DQI-I. This is more understandable when we consider the common components present in HEI-C 2015, DQI-I, and HEFI-2019, such as sodium. Apart from a narrower range of standard scores for DQI-I compared to HEI-C 2015 and HEFI-2019, variations in scoring methods among indices seem to contribute significantly to the variability in the scores; in fact, HEI-C 2015 and HEFI-2019 assign a broad spectrum of scores from 0 to 10 to the children whose sodium consumption falls within predetermined standard levels,[2, 4] while DQI-I allocates only a score of 3 to those consuming between the standards for maximum and minimum scores, lead to a narrower range of possible scores (i.e., 0, 3, or 6 points) for all individuals.[3] The same scoring pattern is applied to other DQI-I components within the moderation (total fat, saturated fat, cholesterol, empty calorie foods), variety (overall food group variety, within-group variety for protein source), and overall balance (macronutrient ratio and fatty acid ratio) subgroups.[3]

While in this thesis, HEFI-2019 scores indicated greater variability when compared with HEI-C 2015 and especially DQI-I, Brassard et al. reported a score range of 27.6% to 78.6% for HEFI-2019, notably narrower than this thesis's results (8.6%-90.1%).[5] However, in their study, the mean HEFI-2019 scores for 9-13-year-old Canadian girls and boys were 48.37% and 47%, respectively, closely aligning with the mean score observed in this thesis (44.9%).[5] The score range discrepancy could be due to the larger sample size in the study by Brassard et al. (n=20,103) and their recruitment of a broader age range (≥two years). Another possible reason might be the use of usual dietary intake data in their investigation.

Regarding the HEI scores variability, the findings from Reedy et al.'s study on 7,935 individuals aged two years and older, revealed a similar yet slightly higher mean HEI-2015 score of 56.6 compared to that in this thesis, alongside a narrower score range of 32.6 to 81.2.[6] These disparities in HEI mean scores likely stem from variations in age range, sample size, and the choice of indices employed.

Gaudin et al.'s study of the diet quality among 3,956 Canadian students aged 6–18 years yielded results closely in line with those of this thesis, with the mean DQI-I score at 52.48 and the mean HEI-2015 score at 55.85. The consistency between the two studies was further supported by comparable CVs, with HEI-2015 and DQI-I showing CVs of 25.07% and 20.03%, respectively.[7]

In conclusion, the higher variability in HEFI-2019 and HEI-C 2015 scores compared to DQI-I highlights the impact of assessment methods on differentiating between individuals with different diet qualities, emphasizing the need for careful consideration of index selection in dietary studies.

4.2.2. Agreement Between HEI-C 2015, DQI-I, and HEFI-2019 Scores

Fair to moderate agreement between indices revealed in this thesis is expected considering the differences in indices' components, their respective contributions to the total score, as well as the standards and units of scoring across indices, notably between HEFI-2019 and the other two.[2, 3, 4] For example, while DQI-I and HEI-C 2015 evaluate both adequacy and moderation in dietary assessments, HEFI-2019 components do not follow the same categorization.[2, 3, 4] However, HEFI-2019 introduces unique components, beverages, evaluating water and unsweetened beverage intake, and plant-based protein foods.[4] Moreover, the scores allocated to the common food components vary across the indices, with the most notable difference observable in the fruit and vegetables component.[2, 3, 4] The last but not the least important difference between the indices lies in their various standards and units of scoring; both HEI-C 2015 and DQI-I assess individuals' compliance with dietary recommendations by considering their daily dietary requirements, typically measured in terms of food servings, dietary reference intake (DRI), recommended dietary allowance (RDA), or adequate intakes (AI),[2, 3] while HEFI-2019 assesses diet quality based on RA, which represents the amount of food usually eaten by an individual in one sitting.[4]

While many studies have explored the association between different diet quality indices through score agreements or correlations, none, to the best of my knowledge, has assessed the agreement between HEI and DQI-I or HEFI-2019 and DQI-I. In a study in 2022 by Brassard et al., the Pearson correlation coefficient for comparing HEI-2015 and HEFI-2019 was notably greater than that in this thesis [0.79 vs. 0.6 (Appendix D)].[5] This difference may stem from the use of HEI-2015 adaptation for the Canadian population used in this thesis.[2] In fact, HEI-C 2015 incorporates age-specific scoring standards (Appendix A), whereas HEI-2015 applies the same scoring standards across all age groups.[6] This variation, especially when considering the different age group in Brassard et al.' study (two years and older) compared to this thesis, could result in different HEI scores, potentially contributing to the observed differences in the correlation coefficients between HEI and HEFI-2019 in the two studies. Additionally, differences in studies sample sizes (20,103 vs.1,699 in this thesis) could lead to different studies' results by affecting the statistical power of the research.[8]

Fair to moderate agreement between the indices in this thesis suggests that the choice of a dietary quality index for Canadian children may lead to different conclusions due to variations in components, scoring standards, and units across the indices, particularly between HEFI-2019 and the other indices.

4.2.3. The HEI-C 2015, DQI-I and HEFI-2019's Ability to Differentiate Between Groups with Known Differences in Diet Quality.

The HEI-C 2015, DQI-I and HEFI-2019's Ability to Differentiate Between Girls and Boys

The stronger distinguishment between different sex's diet quality by DQI-I observed in this thesis may arise from the index's incorporation of unique nutrients and dietary components such as cholesterol, vitamin C, and macronutrient ratio (Appendices E-G), which are absent in HEI-C 2015 and HEFI-2019.[2, 3, 4] These findings are supported by numerous studies conducted in different years and countries. For instance, a review article analyzing diets across 185 countries from 1990 to 2018 using AHEI indicated that women tended to have superior diet quality compared to men, particularly in high-income countries, with higher scores for fruit, non-starchy vegetables, and whole grains.[9] Focusing on the Canadian population, females across various age groups, especially within the age range studied in this thesis, consistently demonstrated higher diet quality compared to males, as assessed by both HEI-C 2005 and HEFI-2019.[5, 10] This conclusion is further supported by similar findings for fruit and vegetables, and sodium from Health Canada.[11, 12]

The HEI-C 2015, DQI-I and HEFI-2019's Ability to Differentiate Between Grade Levels

Previous studies, to the best of my knowledge, typically studied a wider age range,[13, 14, 15] making it difficult to directly compare with the specific age range recruited in this thesis. This might stem from the fact that dietary guidelines typically group 9-12-year-old children together due to their similar dietary requirements. This, in turn, justifies the result of this thesis of no statically significant difference between students' diet quality at different grade levels (as a proxy for age groups within the 9 to 12 age range).

The HEI-C 2015, DQI-I and HEFI-2019's Ability to Differentiate Diet Quality Between Students with Different Levels of Area-based Material and Social Deprivations

One possible explanation for the stronger inverse association between the average scores of HEI-C 2015 and HEFI-2019 and students' material deprivation level compared to DQI-I scores could be that in this thesis, HEI-C 2015 and HEFI-2019 reflected lower diet quality, particularly in terms of specific components (i.e., fruit and vegetables, whole grain and added sugar for HEI-C 2015 and free sugar, healthy beverages, and fatty acid ratio for HEFI-2019), among students residing in more materially deprived areas, whereas DQI-I did not show significant differences in the consumption of equivalent dietary components (i.e., vegetables, fruit, and empty calory food groups) between students from high and low materially deprived regions (Appendices H-J).

In essence, the material deprivation index reflects broader community-level factors related to SES, which can have significant implications for children's access to healthy foods and diet quality. The index components (i.e., area-level unemployment, as well as education and income levels)[16] offer a more comprehensive understanding of the socioeconomic environment in which children are raised beyond just household income or parental education levels. Few studies evaluated the association between children's diets and neighbourhood material deprivation index; one study evaluated the association between school region SES (the median family income based on the location's postal code and the type of school [public or private]) and diets of 2,621 students in grades 9 and 10 from 53 high schools in Alberta and Ontario.[17] Aligned with this thesis's results, they observed school region SES positively associated with the average daily intake of fruit and vegetables, and fibre while inversely associated with students' added sugar intake.[17] Similarly, in concordance with this thesis’s outcomes, a study recruiting 3,348 students aged 11-19 years from the UK revealed that adolescents residing in areas with lower SES consumed lower fruit and vegetables and higher added sugar and energy drinks compared to those in the least deprived areas.[18] While the two last studies similar to this thesis employed area-based SES, they used the amount of separate food groups consumption instead of evaluating the whole diets by diet quality indices.

On the other hand, there are some Canadian studies employing indices comparable to those evaluated in this thesis while mainly assessing individual-level SES. These studies found small to no association between diet quality and household income.[10, 14] However, they demonstrated a more significant association between diet quality and households' education levels: using HEI-C 2005, Garriguet et al. observed that a significant increase in mean HEI-C 2005 scores was associated with households' education levels, alongside a slight, albeit statistically nonsignificant, rise in the scores across higher quantiles of household income among Canadian children aged 2-11 years.[10] Similarly, another study on Canadian children aged 6-17 revealed that children from households with higher levels of education tended to score higher on the school-HEI, whereas this association was not observed in children from higher-income households.[14] Overall, taking into account these results and the findings of this thesis, the HEI has the capability to differentiate diet quality variations among students with different individual and area-level SES.

While no previous study has specifically investigated the relationship between HEFI-2019 scores and SES, Rochefort et al. conducted a study in 2022 that explored the link between HEFI-2019 scores and daily dietary costs, involving 1,147 individuals.[19] After adjusting for energy intake, they observed that a higher HEFI-2019 score (the 75th percentile vs. the 25th percentile) was associated with a 1.09 $CAD increase in daily dietary expenditure based on the 2016 food price database.[19]

The discrepancy between indices studied in this thesis in terms of differentiating diets of children in different levels of social deprivation could be explained by a similar rationale for the material deprivation index as more dietary components included in the DQI-I (i.e., grain group, fruit group, fibre, calcium, and vitamin C) may contribute to greater differentiation between individuals residing in various socially deprived areas compared to the HIE-C 2015 (i.e., fruit and vegetables, whole fruit, and whole grains) and HEFI-2019 (i.e., saturated fat and sodium) (Appendices H-J).

The social deprivation index reflects the population's marital status, proportion of individuals living alone and rates of single-parent households.[16] Previous studies' findings were inconsistent regarding the association between diet quality and social deprivation. A longitudinal study on 1,114 Chinese children examined the effect of one parent leave on children's food and nutrient consumption.[1] In concordance with this thesis's findings, their results indicated that children raised in single-parent households not only did not experience detrimental effects on their food consumption and nutritional intake, but they also had even better dietary status than their counterparts living in dual-parent families, since their single parents tend to provide more food to compensate for the absence of the other parent.[20] Similarly, a Canadian study revealed that single mothers frequently prioritize their children's diets over their own, leading to children consistently having more adequate intakes of several nutrients, including vitamin C, vitamin A, thiamin, riboflavin, vitamin B6, vitamin B12, and iron.[21] Additionally, research has shown that Canadian children from single-parent families have significantly higher calcium and meat consumption.[22, 23] Despite that, the results of the Korean study on 3,217 3-18-year-old children and adolescents found that children living with one parent had a lower intake of fruit, and milk and dairy products compared to children living with both parents.[24]

It is worth noting that methods used to assess children's diets and social deprivation in all abovementioned studies were different from those employed in this thesis. These studies typically focused on evaluating specific nutrients or food groups rather than assessing the whole diet quality of children and used individual-level rather than area-level measures of social deprivation. These differences may affect the comparability of their results with those of this thesis. However, the findings of this thesis and the mentioned studies, regardless of whether their results align with or contradict the findings presented here, indicate the significant effects of individual- and area-level social deprivation on children's diet quality that could differ in different societies with different SES.

The HEI-C 2015, DQI-I and HEFI-2019's Ability to Differentiate Diet Quality Between Students Residing in Areas with Different Population Densities

The higher robustness of HEI-C 2015 in discerning diet quality variations across students residing in regions with different population densities compared to two other indices, as observed in this thesis, could be attributed to the unique dietary components of HEI-C 2015, which are scored differently among children living in areas with populations over or under 10,000, such as fruit and vegetables (i.e., total fruit and vegetables, and whole fruit), grains (i.e., whole grains, and greens, and beans), and a separate component for milk and dairy intake (Appendices H-J).

In line with this thesis results, Tugault-Lafleur et al. observed a slightly better diet quality among rural students than those in urban areas in a sample of 4,728 6-17-year-old students using school-HEI.[14] Nevertheless, this association was not statistically significant. Using DQI-I, Gaudin et al. demonstrated a lower diet quality among rural students compared to their urban counterparts, contrasting with this thesis's findings.[7] This disparity may arise from variations in studies' sample sizes, the classification method employed for classifying areas of residence (e.g., defining areas with fewer than 1,000 residents as rural), and the absence of participants from metropolitan areas in this thesis.

4.2.4. The HEI-C 2015, DQI-I and HEFI-2019's Ability to Assess Diet Quality Independent of Diet Quantity

Consistent with this thesis's results, Reedy et al. observed a slight and statistically insignificant association between total HEI-2015 scores and energy intake.[6] A possible explanation could be that HEI-2015 incorporates total energy intake into each component's score calculation.[6]

Regarding the association between HEFI-2019 scores and energy intake, in line with this thesis results, a study by Brassard et al. showed a similar inverse Pearson correlation coefficient between the index's scores and energy intake (r=-0.13 vs. r=-0.12 in this thesis)[15] (Appendix K). This could be attributed to certain components with inverse correlation with energy intake, particularly beverages, which show the strongest inverse correlation with energy intake (r=-0.17) (Appendix K). Thus, it is suggested that users of the index consider energy intake when examining trends in diet quality over time or differences among groups using the HEFI-2019.

4.3. Strengths and Limitations

This study presents both strengths and limitations that warrant consideration. Utilizing dietary data from APPLE Schools through a validated web-based 24-hour diet recall[25] among Canadian school-age children enhances the accuracy and relevance of the gathered dietary information. Additionally, the study's large sample size ensured adequate variation in students' diet quality, reinforcing the robustness of the findings. Furthermore, including well-established and validated area-level material and social deprivation indices[16] allowed for assessing how diet quality indices differentiate diet quality across Canadian children with diverse socioeconomic backgrounds, providing insights into broader community-level SES factors influencing access to nutritious foods and overall dietary habits.

While it has several strengths, this thesis also faces a number of potential limitations. One such limitation is the reliance on collecting 24-hour dietary recalls at a single time point, which may not fully capture participants' usual dietary intakes. Although obtaining data from multiple recalls would offer a usual dietary intake representation, the logistical challenges and burden on participants and school administrations make this approach impractical for school-based epidemiological studies. Of note, repeated recalls from a subset of participants are necessary to estimate the distribution of usual intakes, particularly for prevalence estimates above or below specific thresholds, a task that falls outside the scope of this thesis.[26] However, a single recall suffices to estimate the mean usual intakes,[26] which was used in the study presented in this thesis.

Another limitation lies in the reliance on self-reported dietary intake, which introduces the potential for measurement error. Individuals, especially children, may struggle to recall the type and amount of food consumed accurately, leading to inaccuracies in reported intake levels. However, the burden of memory may be less for 24-hour dietary recall than that of the FFQ, which requires recall over a longer period.[27] Additionally, social desirability bias may influence participants to underreport unhealthy eating habits or overreport healthy ones, further complicating the interpretation of the data;[26] however, using a web-based 24-hour diet recall in this thesis helped mitigate this bias to some extent compared to traditional paper-based 24-hour dietary recall.[28, 29] Despite these limitations, 24-hour recall methods offer a more detailed account of all foods and beverages consumed over the previous day, exhibiting less bias compared to FFQ.[27] Lastly, this thesis mainly focused on Canadian school-aged children from areas with fewer than 100,000 inhabitants due to a lack of data from major cities like Montreal, Toronto, and Vancouver, which could limit the generalizability of the findings to the populations residing in metropolitan areas. A limitation of cross-sectional studies is their inability to determine causality, and this thesis is no exception. However, assessing causal relationships was not an objective of this thesis and did not substantially impact the findings of this thesis.

4.4. Public Health Implications

This thesis has several important practical implications for public health. Prioritizing children's health and well-being, particularly their diet quality, is a prudent investment for public health. This is because the dietary intake preferences developed in childhood play a pivotal role in shaping long-term health outcomes, as they tend to persist into adulthood.[30] This is more understandable when considering the physical, social, and mental health-related consequences of poor diet quality and its burdens on public health. Diet-related health issues like obesity and chronic diseases such as cancers, CVD, and T2D stand as the leading causes of death and sickness in Canada.[31] In 2021, nearly half of the Canadians, accounting for 45%, were suffering from at least one major chronic disease, with one in 12 individuals having three or more chronic conditions.[32] These health issues constitute the largest proportion of Canada's annual healthcare costs,[33] and they are responsible for 65% of all deaths in Canada.[34] Poor diet quality was linked to approximately 48,000 deaths in Canada, resulted in over 800,000 years of disability in 2016[35] and was recognized to be responsible for CAD 15.8 billion of direct and indirect costs of chronic diseases in Canada in 2018.[36] Poor diet quality is also associated with children's adverse mental health like depression and anxiety.[37] In addition, children's HRQoL, which in addition to physical and mental health includes social well-being, is affected by poor diet quality.[38] Poor diet quality is also associated with school-age children's poor academic performance.[39, 40]

These health and well-being issues have the potential to be prevented or alleviated by adhering to a healthy diet. Canadian children's dietary intake, as analyzed by Health Canada, reveals that approximately 10% of fruit and vegetables, about 30% of protein-rich foods, over 40% of whole grain foods, and more than 50% of other consumed foods do not align with the recommendations in the CFG.[41] Given the poor diet of Canadian children, the burden of diet-related health issues in Canada, and the crucial role of a healthy diet in mitigating these conditions, improving Canadian children's diets has become as a pressing priority for public health decision-makers in Canada. Apart from the latest Health Canada's healthy eating strategies, including improving healthy eating information, improving nutrition quality of foods, and protecting vulnerable groups from food advertising[42] as well as applying tax on sugar-sweetened beverages,[43] which indirectly improve Canadians' diet quality and are beyond this thesis scope, school meal programs have considered as a cost-effective strategy to improve school-age Canadian children diet quality. Globally, school meals have proven to be highly effective in enhancing health, education, and economic growth, delivering a return on investment ranging from $3 to $10 for every dollar spent.[44]

In 2018/19, meals and snacks were provided to 1,018,323 Canadian students, largely supported by a collective of over $93 million in provincial and territorial funding, with less than a quarter contribution from the government.[45] A new national school food program was recently introduced by the prime minister of Canada, funded with $1 billion over five years from Budget 2024.[46] This initiative aims to extend meal services to an extra 400,000 children each year, surpassing current school food program coverage.[46] As Canadian policymakers lay out such a program, they should consider the key prerequisites and fundamental approaches to enhance the success of the program, such as comprehending Canadian children's nutritional deficiencies and dietary intakes, recognizing the vulnerable groups, and determining the other modifiable risk factors responsible for this population's poor diet. Reaching these objectives first involves getting access to an optimal diet quality index to evaluate Canadian children's diet quality. In recent years, various indices emphasizing different aspects of diet quality, have been employed to assess Canadian children's diet status. This could lead to several public health concerns and necessitates a consensus on the most appropriate diet quality index for evaluating Canadian children’s diets because:

- The choice of the diet quality index, as highlighted in this thesis, affects the interpretation of the research outcomes and practical considerations. Employing various diet quality indices could generate confusion among policymakers regarding what constitutes a healthy diet and how to achieve it, preventing them from understanding Canadian children's dietary requirements.
- This could cause inconsistent dietary recommendations and policies for Canadian children, posing challenges in establishing effective dietary intervention programs

such as the national school food and nutrition education programs for Canadian children.

- This could lead to inconsistent interpretations of Canadian children's diet quality, making it challenging to compare studies' results and the formation of practical conclusions. Thus, despite substantial resources devoted to numerous studies, designing and implementing consistent and effective dietary interventions for Canadian children would remain challenging.
- Applying different diet quality indices can make it difficult to monitor dietary intervention programs, track the trends in Canadian children's diets over time, and accurately compare the effectiveness of different dietary interventional approaches. This can eventually cause a waste of allocated resources due to inconsistency in dietary intervention prioritization.
- An optimal diet quality index provides clear metrics, ensuring that policymakers effectively allocate resources to the areas where interventions are most required, guided by evidence of the Canadian children's diet quality status.

Thus, policymakers must reach a consensus on the most appropriate diet quality index for evaluating Canadian children's diet. This thesis demonstrated the efficacy of frequently used diet quality indices in comparison with each other to assess Canadian children's diet quality. It also explained the key criteria for determining the population's optimal diet quality index and, consequently, provided recommendations to enhance the latest Canadian diet quality index to suit the Canadian children population better. Therefore, this thesis's results facilitate the agreement among researchers and public health decision-makers regarding the most appropriate index for evaluating Canadian children's diet quality by clearly uncovering differences between frequently used indices. This can be considered as an initial and pivotal step to improve Canadian children's short-term and long-term diet quality and health status.

4.5. Recommendations for Future Studies

This thesis was the initial endeavour to compare established and frequently employed diet quality indices among Canadian school-age children, providing novel perspectives on dietary evaluation approaches tailored to this specific population. However, there is a need for future research to delve deeper into the comparative analysis of common diet quality indices among Canadian children, investigating their ability to track changes in diet quality over time and compare their effectiveness in evaluating diet quality following nutritional interventions among Canadian children.

In this thesis, material and social deprivation indices were utilized to evaluate how well the diet quality indices could differentiate between the diet quality of children from different socioeconomic backgrounds. While these indices offer insight into broader community-level socioeconomic factors impacting access to healthy foods, they do not encompass individual-level SES indicators like household income or parental education level, which have been shown to influence children's diets in previous studies.[14, 47] Future investigations should also consider other potential contributing factors to Canadian children's diets, such as ethnicity, immigration status and food security, given Canada's multicultural landscape.

Furthermore, future studies are recommended to assess how well these diet quality indices predict health outcomes among Canadian children by conducting prospective studies. In addition, given the focus of this thesis on Canadian school-aged children primarily from areas with fewer than 100,000 inhabitants and the absence of dietary information from major cities like Montreal, Toronto, and Vancouver, future studies are suggested to include children from diverse geographic areas, spanning from metropolitan regions with over 100,000 residents to rural areas with fewer than 1,000 residents.

This thesis highlighted the pivotal criteria for an optimal diet quality index among Canadian children and identified the essential approaches to address the indices' limitations. For example, the absence of established cut-off points for HEFI-2019 scores restrains the classification of diets based on their healthfulness, restricting the comprehensive comparison of diet quality indices and limiting the identification of groups with the highest priority for dietary improvement. Determining cut-off points for HEFI-2019 scores is recommended as one of the future practices to improve the index. Furthermore, the inverse association between the average HEFI-2019 score and Canadian children's mean energy intake suggests a need for revision in scoring methods to address this drawback. This is very important because without this revision, measuring the accurate diet quality of the population would be impossible, leading to confusion for policymakers on what features a healthy diet has, misguiding future dietary interventions. Such an index may not accurately reflect the effects of dietary interventions correctly as it conflates diet quality with energy intake. Finally, public health resources would mistakenly allocate to target diet quantity rather than focusing on improving diet quality. This has the potential to increase costs without significant health benefits.

Moreover, it is essential for future studies to ensure that higher HEFI-2019 scores are positively linked to adequate nutrient intake among Canadian children, especially considering previous findings that have shown an inverse relationship between higher HEFI-2019 scores and essential nutrients like folate, vitamin D, and calcium in older adults.[48] Future investigations should aim to address these limitations and revise HEFI-2019 to enhance its accuracy in assessing diet quality in Canadian children. Finally, it is also worth mentioning that in this thesis, HEFI-2019 was less effective at differentiating between different groups' diet quality than HEI-C 2015, likely due to HEFI-2019's use of standards intended for a broader age range. This emphasizes the significance of establishing age-specific dietary recommendations by the government of Canada to enhance adherence to dietary recommendations and more accurately assess Canadian children's diets. Future studies should revise HEFI-2019's scoring methods to ensure an accurate evaluation of Canadian children's diet quality, considering their specific dietary requirements based on age.

4.6. Conclusion

This thesis highlights the critical impact of selecting an optimal diet quality index for Canadian school-age children on interpreting research findings and formulating practical strategies. Therefore, researchers, practitioners, and policymakers must establish a consensus regarding selecting and utilizing one suitable diet quality index in various studies and projects among Canadian children. Among the three indices investigated in this thesis, HEFI-2019 is the most contemporary, aligning with the dietary recommendations outlined in the CFG-2019 and reflecting current insights into diet quality assessment. However, despite its strengths, HEFI-2019 presents limitations that warrant attention in future research endeavours. One of the HEFI-2019 limitations that must be addressed is the lack of cut-off points for distinguishing high-quality diets from low-quality ones. Additionally, the index's dependence on energy intake is another drawback. Finally, using scoring standards specifically tailored for Canadian children is also expected to make this index more efficient in evaluating Canadian children's diet quality.

4.7. References

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Appendices

Appendix A: HEI-C 2015 components, points and standards for scoring

	Component	Maximum points	Standard for Maximum points	Standard for Minimum Score of Zero
Adequacy	Total Fruits[a] and Vegetables[b]	10	6 servings	No Fruits and Vegetables
	Whole Fruits[c,d]	5	1.26 servings	No Whole Fruits
	Greens and Beans[e,f]	5	0.63 servings	No dark green vegetables or Legumes
	Whole Grains[g,h]	10	3 servings	No whole Grains
	Dairy[i]	10	3-4 servings	No Dairy
	Total Protein Foods[j]	5	1-2 servings	No Protein Foods
	Seafood & Plant Proteins[k,l]	5	0.32-0.64 servings	No seafood or Plant Proteins
	Fatty Acids	10	(PUFA + MUFA)/SFA≥2.5	(PUFA + MUFA)/SFA≤1.2
Moderation	Refined Grains	10	<50% of grains refined	100% of grains refined
	Sodium[m]	10	≤UL (2200 mg/day)	≥2 x UL (4400 mg/day)
	Added Sugars	10	≤6.5% of energy	≥26% of energy
	Saturated Fats	10	≤8% of energy	≥16% of energy

Abbreviations: HEI-C 2015, Healthy Eating Index-Canada 2015; PUFA, polyunsaturated fatty acids; MUFA, monounsaturated fatty acids; SFA, saturated fatty acids; UL, Tolerable Upper Intake Level.

Note: Standards for scoring are based on Canada's Food Guide (CFG)-2007dietary recommendations for 6-11-year-old children.

[a]Total fruit includes all fresh, frozen, canned, and dried fruits and fruit juices.

[b]Total vegetables includes dark green vegetables, red and orange vegetables, legumes, starchy vegetables, and other vegetables (fresh, frozen, canned, cooked, raw, juice).

[c]Includes all forms of fruit except juice; this category was created in HEI-2005 because Dietary Guidelines for Americans (DGA) 2005-2010 suggested that the majority of fruit intake should be whole fruit rather than fruit juice.

[d]Standard for maximum score of "whole fruit" component represents 21% of the "vegetables and fruits" recommendations in CFG.

[e]Greens and beans includes dark green vegetables (e.g., broccoli, spinach, romaine, kale) and legumes (e.g., kidney beans, white beans, lentils, chickpeas).

[f]Standard for maximum score of "greens and beans" component represents 10.5% of the "vegetables and fruits" recommendations in CFG.

[g]The standard for maximum score of "whole grains" component is 50% of the "grain products" recommendation in CFG.

[h]Whole grains include all whole-grain products and whole grains used as ingredients (e.g., whole-wheat bread, oatmeal, quinoa, brown rice).

[i]Milk/dairy includes all milk, including lactose-free and lactose-reduced products and fortified soy beverages (soymilk), yogurt, cheese.

[j]Total protein foods includes all seafood, meats, poultry, eggs, soy products, nuts, legumes, and seeds.

[k]The standard for maximum score of "seafood and plant proteins" component represents 32% of the "meat and alternatives" recommendation in CFG.

[l]Seafood and plant proteins includes all seafood, nuts, seeds, legumes, and soy products (except for soy beverages).

[m]Sodium intake is based on Institute of Medicine Dietary Reference Intake and Tolerable Upper Level of Intake 2006 iteration.

Appendix B: DQI-I components, points and standards for scoring

	Component	Maximum points	Scoring criteria
Variety	Overall food group variety (meat/poultry/fish/eggs; dairy/beans; grains; fruit; vegetables)	15	≥1 serving from each food group/day = 15 Any 1 food group missing/day = 12 Any 2 food groups missing/day = 9 Any 3 food groups missing/day = 6 ≥4 food groups missing/day = 3 None from any food groups = 0
	Within-group variety for protein source (meat; poultry; fish; dairy; beans; eggs)	5	≥3 different sources/day = 5 2 different sources/day = 3 1 source/day = 1 None = 0
Adequacy	Vegetable group	5	≥3-5 servings/day = 5 Proportionately scored in between 0 servings/day = 0
	Fruit group	5	≥2-4 servings/day = 5 Proportionately scored in between 0 servings/day = 0
	Grain group	5	≥6-11 servings/day = 5 Proportionately scored in between 0 servings/day = 0
	Fiber	5	≥20-30 grams/day = 5 Proportionately scored in between 0 grams/day = 0
	Protein	5	≥10% of energy/day = 5 Proportionately scored in between 0% of energy/day = 0
	Iron	5	≥100% RDA (AI)/day = 5 Proportionately scored in between 0% RDA (AI)/day = 0
	Calcium	5	≥100% AI/day = 5 Proportionately scored in between 0% AI/day = 0
	Vitamin C	5	≥100% RDA (RNI)/day = 5

			Proportionately scored in between 0% RDA (RNI)/day = 0
Moderation	Total fat	6	≤20% total energy/day = 6 >20-30% total energy/day = 3 >30% total energy/day = 0
	Saturated fat	6	≤7% total energy/day = 6 >7-10% total energy/day = 3 >10% total energy/day = 0
	Cholesterol	6	≤300 milligrams/day = 6 >300-400 milligrams/day = 3 >400 milligrams/day = 0
	Sodium	6	≤2400 milligrams/day = 6 >2400-3400 milligrams/day = 3 >3400 milligrams/day = 0
	Empty calorie foods[a]	6	≤3% total energy/day = 6 >3-10% total energy/day = 3 >10% total energy/day = 0
Overall balance	Macronutrient ratio (carbohydrate:protein:fat)	6	55-65:10-15:15-25 = 6 52-68:9-16:13-27 = 4 50-70:8-17:12-30 = 2 Otherwise = 0
	Fatty acid ratio (PUFA:MUFA:SFA)	4	PUFA/SFA = 1-1.5 and MUFA/SFA = 1-1.5 = 4 Else if PUFA/SFA = 0.8-1.7 and MUFA/SFA = 0.8-1.7 = 2 Otherwise = 0

Abbreviations: DQI-I, Diet Quality Index-International; DRI, Dietary Reference Intakes; RDA, Recommended Dietary Allowance; AI, Adequate Intakes; RNI, Recommended Nutrient Intake; PUFA, polyunsaturated fatty acids; MUFA, monounsaturated fatty acids; SFA, saturated fatty acids.

[a]Assesses how much a person's energy supply is dependent on low nutrient-density foods, which provide only energy but insufficient nutrients. Foods such as table sugar, oil and alcohol are examples of empty calorie foods.

Appendix C: HEFI-2019 components, points and standards for scoring

Component	Measurement (ratio)	Max Points	Unit	Standard for Minimum score	Standard for Maximum score
Vegetables and fruits	Total vegetables and fruits[a] / Total foods[b]	20	RA/RA	No vegetables and no fruits	≥0.50
Whole-grain foods	Total whole-grain foods[c]/ Total foods[d]	5	RA/RA	No whole-grain foods	≥0.25
Grain foods ratio	Total whole-grain foods[c]/ Total grain foods[d]	5	RA/RA	No whole-grain foods	1.0
Protein foods	Total protein foods[e] / Total foods[b]	5	RA/RA	No Protein foods	≥0.25
Plant-based protein foods	Plant-based protein foods[f] / Total protein foods[e]	5	RA/RA	No plant-based protein foods	≥0.50
Beverages	(Plain water including carbonated + unsweetened beverages)[g]/ Total beverages[h]	10	g/g	No water and no unsweetened beverages	1.0
Fatty acids ratio,	(Mono- + polyunsaturated fat) / Total saturated fat	5	g/g	≤1.1[i]	≥2.6[j]
Saturated fats	Total saturated fat / energy	5	%E (kcal/kcal)	≥15%E[k]	<10%E
Free sugars	Total free sugars / energy	10	%E (kcal/kcal)	≥20%E[k]	<10%E
Sodium	Total sodium / energy	10	Mg/kcal	≥2.0[k]	<0.9[l]

Abbreviations: HEFI-2019, Healthy Eating Food Index-2019; RA, Reference Amounts (amount of food usually eaten by an individual at 1 sitting, defined as the Table of Reference Amounts in Health Canada 2016); %E, percent of total energy.

[a]All whole, dried and canned vegetables and fruits, regardless of saturated fat, sodium or free sugar content; excludes fruit juice (i.e., considered as sugary drinks in CFG-2019). All types of potatoes irrespective of preparation method (e.g., oven-cooked, boiled, fried) are also included. On the new food guide, 100% juice is not included with vegetables and fruits.

[b]Includes all foods consumed as well as beverages considered in protein foods (i.e., unsweetened milk and unsweetened plant-based beverages that contain protein); excludes all other beverages as well as solid fats, oils and spreads and culinary ingredients (e.g., spices and baking soda).

[c]Foods where the first ingredient is either whole grains or whole wheat, regardless of saturated fat, sodium or free sugar content.

[d]Foods where the first ingredient is grains (whole or not) regardless of saturated fat, sodium or free sugar content.

[e]All protein foods regardless of fat, sodium or sugars content; excludes processed meats (i.e., not considered protein foods in CFG-2019) and sweetened milks (i.e., considered as sugary drinks in CFG-2019).

[f]All plant-based protein foods, regardless of saturated fat, sodium or free sugar content.

[g]Unsweetened beverages include (unsweetened) coffee and tea, (unsweetened) milk and plant-based beverages.

[h]Total beverages include water (plain or carbonated), coffee, tea, milk and plant-based beverages, fruit and vegetable juices, alcoholic drinks, artificially sweetened beverages and sugary drinks.

[i]Approximately the 15th percentile of intake based on data (single 24-hour recall) in Canadians from the 2015 CCHS-Nutrition.

[j]Corresponds to the 1st percentile of unsaturated to saturated fats ratios among simulated diets developed to be fully consistent with all recommendations in CFG-2019.

[k]Approximately the 85th percentile of intake based on data (single 24-hour recall) in Canadians from the 2015 CCHS-Nutrition.
[l]Standard for maximum points based on the CDRR for 14+ years (i.e., 2300 mg) over the 90th percentile of usual energy intakes in respondents aged 2 years and older from the 2015 CCHS-Nutrition (i.e., approximately 2600 kcal, see Brassard et al. 2022 for details).

Appendix D: Estimated correlations between HEI-C 2015, DQI-I, and HEFI-2019 total scores, based on dietary intakes of Canadian children (n=1,699)

Index	**DQI-I**	**HEFI-2019[a]**	**HEI-C 2015**
DQI-I	1		
HEFI-2019[a]	0.40*	1	
HEI-C 2015	0.63*	0.60*	1

Abbreviations: HEI-C 2015, Healthy Eating Index-Canada 2015; DQI-I, Diet Quality Index-International; HEFI-2019, Healthy Eating Food Index 2019.
[a]HEFI-2019 scores have been recalibrated from a maximum of 80 to a maximum of 100 by multiplying the scores by 1.25.
*p-value<0.001

Appendix E: Estimated mean (SD) of HEI-C 2015 components and total scores over different sexes, based on dietary intakes of Canadian children (n=1,699)

Component	Sex		
	Girls (n=874)	**Boys (n=825)**	**p-value**
Total fruits and vegetables	5.33 (3.4)	4.46 (3.36)	<0.001*
Whole fruit	2.56 (2.28)	2.15 (2.28)	<0.001*
Greens and beans	1.18 (1.89)	1.32 (1.97)	0.121
Whole grains	3.99 (3.75)	4.48 (3.94)	0.008*
Milk and dairy	6.02 (3.54)	6.18 (3.6)	0.347
Total protein foods	4 (1.75)	4.23 (1.63)	0.007*
Seafoods and plant proteins	0.94 (1.94)	1.14 (2.08)	0.041*
Fatty acids	4.58 (3.52)	4.45 (3.6)	0.479
Refined grains	3.78 (3.68)	4.05 (3.75)	0.128
Sodium	6.12 (3.99)	5.59 (4.19)	0.008*
Added sugars	7.95 (2.74)	8.05 (2.76)	0.48
Saturated fats	1.34 (2.04)	1.22 (2.06)	0.227
Total HEI-C	51.69 (12.63)	50.88 (13.86)	0.211

Abbreviations: SD, standard deviation; HEI-C 2015, Healthy Eating Index-Canada 2015.
*p-value<0.05

Appendix F: Estimated mean (SD) of DQI-I components and total scores over different sexes, based on dietary intakes of Canadian children (n=1,699)

Component	**Sex**		
	Girls (n=874)	**Boys (n=825)**	**p-value**
Overall food group variety	10.95 (3.04)	10.85 (3.06)	0.47
Within-group variety for protein source	3.07 (1.52)	3.27 (1.51)	0.007*
Grain group	3.87 (1.3)	4 (1.25)	0.025*
Vegetable group	1.86 (1.65)	1.43 (1.48)	<0.001*
Fruit group	2.64 (2.07)	2.22 (2)	<0.001*
Fiber	3.22 (1.21)	3.16 (1.21)	0.391
Protein	4.88 (0.41)	4.94 (0.3)	0.002*
Iron	4.73 (0.72)	4.78 (0.63)	0.111
Calcium	3.12 (1.46)	3.27 (1.5)	0.038*
Vitamin C	3.9 (1.68)	3.59 (1.85)	<0.001*
Total fat	1.46 (2)	1.28 (1.94)	0.057
Saturated fat	1.34 (2.04)	1.22 (2.06)	0.227
Cholesterol	4.28 (2.57)	3.87 (2.67)	0.001*
Sodium	3.18 (2.61)	2.89 (2.66)	0.028*
Empty calorie foods	1.35 (2.08)	1.89 (2.32)	<0.001*
Macronutrient ratio	0.63 (1.38)	0.48 (1.2)	0.016*
Fatty acid ratio	0.32 (0.89)	0.26 (0.83)	0.197
Total DQI-I	54.8 (9.52)	53.42 (10.01)	0.004*

Abbreviations: SD, standard deviation; DQI-I, Diet Quality Index-International.
*p-value<0.05

Appendix G: Estimated mean (SD) of HEFI-2019 components and total scores over different sexes, based on dietary intakes of Canadian children (n=1,699)

Component	Sex		p-value
	Girls (n=874)	**Boys (n=825)**	
Vegetables and fruits	7.15 (5.8)	5.47 (5.3)	<0.001*
Whole-grain foods	1.22 (1.53)	1.42 (1.69)	0.01*
Grain foods ratio	1.3 (1.66)	1.53 (1.81)	0.005*
Protein foods	3.45 (1.72)	3.63 (1.68)	0.031*
Plant-based protein foods	0.37 (1.19)	0.5 (1.34)	0.031*
Beverages	6.21 (3.43)	6.23 (3.62)	0.9
Fatty acids ratio	1.48 (1.53)	1.47 (1.54)	0.862
Saturated fats	3 (2.02)	2.8 (2.07)	0.039*
Free sugars	6.23 (4.01)	6.76 (3.99)	0.007*
Sodium	5.83 (3.51)	5.81 (3.41)	0.891
Total HEFI-2019	45.31 (13.38)	44.53 (13.66)	0.235

Abbreviations: SD, standard deviation; HEFI-2019, Healthy Eating Food Index 2019.
HEFI-2019 scores have been stretched from a maximum of 80 to a maximum of 100 by multiplying the scores by 1.25.
*p-value<0.05

Appendix H: Estimated mean (SD) of the HEI-C 2015 components and total scores over different material and social deprivation levels and regions with over and under 10,000 residents, based on dietary intakes of Canadian children (n=1,699)

Component	Material deprivation level		p-value	Social deprivation level		p-value	Region of residence		p-value
	Low (n=1221)	High (n=443)		Low (n=721)	High (n=943)		Over 10,000 residents (n=864)	Under 10.000 residents (n=800)	
Total fruits and vegetables	5.09 (3.49)	4.46 (3.15)	<0.001*	4.54 (3.28)	5.21 (3.5)	<0.001*	4.66 (3.39)	5.2 (3.43)	0.001*
Whole fruit	2.43 (2.31)	2.18 (2.23)	0.054	2.22 (2.25)	2.47 (2.32)	0.033*	2.16 (2.29)	2.58 (2.28)	<0.001*
Greens and beans	1.27 (1.96)	1.18 (1.86)	0.412	1.15 (1.83)	1.32 (2)	0.060	1.14 (1.9)	1.36 (1.96)	0.017*
Whole grains	4.41 (3.94)	3.67 (3.58)	<0.001*	4 (3.72)	4.38 (3.96)	0.045*	4 (3.8)	4.44 (3.91)	0.019*
Milk and dairy	6.21 (3.6)	5.77 (3.49)	0.027*	5.97 (3.5)	6.18 (3.64)	0.241	5.88 (3.59)	6.32 (3.55)	0.013*
Total protein foods	4.14 (1.68)	4.07 (1.73)	0.454	4.13 (1.65)	4.12 (1.72)	0.883	4.08 (1.74)	4.17 (1.64)	0.279
Seafoods and plant proteins	1.08 (2.05)	0.9 (1.9)	0.092	1.03 (2.01)	1.04 (2.01)	0.939	1.06 (2.03)	1.01 (1.99)	0.614
Fatty acids	4.58 (3.6)	4.34 (3.43)	0.214	4.4 (3.6)	4.6 (3.53)	0.248	4.53 (3.59)	4.5 (3.52)	0.853
Refined grains	4 (3.76)	3.61 (3.6)	0.056	4.01 (3.77)	3.81 (3.68)	0.278	3.74 (3.69)	4.06 (3.74)	0.078
Sodium	5.65 (4.12)	6.44 (3.97)	<0.001*	6.23 (4.04)	5.57 (4.12)	0.001*	6.13 (4.04)	5.56 (4.14)	0.004*
Added sugars	8.14 (2.64)	7.69 (2.96)	0.003*	7.99 (2.84)	8.04 (2.66)	0.740	8.01 (2.77)	8.03 (2.71)	0.910
Saturated fats	1.35 (2.09)	1.07 (1.91)	0.012*	1.21 (1.96)	1.33 (2.11)	0.270	1.37 (2.13)	1.18 (1.95)	0.063
Total HEI-C	52.14 (13.54)	48.92 (12.28)	<0.001*	50.48 (12.66)	51.89 (13.73)	0.032*	50.52 (13.26)	52.1 (13.28)	0.015*

Abbreviations: SD, standard deviation; HEI-C 2015, Healthy Eating Index-Canada 2015.
*p-value<0.05

Appendix I: Estimated mean (SD) of the DQI-I components and total scores over different material and social deprivation levels and regions with over and under 10,000 residents, based on dietary intakes of Canadian children (n=1,699)

	Material deprivation level			**Social deprivation level**			**Region of residence**		
Component	**Low (n=1221)**	**High (n=443)**	**p-value**	**Low (n=721)**	**High (n=943)**	**p-value**	**Over 10,000 residents (n=864)**	**Under 10.000 residents (n=800)**	**p-value**
Overall food group variety	10.98 (3.01)	10.75 (3.16)	0.181	10.79 (3.09)	11.02 (3.03)	0.115	10.64 (3.13)	11.22 (2.94)	<0.001*
Within-group variety for protein source	3.2 (1.51)	3.12 (1.52)	0.394	3.2 (1.51)	3.16 (1.51)	0.633	3.13 (1.55)	3.23 (1.48)	0.157
Grain group	3.96 (1.29)	3.89 (1.22)	0.346	3.82 (1.3)	4.04 (1.24)	<0.001*	3.9 (1.32)	3.98 (1.22)	0.195
Vegetable group	1.7 (1.63)	1.56 (1.47)	0.114	1.59 (1.5)	1.71 (1.65)	0.113	1.55 (1.56)	1.78 (1.61)	0.004*
Fruit group	2.49 (2.07)	2.27 (1.96)	0.052	2.31 (2.03)	2.53 (2.05)	0.033*	2.35 (2.06)	2.52 (2.04)	0.101
Fiber	3.25 (1.21)	3.03 (1.2)	<0.001*	3.04 (1.19)	3.32 (1.22)	<0.001*	3.06 (1.22)	3.34 (1.19)	<0.001*
Protein	4.9 (0.36)	4.93 (0.32)	0.209	4.93 (0.32)	4.9 (0.37)	0.092	4.9 (0.35)	4.92 (0.36)	0.384
Iron	4.77 (0.64)	4.72 (0.75)	0.169	4.76 (0.63)	4.76 (0.7)	0.894	4.7 (0.75)	4.82 (0.57)	<0.001*
Calcium	3.25 (1.47)	3.05 (1.49)	0.019*	3.09 (1.47)	3.27 (1.49)	0.012*	3.07 (1.47)	3.33 (1.48)	<0.001*
Vitamin C	3.74 (1.78)	3.78 (1.74)	0.650	3.64 (1.82)	3.83 (1.73)	0.034*	3.65 (1.83)	3.86 (1.7)	0.016*
Total fat	1.39 (1.98)	1.29 (1.94)	0.353	1.29 (1.97)	1.41 (1.97)	0.224	1.42 (2.03)	1.3 (1.9)	0.232
Saturated fat	1.35 (2.09)	1.07 (1.91)	0.012*	1.21 (1.96)	1.33 (2.11)	0.270	1.37 (2.13)	1.18 (1.95)	0.063
Cholesterol	4.07 (2.62)	4.07 (2.65)	0.980	4.07 (2.65)	4.08 (2.62)	0.964	4.18 (2.59)	3.96 (2.67)	0.082

Sodium	2.91 (2.63)	3.38 (2.6)	0.001*	3.26 (2.62)	2.86 (2.63)	0.002*	3.19 (2.62)	2.86 (2.64)	0.009*
Empty calorie foods	1.65 (2.25)	1.52 (2.13)	0.266	1.59 (2.2)	1.64 (2.23)	0.655	1.74 (2.26)	1.49 (2.16)	0.023*
Macronutrient ratio	0.55 (1.3)	0.59 (1.31)	0.554	0.55 (1.32)	0.56 (1.29)	0.884	0.55 (1.27)	0.58 (1.33)	0.653
Fatty acid ratio	0.3 (0.86)	0.25 (0.82)	0.320	0.33 (0.91)	0.26 (0.8)	0.093	0.29 (0.84)	0.29 (0.86)	0.917
Total DQI-I	54.47 (9.87)	53.28 (9.64)	0.030*	53.47 (9.73)	54.67 (9.86)	0.013*	53.69 (10.19)	54.64 (9.37)	0.048*

Abbreviations: SD, standard deviation; DQI-I, Diet Quality Index-International.
*p-value<0.05

Appendix J: Estimated mean (SD) of the HEFI-2019 components and total scores over different material and social deprivation levels and regions with over and under 10,000 residents, based on dietary intakes of Canadian children (n=1,699)

	Material deprivation level			**Social deprivation level**			**Region of residence**		
Component	**Low (n=1221)**	**High (n=443)**	**p-value**	**Low (n=721)**	**High (n=943)**	**p-value**	**Over 10,000 residents (n=864)**	**Under 10.000 residents (n=800)**	**p-value**
Vegetables and fruits	6.38 (5.69)	6.16 (5.46)	0.474	6.28 (5.66)	6.36 (5.61)	0.765	5.93 (5.54)	6.75 (5.7)	0.003*
Whole-grain foods	1.34 (1.62)	1.28 (1.61)	0.516	1.35 (1.63)	1.3 (1.6)	0.460	1.3 (1.61)	1.34 (1.62)	0.657
Grain foods ratio	1.42 (1.73)	1.37 (1.73)	0.574	1.44 (1.73)	1.38 (1.73)	0.500	1.34 (1.71)	1.48 (1.75)	0.114
Protein foods	3.55 (1.7)	3.49 (1.72)	0.503	3.67 (1.66)	3.44 (1.74)	0.006*	3.55 (1.71)	3.52 (1.71)	0.678
Plant-based protein foods	0.45 (1.29)	0.35 (1.15)	0.158	0.42 (1.27)	0.42 (1.24)	0.940	0.42 (1.23)	0.43 (1.28)	0.800
Beverages	6.34 (3.5)	5.93 (3.56)	0.037*	6.4 (3.5)	6.1 (3.53)	0.081	6.16 (3.56)	6.3 (3.47)	0.435
Fatty acids ratio	1.52 (1.56)	1.35 (1.43)	0.039*	1.44 (1.54)	1.5 (1.52)	0.435	1.51 (1.55)	1.44 (1.51)	0.361
Saturated fats	2.99 (2.05)	2.66 (2.04)	0.003*	2.76 (2.06)	3.01 (2.04)	0.014*	3.01 (2.03)	2.79 (2.06)	0.033*
Free sugars	6.64 (3.97)	6.13 (4.08)	0.020*	6.71 (3.95)	6.35 (4.04)	0.069	6.54 (4.07)	6.47 (3.93)	0.712
Sodium	5.77 (3.5)	6.07 (3.33)	0.115	5.6 (3.45)	6.03 (3.45)	0.013*	5.9 (3.46)	5.79 (3.46)	0.503
Total HEFI-2019	45.51 (13.42)	43.48 (13.71)	0.007*	45.1 (13.69)	44.86 (13.4)	0.723	44.59 (13.44)	45.37 (13.61)	0.236

Abbreviations: SD, standard deviation; HEFI-2019, Healthy Eating Food Index 2019.
HEFI-2019 scores have been stretched from a maximum of 80 to a maximum of 100 by multiplying the scores by 1.25.
*p-value<0.05

Appendix K: Correlation between HEFI-2019 components scores with daily energy intake and total HEFI-2019 score based on dietary intakes of Canadian children (n=1,699)

Component	Vegetables and fruits	Whole-grain foods	Grain foods ratio	Protein foods	Plant-based protein foods	Beverages	Fatty acids ratio	Saturated fats	Free sugars	Sodium	Total HEFI-2019	Energy
Vegetables and fruits	1.00											
Whole-grain foods	-0.12*	1.00										
Grain foods ratio	-0.02	0.79*	1.00									
Protein foods	-0.14*	0.03	0.09*	1.00								
Plant-based protein foods	0.00	0.08*	0.13*	0.13*	1.00							
Beverages	-0.01	0.13*	0.07*	0.17*	0.03	1.00						
Fatty acids ratio	0.15*	0.02	0.00	-0.17*	0.22*	-0.03	1.00					
Saturated fats	0.11*	0.06*	-0.08*	-0.19*	0.15*	-0.03	0.49*	1.00				
Free sugars	0.06*	0.07*	0.02	0.16*	-0.02	0.47*	0.00	-0.18*	1.00			
Sodium	0.11*	0.01	-0.03	0.10*	0.00	-0.06*	-0.07*	0.19*	-0.20*	1.00		
Total HEFI-2019	0.57*	0.31*	0.30*	0.20*	0.23*	0.53*	0.28*	0.29*	0.49*	0.32*	1.00	
Energy	-0.05*	-0.11*	-0.04	0.06*	-0.02	-0.17*	-0.07*	-0.10*	0.00	0.01	-0.12*	1.00

Abbreviations: HEFI-2019, Healthy Eating Food Index 2019.
HEFI-2019 scores have been stretched from a maximum of 80 to a maximum of 100 by multiplying the scores by 1.25.
*p-value<0.05