

INVESTIGATING THE RELATIONSHIP BETWEEN HOUSEHOLD  
FOOD INSECURITY AND ACADEMIC PERFORMANCE AMONG  
NOVA SCOTIA ELEMENTARY SCHOOL STUDENTS

by

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Submitted in partial fulfilment of the requirements  
for the degree of Master of Science

at

Dalhousie University  
Halifax, Nova Scotia  
April 2019

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## **DEDICATION**

To Grammie.

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## ABSTRACT

*Background:* Education is a fundamental determinant of health, and as such, good academic performance of children has instrumental importance for their health. Household food insecurity, given its association with poor development, may play a critical role in determining academic performance among children. A population-based cross-sectional survey conducted in the Tri-County Region of Nova Scotia, Canada in Spring 2014 provided a unique opportunity to investigate an association between household food insecurity and academic performance.

*Research questions:* We set out to answer the following research questions: (1) Is household food insecurity associated with the academic performance among grade 4-6 students of the Tri-County Regional School Board in Nova Scotia? and (2) Is diet quality a mediator in the association between household food insecurity and student academic performance?

*Methods:* This study was a secondary data analysis of a population-based cross-sectional survey, the Influence of Comprehensive School Health on School Culture and Health Behaviors in Children, conducted in 2014 with children in grade 4-6 ( $n=590$ ) in the Tri-County Regional School Board of Nova Scotia. We used a dichotomous household food insecurity measure (food secure or food insecure); two dichotomous measures of academic performance (English Language Arts and Mathematics ratings of poor or good); and two continuous diet quality measures, the Youth Healthy Eating Index (YHEI) and Diet Quality Index-International (DQI-I). We followed a classic mediation analysis, the Four Step Approach, to examine the associations between household food insecurity, diet quality, and academic performance, separately for each of the diet quality and academic performance measures, using logistic or linear regression models adjusting for household education.

*Results:* In the sample of grade 4-6 students, 24.2% of children were living with household food insecurity. Results were inconclusive regarding whether diet quality was a mediator in the association between household food insecurity and academic performance because prerequisites were not met to complete mediation analysis with the Four Step Approach: Step 1 did not find a consistent total effect of household food insecurity on academic performance: children with household food insecurity were 1.92 times more likely to have poor academic performance in Mathematics (95% confidence interval [CI]: 1.06, 3.46) but association of household food insecurity with English Language Arts was statistically insignificant. Step 2 did not find a consistent moderate or strong association between household food insecurity and diet quality: children with household food insecurity scored 3.31 points lower YHEI than children without household food insecurity (95% CI: -5.23, -1.36) but association of household food insecurity with DQI-I was statistically insignificant. Step 3 did not find a consistent moderate or strong association between diet quality and academic performance: for every unit increase in children's diet quality (on a 100-point scale), odds of poor academic performance in English Language Arts and Mathematics decreased by 5 and 3%, respectively.

*Conclusions:* This study did not find the mediating role of diet quality in the relationship between household food insecurity and academic performance. Further research with a larger sample and better measures is necessary to conduct mediation analysis of the relationships and causal pathways between household food insecurity, diet quality, and academic performance.

## LIST OF ABBREVIATIONS USED

HFI	Household Food Insecurity
PROOF	Research to Identify Policy Options to Reduce Food Insecurity
HFSSM	Household Food Security Survey Module
HFSSM-6SF	Short Form Six-Item Household Food Security Survey Module
DQ	Diet Quality
DQI-I	Diet Quality Index-International
YHEI	Youth Healthy Eating Index
HEI	Healthy Eating Index
YAQ	Harvard Youth/Adolescent Food Frequency Questionnaire
CLASS	Children's Lifestyle and School Performance Study
SD	Standard Deviation
OR	Odds Ratios
CI	Confidence Intervals



## ACKNOWLEDGEMENTS

Thank you to my friends and family who have supported me throughout this academic degree. I would especially like to thank my classmates who have become lifelong friends, Laura Keeler and Ashley Chisholm. Thank you to my oldest friends from childhood, Deanna Yarr and Emma Robertson, who were by my side when life delivered challenges that were far greater than my academics. And to Jill Carter and Colleen Morley, whose unwavering friendship continues to provide me with a safe space to land.

Thank you to Dalhousie University, a place that now stands as a major chapter in my life. Thank you to the Department of Community Health and Epidemiology, and to Dr. Sam Stewart and Dr. Leslie-Anne Campbell, who are my extended family members in the Department. Thank you to Patsy Koelink of Dalhousie Student Accounts for her selfless act of kindness and generosity that brought a renewal to my sense of strength during this work. I would like to thank my co-supervisors, Dr. Stefan Kuhle and Dr. Sara Kirk, and committee member, Dr. Yukiko Asada. In particular, to Dr. Yukiko Asada, thank you for a mentorship that has helped me to trust in my capabilities once again and to find meaning in the process.

I would like to especially acknowledge my Dad and my Grammie who have loved and supported me unconditionally, and my mother who has taught me resilience. Above anything else, they have wanted for me to be happy and to thrive, and for that I am grateful. And finally, Taylor Callan. Thank you for entering my life in the final stretch of this work and for encouraging me to persist. Your belief in me reminds me of who I am with refreshing clarity. You are a light in my days.

The study design and data collection tools were adapted from previous research by Dr. Paul Veugelers (University of Alberta), including the Children's Lifestyle And-School Performance Study ([www.nsclass.ca](http://www.nsclass.ca)) and Raising healthy Eating and Active Living Kids Alberta ([www.realkidsalberta.ca](http://www.realkidsalberta.ca)). Thank you to Connie Lu, data analyst in the School of

Public Health at the University of Alberta, for processing the food frequency questionnaires and calculating the dietary indices.

## CHAPTER 1. INTRODUCTION

Household food insecurity (HFI), or insufficient access to adequate food resources, is a serious public health concern that affects 4 million Canadians, of whom more than 1.15 million are children. (1) The most recent household food insecurity report for Canada that includes rates of household food insecurity for all provinces and territories in 2012 reveals that rates are continuing to increase. (1) Household food insecurity reports for 2013 and 2014, which include the participation of some but not all provinces, show that trends in household food insecurity in many provinces are persisting. (2,3) In 2012, an additional 130,000 Canadians were living with household food insecurity than in 2011, raising the prevalence in Canada to 12.6%. (1) In 2012, rates of household food insecurity in Prince Edward Island, Nova Scotia, Quebec, Saskatchewan, British Columbia, Northwest Territories and Nunavut were the highest rates observed since consistent and robust reporting of household food insecurity became available for Canada in 2005. (1) The number of children affected by household food insecurity is particularly concerning. There is a considerably greater prevalence of household food insecurity among homes with children under the age of 18 compared to those without children (15.6% versus 10.4% in 2014). (3) Taken together, about one in six children in Canada are affected by household food insecurity. (1–3)

Research has linked household food insecurity with a range of negative physical, psychological, and/or social health outcomes. (4–11) Higher rates of protein and vitamin deficiencies, heart disease, diabetes, high blood pressure, depression, and poor cognitive functioning have been found in individuals that come from food insecure households compared to those from food secure households. (4,5,12,13) Furthermore, household food insecurity has been linked to significant problems in the development of children. (6–9,14) Children experiencing household food insecurity, through mechanisms of poor diet quality and psychosocial stress, tend to have lower physical, mental, and psychosocial functioning than those without household food insecurity. These issues, in turn, can manifest into increased rates of obesity and mood and externalizing disorders as well as decreased quality of peer relationships and academic performance. (7,8)

This potentially negative consequence of household food insecurity on academic performance of children is of particular interest from a perspective of population health because academic performance inevitably influences educational attainment. Education is recognized as one of the fundamental determinants of health and capacity for upward social mobility. (15,16) Higher educational attainment is associated with having a greater likelihood for employment, full-time work, jobs that bring a sense of fulfillment, high income and low economic hardships, greater social support networks, adequate exercise, and a lower likelihood of smoking and drinking to excess. (17) All of these economic, psychosocial, and lifestyle factors, in turn, indirectly or directly affect an individual's health. (17)

Thus, household food insecurity can be hypothesized to have health consequences through academic performance and educational attainment. For this reason, the relationship between household food insecurity and the academic performance among children deserves close investigation. Furthermore, malnourishment among children experiencing household food insecurity extends the hypothesis with a potential role of diet quality in the association between household food insecurity and academic performance. Much of the literature discussing the role of diet quality in the association between household food insecurity and academic performance among children is theoretical, without the use of statistical methods to test the hypothesized mechanisms for why this association occurs. This study employs a secondary data analysis to explore the association between household food insecurity and the academic performance of students, while considering diet quality as a mechanism through which this association occurs.

## CHAPTER 2. BACKGROUND

This chapter provides background information on each of household food insecurity, diet quality, and academic performance, key concepts when addressing household food insecurity among children from a population health perspective. For each of these three aspects, after a general overview, measurement and a review of pertinent literature follow. After providing the background information on each of these key concepts, this chapter provides a description of mediation analysis, an established analytical strategy well suited to examine three-way relationships like the focus of this study.

### 2.1 HOUSEHOLD FOOD INSECURITY

Food security is an important concept in the discussion of population health. It relates to social and economic environment, physical environment, and individual characteristics and behaviours, which are collectively recognized as overarching determinants of health. (18) The World Food Summit of 1996 defined food security based on three foundational components: food availability (“sufficient quantities of food available on a consistent basis”), food access (“having sufficient resources to obtain appropriate foods for a nutritious diet”), and food use (“appropriate use based on knowledge of basic nutrition and care, as well as adequate water and sanitation”), and further stated that food security is achieved when “all people at all times have access to sufficient, safe, nutritious food to maintain a healthy and active life.” (18,19)

In reality, however, food *insecurity* exists as a global and domestic issue and is defined in contrast to food security as the “limited or uncertain availability of nutritionally adequate and safe foods or limited or uncertain ability to acquire acceptable foods in socially acceptable ways.” (20) Food insecurity occurs at the level of individuals, households, communities, regions, and nations, with vast geographical variances throughout first, second, and third world countries. (20) In Canada, food insecurity is most often measured and reported at the household level. (1)

Household food insecurity occurs as a result of financial constraint, specifically in terms of food access. (1,20) Household food insecurity is characterized by experiences

such as having to prioritize household and living expenses before food expenses, an inability or lack of knowledge to allocate funds as needed to achieve adequate balance across food groups, persistent hunger, consistently having to skip meals, or in the most severe sense, having to endure extended periods without food due to lack of food availability or money for food. (1,20)

Unsurprisingly, household food insecurity is closely related to insufficient household income, but an important distinction is necessary here as these terms are not synonymous. (20) While insufficient household income may be a good predictor of household food insecurity, the latter is a multi-faceted construct and can occur in households with sufficient income as a result of abrupt and unanticipated changes in life circumstances, lack of knowledge for allocating funds appropriately for basic nutritional needs, and limited accessibility and affordability of food and living due to location and geography. (20)

Hunger is another important concept in the discussion of household food insecurity. Here, hunger is defined as “the uneasy or painful sensation caused by a recurrent and involuntary lack of access to food.” (20) As such, in the discussion of household food insecurity, the experience of ‘hunger’ refers to a consequence of severe household food insecurity as opposed to a consequence of commonplace experiences such as dieting or voluntary delay of a meal during a busy workday. (20) Although household food insecurity and hunger often occur together, one does not assume the other, as the experience of household food insecurity can coincide with an absence of hunger. (20)

In 2005, consistent and robust reporting of household food insecurity in Canada became available through Research to Identify Policy Options to Reduce Food Insecurity (PROOF). It has revealed that rates of household food insecurity across Canada are increasing, with distinct geographic patterns across provinces. (1–3) According to the most recent household food insecurity report in Canada that includes rates of household food insecurity for all provinces and territories, in 2012 four million Canadians were affected by household food insecurity, of whom more than 1.15 million were children. (1) The 2012 report, as well as the household food insecurity reports available for 2013 and 2014, which include the participation of some but not all provinces, show that the prevalence of household food insecurity in Canada has now reached close to 13%. (1–3) The 2012 report

found that the lowest rates of household food insecurity were in Alberta (11.5%) and the highest in the territories (17.1%, 20.4%, and 45.2% in the Yukon, Northwest Territories, and Nunavut respectively). (1) Rates of household food insecurity in Prince Edward Island, Nova Scotia, Quebec, Saskatchewan, British Columbia, Northwest Territories and Nunavut were the highest rates observed since reporting became available from PROOF. (1) The number of children affected by household food insecurity is particularly concerning. There is a considerably greater prevalence of household food insecurity among homes with children under the age of 18 compared to those without children (15.6% versus 10.4% in 2014). (3) About one in six children in Canada are affected by household food insecurity. (1–3) Household food insecurity reports for 2013 and 2014 show that trends in household food insecurity across Canada are persisting, although rates in 2013-2014 are not significantly higher than those rates reported in the 2012 report. (2,3)

The rate of household food insecurity in Nova Scotia is of particular concern as the prevalence of household food insecurity had a statistically significant increase from 13.5% in 2008 to 17.5% in 2012. (1) Among the 33 major census metropolitan areas that were included in the 2012 household food insecurity report in Canada, the highest rate of household food insecurity was in Halifax, where 1 in 5 households were affected. (1) In Nova Scotia, the proportion of children living with household food insecurity in 2012 was 21.2% and up to 22% in 2014. (1,3) Rates of household food insecurity in Nova Scotia outside of the Halifax Regional Municipality have not yet been reported.

### **2.1.1 Measurement of Household Food Insecurity**

In Canada, the issue of food insecurity at the household level gained attention as a public health concern in the 1980s when demands for charitable food assistance increased. (21,22) As a result, measurement tools for monitoring household food insecurity in Canada started to emerge in the 1990s. (23,24) More recently, a validated measurement tool called the Household Food Security Survey Module (HFSSM) has improved studies of household food insecurity trends.

The 18-item HFSSM was developed based on the analysis of data obtained from the 1995 Current Population Survey in the U.S. For this survey, categorical and numerical

measures of food security were established to determine the food security status of the U.S. households during a 12-month period. (20) Since 2004, Statistics Canada has included the 18-item HFSSM in the Canadian Community Health Survey, an annual cross-sectional study administered to a representative sample of the ten provinces and three territories. (1) Four major topic areas are addressed throughout the 18-item HFSSM, all of which rely on self-reported responses. These major topic areas are household food expenditures, participation in public food assistance programs, coping behaviour to augment food supply from emergency sources, and direct indicators of food insecurity and hunger. (20) Depending on the number of affirmative responses provided for the questions regarding these major topic areas, households are classified according to four categories: *food secure* (“No report of income-related problems of food access”), *marginally food insecure* (“Some indication of worry or an income-related barrier to adequate, secure food access”), *moderately food insecure* (“Compromise in quality and/or quantity of food consumed by adults and/or children due to a lack of money for food”), and *severely food insecure* (“Disrupted eating patterns and reduced food intake among adults and/or children”). (1)

To minimize response burden, an abbreviated six-item Food Security Scale (HFSSM-6SF) was developed based on the original 18-item HFSSM. (20) A subset of items from the original 18-item HFSSM were selected based on statistical testing that identified the strongest indicators for approximating food security status. (20) The following adjustments from the 18-item HFSSM were made in developing the abbreviated six-item HFSSM. Households with or without children were considered equally in the short form survey, meaning that those items in the original 18-item HFSSM that applied exclusively to one group or the other were not included in the abbreviated scale. (25) The short form excludes those items from the 18-item survey that distinguish the two upper levels of food insecurity as well as an item directed toward households with the least severe food insecurity. (25) With the short form survey, households are classified according to the categories of *high food security*, *marginal food insecurity*, *moderate food insecurity*, and *severe food insecurity*. (26) However, depending on the methods of reporting, the nomenclature of these categories tends to vary. In addition, the two lower and two upper categories may be combined to create the binary categories of “food insecure” or “food secure” to ensure adequate power in studies with small sample sizes due to time and



resource constraints. (6,25,26)

In comparison to the original 18-item HFSSM, the short form HFSSM-6SF has been found to have reasonably high specificity and sensitivity as well as minimal bias and respondent burden. (25) The sensitivity and specificity of the HFSSM-6SF to determine household food insecurity is 92.0% and 99.4%, respectively. (25) It is worth noting that because specificity is greater than sensitivity, the short form survey is better at identifying food secure households than identifying food insecure households. (25) The overall accuracy of the survey is somewhat dependent on the prevalence of food security in the population being studied compared to the 1995 Current Population Survey sample, from which the food security scale was developed. (25) While the short form survey is a suitable tool for a study that uses a general population-based sample, accuracy and bias should be of concern in studying unique populations that differ greatly from the 1995 U.S. national population. (20,25)

### **2.1.2 Household Food Insecurity: Reviewing the Literature**

The original 18-item and short form six-item HFSSM have been used to identify important links between household food insecurity, nutrient inadequacies, and decreased health outcomes. (4,11) For example, higher rates of protein and vitamin deficiencies, heart disease, diabetes, high blood pressure, depression, and poor functional health have been found in individuals that come from food insecure households. (4,5,11) Moreover, associations have been found between household food insecurity and poor developmental health outcomes in children. (7,8,14) Children experiencing household food insecurity, through mechanisms of poor diet quality and psychosocial stress, tend to have lower physical, mental, and psychosocial functioning than those without household food insecurity. These issues, in turn, can manifest into increased rates of obesity and mood and externalizing disorders as well as decreased quality of peer relationships and academic performance. (7,8)

The associations between household food insecurity and these adverse outcomes are demonstrated in the literature. For example, the cross-sectional investigation by Kleinman et al. (1998) found that children with household food insecurity were more likely

to have psychosocial dysfunction than those without household food insecurity. (27) They also found that children with household food insecurity were statistically significantly more likely to be receiving special education services and to have a past or current history of mental health counseling than children from food secure homes. (27) Findings from the cross-sectional investigation of Alaimo et al. (2001) showed an association between children and teenagers with household food insecurity and lower cognitive functioning. (14) They also investigated the academic performance of children and teenagers living with household food insecurity and found that those with household food insecurity performed lower in standardized testing for reading and mathematics, and were more than twice likely to have repeated a grade and to have missed more school days than their food secure peers. (14)

Various hypotheses have been suggested for why these types of associations exist. For example, it is postulated that household food insecurity can have cumulative effects in child development based on the finding that malnutrition during infancy is shown to have detrimental effects on proper neurodevelopment. (28) Other hypotheses suggest that the association between household food insecurity and poor developmental outcomes is attributable to the effect of malnutrition on cognitive functioning and on motivational and emotional behaviours, as undernourished children tend to be more withdrawn and have greater apathy and anxiety. (29,30) However, a gap exists in the literature in examining these hypotheses. Although an association between household food insecurity and poor academic performance is supported in the literature, existing studies have become outdated (27), inadequately defined the measurement of academic performance (31), or rarely applied sound methods in testing a mechanism through which household food insecurity affects academic performance among students.

## **2.2 DIET QUALITY**

Malnourishment among children experiencing household food insecurity hints to a potential role of diet quality in the association between household food insecurity and academic performance. There are four important dimensions of diet quality consistent across dietary guidelines, including Canada's Food Guide. (32,33) These dimensions of

diet quality include variety (diversity of food choices across and within food groups), adequacy (sufficiency of particular dietary components that are required in a healthy diet), moderation (restriction of food and nutrients associated with the onset of chronic diseases), and balance (proportionality of macronutrients and energy sources). (6,32)

### **2.2.1 Measurement of Diet Quality**

Dietary indexes are a type of measurement tool used in the assessment of diet quality. Various types of dietary indexes are available, and they differ in terms of the operationalization of the four aforementioned dimensions of diet quality (variety, adequacy, moderation, and balance). The Diet Quality Index-International (DQI-I) is a widely used tool that was specifically developed for cross-national comparisons of diet quality by Kim et al. (2003). (32) The DQI-I generates a composite summary score of 0 (poorest) to 100 (highest) that represents the overall diet quality of an individual based on the evaluation of the four dimensions of diet quality, including two components for variety (overall food group diversity and within food group diversity), eight components for adequacy (vegetables, fruits, grains, fiber, protein, iron, calcium, and vitamin C), five components for moderation (total fat, saturated fat, cholesterol, sodium, and empty calories), and two components for balance (macronutrient ratio and fatty acid ratio). (32) While some dietary indexes group adequacy and moderation together, the DQI-I offers the advantage of separating these dimensions. Thus, using the DQI-I, it is possible to assess whether poor diet quality of an individual is the result of an excess of foods (where moderation is concerned) or a deficit of foods (where adequacy is concerned). (32)

The DQI-I is also unique in its inclusion of “empty calories” as a component of moderation in the evaluation of diet quality. Empty calorie foods are those foods that are high in added refined sugars and solid fats (such as sweetened beverages, ice cream, cakes and pastries), thus, contain low nutrient density yet high-energy values. (32) The consideration of empty calories in the evaluation of diet quality is of particular importance when assessing diet quality in relation to household food insecurity because packaged empty calorie foods tend to be less expensive and more accessible than nutrient-dense, whole food options. (32,34)

Another popular dietary index is the Youth Healthy Eating Index (YHEI), developed to assess the food quality and eating behaviours in older children and adolescents. (35) The YHEI was created to modify and simplify The Healthy Eating Index (HEI), which assesses adherence to The Dietary Guidelines for Americans. (35) The YHEI was developed from the HEI by modifying the scoring system of the HEI create a dietary index tool more applicable to the dietary issues of children and adolescents. For example, as compared to the HEI, the YHEI includes the added components of frequency of eating breakfast and frequency of eating dinner with family, which, respectively, are linked to improved academic performance in children and healthful dietary patterns (such as less intake of trans-fatty acids and greater intake of fiber and micronutrients). (36,37) The YHEI is also modified from the HEI for simplicity with improved suitability for younger age groups. (35) Like the DQI-I, the YHEI generates a composite summary score of 0 (poorest) to 100 (highest) that represents the overall diet quality of an individual. However, the YHEI differs from the DQI-I in its included components. The YHEI components are not specifically grouped under the aforementioned dimensions of diet quality (variety, adequacy, moderation, and balance) but are selected for the consideration of healthful and unhealthful eating behaviours of youth and adolescents. (35) The YHEI includes a total of 13 components (as compared to a total of 18 for the DQI-I), which are listed in order as: whole grains, vegetables, fruits, dairy, meat ratio, snack foods, soda and drinks, multivitamin use, margarine and butter, fried foods outside of home, visible animal fat, eat breakfast, and dinner with family. (35) The first seven components of the YHEI are scored out of ten, while components eight to thirteen are scored out of five. (35) Although not specifically grouped under the aforementioned four dimensions of diet quality, the YHEI components do take them into consideration as they contribute to the overall diet quality of an individual.

The use of dietary indices, such as the DQI-I and YHEI, requires the availability of data pertaining to food intake of individuals. Examples of individual dietary data collection tools include 24-hour quantitative intake recalls, dietary records, and food frequency questionnaires. (38) While 24-hour recall methods and dietary records collect self-reported information for the intake of foods and quantities without the use of a defined scope, food frequency questionnaires collect self-reported responses to questions that address energy

and nutrient intake, foods and food groups, food preparation, and the number of meals eaten away from home. (39) Food frequency questionnaires have been found to be reliable and accurate measurement tools for assessing usual dietary intake over a specified time frame. (40,41) An important consideration with methods of measurement of diet quality, such as the use of food frequency questionnaires and dietary indexes, is that energy intake and nutrient intake (particularly macronutrients) are often correlated. (42) Therefore, energy intake has the potential to act as a confounder in the investigation of the relationships between diet quality (which accounts for intake of specific nutrients) and outcomes of interest. As such, when assessing diet quality, it is important to adjust for total energy intake. (42) Distinguishing energy intake and nutrient intake also enables the assessment of diet quality across individuals whose dietary composition may be very different despite having comparable energy intakes. This is an important consideration in the methods of measurement of diet quality given that diet quality cannot be assessed on energy intake alone and that an attention to differences in dietary composition across individuals are critical. (42)

A widely used food frequency questionnaire is the Harvard Youth/Adolescent Food Frequency Questionnaire (YAQ). The YAQ is a 147-item instrument that was developed specifically for younger age groups based on the validated Nurses' Health Study food frequency questionnaire. (39) The YAQ includes questions for a variety of foods and beverages and the choice of nine levels for frequency of eating these items over the past year. (39) These levels range from "never or less than once per month" to "greater than 6 per day". (39) Energy intake and various indicators of diet quality are estimated through the YAQ by obtaining nutrient information of foods through a foods database. The Canadian Nutrient File is a type of such database, which provides the nutrient content information for the most common foods consumed in Canada. (43) The survey responses provided in the YAQ also allow for the assessment of whether dietary intake of respondents complies with existing food group guidelines, such as those defined in Canada's Food Guide. (44)

The YAQ has been evaluated for validity and test-retest reproducibility of energy and nutrient intake over a one-year period. For the latter, respondents' first questionnaire was compared to a second questionnaire completed at a later time, for which Pearson

correlation coefficients varied from 0.26 to 0.58, depending on the nutrient being measured. (39) However, the effectiveness of this tool among populations with greater ethnic and racial diversity requires further investigation. (45)

The most notable advantages of using a food frequency questionnaire (such as the YAQ) are the greatly reduced costs, achieved by using self-administered questionnaires that do not require trained interviewers, and its representativeness to estimate usual dietary intake, achieved through the comprehensiveness of the list of food items included in the YAQ as compared to other dietary assessment tools that assess a limited number of food items. (46) Furthermore, the YAQ asks for frequencies of food items eaten over the past year, which offers greater representativeness of an individual's typical food consumption than other dietary assessments, such as 1-3 day food records or recall questionnaires. This helps in avoiding the misclassification of subjects across established categories of food intake whilst increasing the validity of any associations that are drawn between diet quality and outcomes of interest. (46)

Although the use of a food frequency questionnaire such as the YAQ is advantageous in an investigation where time and financial resources are limited, food frequency questionnaires have important limitations. There is a risk of recall bias by relying on participants to recollect what they ate over such a long period of time. (46) There is also a potential for social desirability bias (the tendency to answer questions based on what is thought to be viewed as favourable by others). (47) Another concern with food frequency questionnaires is a challenge of including enough different foods and methods of food preparation to capture the wide range of variability of a population's diet within space and time constraints. (48) The YAQ overcomes this challenge by including a comprehensive list of 147 items, addressing in detail food practices, food and beverage varieties, as well as an opportunity to list any foods that were not included in the list of survey items. Finally, it is important to consider that dietary patterns are highly changeable due to the constantly developing food market; thus, caution should be applied in generalizing findings from the DQI-I, YHEI, and YAQ tools to future populations.

### **2.2.2 Diet Quality: Reviewing the Literature**

Although adverse associations between household food insecurity and developmental outcomes, such as academic performance in children, have been attributed to various mechanisms, poor diet quality in individuals with household food insecurity is recognized as a common denominator among these mechanisms. (49) Research shows that household food insecurity is associated with lower intakes of certain vitamins and minerals as a result of individuals with household food insecurity being less likely to purchase fruits, vegetables, and animal products and being less likely to consume recommended daily servings across food groups. (4,50,51) Diet quality in food insecure homes is hindered not only by low consumption of fruits, vegetables, and animal products, but also through the replacement of these foods with high amounts of energy-dense foods that are often less expensive but much lower in nutrient density, have poor bioavailability, and have been linked to poor health outcomes and morbidities. (5,30,52–54) Inadequate vitamin and mineral intake is of particular concern because bioavailability becomes further reduced when nutrients critical for the absorption of other nutrients are insufficient in a diet or when malnourishment leads to malabsorption and inflammatory responses along with morbidities. (30,55–57)

Malnourishment as a result of household food insecurity is shown to manifest in contrasting ways across individuals. Recent paradoxical findings in the literature link household food insecurity, malnourishment, and obesity. (12,54) Individuals with household food insecurity paradoxically have overnutrition when they have adequate or excess caloric intake to meet their energy requirements but lack a level of dietary quality needed to satisfy hunger and promote optimal health. (54) Such individuals suffer from “hidden hunger”, defined as “the experience of subclinical nutrient deficiencies without the overt clinical signs associated with undernutrition.” (54) Overnutrition may show up in the form of chronic diseases associated with obesity, such as type 2 diabetes, hypertension, and coronary vascular disease. (54) As a result, the construct of malnutrition has evolved to include both “undernutrition” and “overnutrition,” recognizing that these contrasting conditions are both possible consequences for individuals with household food insecurity. Malnourishment in the form of undernutrition is associated with the experience of hunger (recurring and involuntary painful or uneasy sensation caused by inadequate food access)

and with obvious and apparent clinical signs of nutrient deficiency, whereas overnutrition is associated with the experience of hidden hunger (sensation of hunger caused by deficiencies in micronutrients such as iron, folic acid, and vitamin A) and often with obesity and its related health consequences. (54)

Despite the contrasting ways that poor diet quality manifests in children with household food insecurity, malnourishment among children, whether in the form of undernutrition or overnutrition, is tied to adverse cognitive functioning and academic outcomes. Malnourished children are more likely to experience illness and morbidities and are therefore more likely to be absent from school, which negatively affects academic performance. (58) Even in the short term, malnourishment can adversely affect children's cognitive abilities because malnourished children often cannot concentrate and perform complex tasks. (58) For example, deficiencies in specific nutrients, such as iron, which can be obtained from consuming dark green vegetables and animal products, negatively influence concentration and memory, thus, affecting children's ability to learn. (58) Among malnourished children who experience undernutrition and inadequate energy consumption, allocation of energy for critical biological functions, such as organ function and growth, is prioritized over the allocation of energy for non-critical survival functions, such as cognitive development and social engagement. (58) Therefore, children with malnourishment in the form of undernutrition tend to have decreased activity levels, social interaction, inquisitiveness, and interest in their physical environments, all of which contribute to decreased academic performance. (54,58) Children with malnourishment in the form of overnutrition may suffer similar consequences as a result of the social difficulties resulting from obesity and cognitive difficulties associated with micronutrient depletion. (54,58–60) Finally, children who experience the effects of malnourishment such as hunger during school perform significantly lower on standardized tests than their non-malnourished peers. (58)

An association between poor diet quality and decreased academic performance among children is demonstrated in the existing literature. In fact, specific effects of household food insecurity on diet quality, such as lower consumption of fruits and vegetables, lower intake of certain micronutrients (vitamins and minerals), and higher consumption of energy-dense “junk” foods, are also the specific aspects of diet quality



identified in the systematic review by Burrows et al. (2016) associated with decreased academic performance in children. (61) The positive association between adequate consumption of fruits and vegetables and better academic performance is also demonstrated in the literature, with consistent finding across widespread settings and differing populations. (62–66) With regard to lower intake of micronutrients, folate and iron are the most commonly reported to be associated with academic performance among children. (61,67,68) A study by Nilsson et al. (2011) used 24-hour dietary intake recalls and school grades to show that higher folate intake had a positive association with academic achievement in a group of Swedish youth age 15 years old, while controlling for important confounders such as socioeconomic status. (67) Aquilani et al. (2011) used 7-day food diaries and school subject grades in mathematics and found that higher intakes of iron were associated with better academic performance in girls age 13-15 years old. (68) Furthermore, studies have reported intakes of protein, B group vitamins, and omega-3 fatty acids are positively associated with children's academic performance. (69,70) These are important findings in the context of household food insecurity because children with household food insecurity have an increased risk of inadequate consumption of fruits and vegetables and balance across food groups, and are therefore at an increased risk of inadequate consumption of these macro- and micronutrients. (4,50,51)

With regard to the association of household food insecurity and increased consumption of “junk” foods in the context of academic performance, the cross-sectional study by Tobin et al. (2011) found that increased fast-food consumption among grade five students was associated with decreased academic performance in both mathematics and reading: higher-than-average fast-food consumption was statistically significantly associated with lower mathematics and reading scores of -11.13 (SD 0.52) and -11.15 (SD 0.48) points, respectively. (71) The longitudinal study by Li et al. (2012) also focusing on fast food consumption among grade five students found a similar result that fast food consumption had a statistically significant negative association with children's mathematics and reading scores (-2.6 and -2.87 points, respectively) as well as with the growth rate of these subjects through the first six years of school. (72) Studies examining the sum of the collective scores of several school subjects as an outcome variable, such as those of Feinstein et al. (2008), Kristjansson et al. (2007), and Kristjansson et al. (2010),

have also identified negative associations between dietary patterns of “junk” food consumption and decreased academic performance in children. (61–63,73) The observation that poor diet quality adversely affects children’s academic performance is further supported by studies that have observed the expected effects of school nutrition programs, such as hunger prevention, correction of nutritional deficiencies, and improvement in school attendance and standardized testing results. (30,74,75)

In summary, the literature showing associations between household food insecurity and decreased diet quality and between poor diet quality and lowered academic performance among children points to diet quality as a pertinent variable to consider in the investigation of the influence of household food insecurity on the academic performance among children.

### **2.3 ACADEMIC PERFORMANCE**

Academic performance is a reliable indicator for the cognitive function of individuals and is a critical component of educational attainment. Educational attainment, in turn, predicts future income, social, and health outcomes. (17,76) Factors shown to influence academic performance of children include sex, ethnicity, quality of school and school experience, health behaviours, such as sleep and physical activity, socioeconomic status, health, and nutrition. (77–79) Given that good nutritional health among children requires proper diet quality and that diet quality is likely associated with household food insecurity, household food insecurity is an important factor in the discussion of academic performance of children.

Two mechanisms have been proposed to explain an association between household food insecurity and low academic performance among children. (8) The first mechanism describes the effect of household food insecurity on academic performance as a direct relationship in which inadequate nutritional intake leads to decreased cerebral and cognitive functioning in children. (58) The second mechanism describes the effect of household food insecurity on academic performance as an indirect relationship in which household food insecurity causes diminished physical and psychological health in children, in turn, leading to school absenteeism and motivational difficulties. (79)

Regardless of the mechanisms, poor academic performance most likely leads to low educational attainment. (6–9,14) This is a serious concern from a health perspective as educational attainment is now recognized in the scientific literature and by the World Health Organization as one of the fundamental determinants of health. (15–17,80–82) In addition, education attainment is an important factor for an individual’s capacity for upward social mobility and future earning potential. (16) A strong positive correlation exists between insufficient household income and household food insecurity. (6) An unfavourable cycle emerges: children from a food insecure household, which results from inadequate household income, tend to have lower academic performance, which leads to lower education attainment, making the children more vulnerable to a lack of capacity for upward social mobility, sufficient income later in life, and perpetuating the cycle of household food insecurity with their children. (5,7,8,14,16)

### **2.3.1 Measurement of Academic Performance**

Various measurements of academic performance have been used in the literature. These include: repeated grades (8,10,27), standardized reading and/or mathematics scores (7,10,31), grades in French or English (8), school absenteeism (10), and student response to the statement, “I did not do very well at school this year” (8). Studies examining an association between food insecurity and decreased academic performance have used diverse measures of academic performance, which makes it difficult to assess the quality of evidence suggested by these studies. For example, self-evaluation measures (8) introduce a risk of self-report biases, especially given the association between low self-esteem and living in a poor family shown in previous studies. (8) This could lead to the finding of an exaggerated association between household food insecurity and decreased academic performance.

One advantage of measuring academic performance through course grades, as in the case for standardized testing, is that there is no time requirement or response burden to study participants. Academic performance can be measured dichotomously, “poor” or “good,” according to the average course grades of students for one full school year. (8,77) The use of binary categories, as opposed to more than two categories, is practical because

it allows for adequate power for analysis and reduces the concern of arbitrary categorization. (77) For example, marking standards may vary too greatly between teachers to create meaningful and consistent categories that can be generalized across all course grades.

An important advantage of using course grades as opposed to standardized testing in assessing academic performance is that course grades, capturing the long-term performance of students, likely reflect greater representativeness of a student's performance in school than a standardized test. Standardized tests are often administered on a one-time basis with the unlikely assumption that all students reach their most representative score on test day. Assessment of academic performance according to course grades also eliminates overt biases that may be associated with self-evaluated scores of academic achievements. Furthermore, grades are one of the main criteria used across educational systems in order to determine whether or not a student will have to repeat a school year, which strongly suggests the direction of a child's education and academic performance in the future. (8)

Course grades as a measure of academic performance have important challenges. Most notably, missing data becomes an issue when course grades are provided for different streams of courses taught in different terms. Risk of systematic error is also an issue because course grades may be given objectively and consistently within one teacher's marking system but may not be across the marking systems of different teachers and schools. Taken together, compared to standardized tests, course grades may offer greater representativeness of student academic performance yet may be less objective.

### **2.3.2 Academic Performance: Reviewing the Literature**

Examples of studies examining the relationship between household food insecurity and decreased academic performance among children are longitudinal studies by Winicki et al. (2003) and Jyoti et al. (2005) and cross-sectional studies by Roustit et al. (2010) and Faught et al. (2017). (7,8,31,83) Winicki et al. investigated the effects of household food insecurity on standardized mathematics scores of kindergarten students for the fall and spring of one school year. They found that children with household food insecurity had

lower initial scores in mathematics in the fall as well as poorer gains between fall and spring mathematics scores, demonstrating that household food insecurity negatively influenced children's capacity for learning over the course of a school year. (31) Jyoti et al. also demonstrated the impact of household food insecurity on learning. They found children's experience of household food insecurity during kindergarten predicted impaired academic performance in reading and mathematics by grade 3. (7) Roustit et al. found an association between household food insecurity and poor academic achievement in adolescents: students with household food insecurity had a greater likelihood of repeating a year, having lower grades in French and English, and responding affirmatively to "I did not do very well in school this year". (8) Finally, Faught et al. measured the academic performance of grade 5 students as "meeting expectations" or "not meeting expectations" using standardized test scores and found that children with household food insecurity were less likely to meet expectations in Reading and Mathematics. (83)

Although these studies show the association between household food insecurity and decreased academic performance among children, there is a need for greater exploration of the mechanisms involved. A potential mechanism may be that, based on the literature reviewed above, diet quality plays an important role in the link between household food insecurity and decreased academic performance among children. Understanding and providing evidence of the mechanisms through which household food insecurity affects academic performance may be an important step forward to help break its repetitive nature.

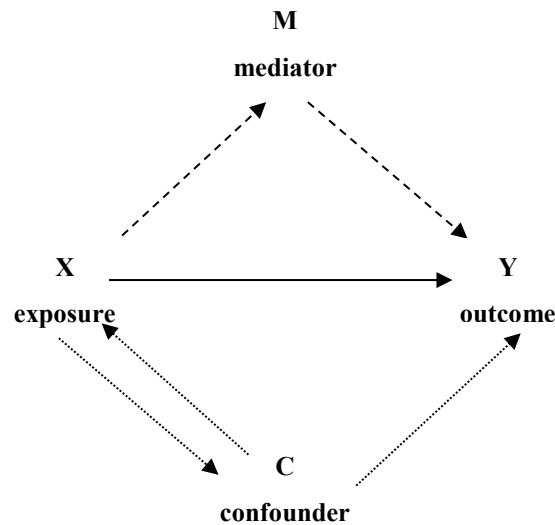
## **2.4 MEDIATION ANALYSIS**

When an important role of an additional variable is suspected in the potential mechanism through which an exposure variable affects an outcome variable, such as the role of diet quality in the relationship between household food insecurity and academic performance, it is necessary to understand causal pathways beyond a single pathway between exposure and outcome by using an appropriate statistical analytical approach. Mediation analysis is a popular analytic approach applied for studying the mechanism through which an exposure variable affects an outcome variable via an intermediate

variable within a predicted causal pathway. (84) Early and frequently cited work on the approach of mediation analysis comes from Baron and Kenny (1986), who define *mediation* as “the generative mechanism through which the focal independent variable is able to influence the dependent variable of interest.” (85,86)

In statistical modelling, regression techniques serve as a means for determining whether or not a relationship exists between an independent exposure variable (X) and a dependent outcome variable (Y), while being able to simultaneously adjust for confounding variables that may otherwise distort the relationship between X and Y. (85,87) While regression modelling techniques often address questions to investigate *what* relationships exist between exposure and outcome variables, mediation analysis techniques address questions to investigate *how* or *why* relationships between exposure and outcome variables exist. (85) The statistical approach of regression analysis is a means for studying a single pathway between X and Y, whereas mediation analysis allows for the study of an alternative stepwise pathway from X to Y via an intermediate variable. This intermediate variable, called a *mediator* (M), is in the causal chain between X and Y, in which X causes M and M causes Y. (85) In a mediation model, given that the exposure is associated with the mediator, and the mediator is associated with the outcome in a causal relationship, temporality is implied such that X occurs before M and M occurs before Y. (84,85) This means that the pathway from exposure to mediator to outcome is unidirectional, where the effect of the exposure variable on the outcome variable is transmitted via the mediator variable. (84,88)

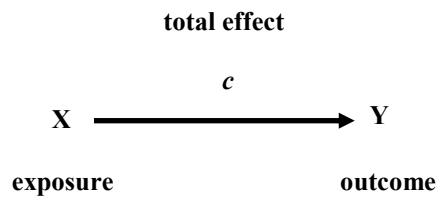
The unidirectional nature of the pathway between the exposure, mediator, and outcome variables distinguishes a mediator variable from a confounder variable, which, like a mediator, is causally associated with the outcome, but may have a bidirectional (non-causal or causal) association with the exposure and is *not* an intermediate variable in the causal pathway between exposure and outcome. (87,88) Therefore, in distinguishing between a confounder (C) and a mediator, a confounder has an association with both the exposure (X) and outcome (Y) but not as part of a causal chain, while a mediator plays a role in the causal chain between X and Y as an intermediate variable because it transmits the effect of X on Y through M. (85)



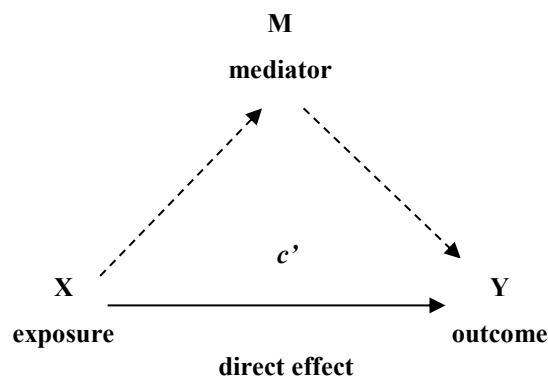
Mediation analysis is prominent in psychology theory and research, especially in the area of social, cognitive, and developmental psychology. (88) Across various fields of research, common examples of mediation analysis include: how attitudes (X) cause intentions (M) that then cause behavior (Y), how exposure to contagious bacteria (X) cause infection (M) that then cause disease (Y), and how exposure to information (X) causes learning (M) that then causes behavior (Y). (85) A challenge of mediation analysis is data requirement. Because temporality is implied in a presumed mediation model with a causal pathway from exposure (X) to mediator (M) to outcome (Y), cross-sectional data are not appropriate, and longitudinal data are necessary. (88,89) Longitudinal data allow for the inference of whether or not the effect between X and Y (and between X and M and M and Y) is occurring and stable over time within a mediation model, unlike cross-sectional data with information at one point in time. (87,88) Despite the inability of cross-sectional data to firmly establish temporality, mediation analysis is still, in practice, frequently applied to cross-sectional data. (88) This is often the case for mediation models in which a presumed relationship is mostly likely unidirectional and reverse causality is highly unlikely. (90)

An example of a study employing a mediation analysis with cross-sectional data is Ashiabi (2005), which predicted a mediation model and found that the exposure of food insecurity (X) was associated with the outcome of children’s school engagement (Y) via the mediator variable of health status (M). (90) Although the Ashiabi study considered additional variables, these three variables serve as a succinct example for describing a mediation model.

In a mediation model with three variables, exposure, mediator, and outcome, the “total effect” ( $c$ ) refers to the pathway from the exposure variable to the outcome variable, without yet considering the influence of the mediator variable in this relationship. (84) In the example of Ashiabi (2005), the total effect would refer to the relationship between food insecurity and children’s school engagement, without yet including the influence of health status in the pathway from X to Y. (90)



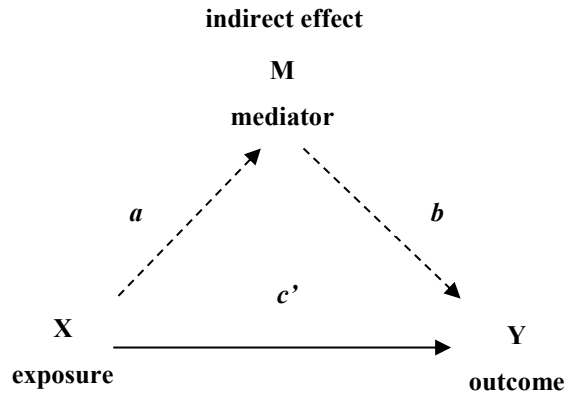
The “direct effect” ( $c'$ ) in a mediation model refers to the pathway from the exposure variable to the outcome variable, with the consideration of the influence of the mediator variable. (84) Here, in the given example of Ashiabi (2005), the direct effect considers how the total effect from food insecurity to school engagement might change when accounting for the influence of the additional intermediate mediator variable of health status in the pathway X to M to Y. (90)



The total effect and direct effect both consider the pathway from X to Y, whereas the indirect effect ( $ab$ ) looks at the pathway through the third mediator variable from X to



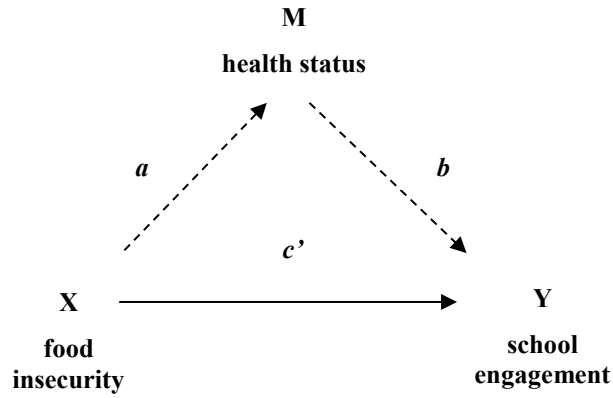
M to Y. The indirect effect is a measure of the amount of mediation in a mediation model, where total effect ( $c$ ) = direct effect ( $c'$ ) + indirect effect ( $ab$ ). (84) In the given example, the indirect effect would be looking at the stepwise pathway from food insecurity to health status ( $a$ ) and from health status to school engagement ( $b$ ).



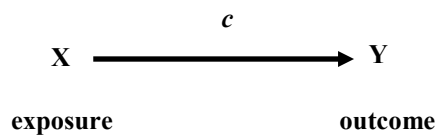
#### 2.4.1 The Four Step Approach to Testing a Mediation Model

There are many different statistical approaches to mediation analysis. A classic and frequently used approach is that of Baron and Kenny (1986), known as the Four Step Approach. (86) The Four Step Approach to mediation analysis looks at the direct effect ( $c'$ ) of the exposure variable on the outcome variable (while controlling for the mediator variable) as the key piece of information in establishing whether or not mediation in the predicted model exists. (84,86,88) The analytical steps to this approach of mediation analysis are outlined below, in which the pathways of  $c$ ,  $a$ ,  $b$ , and  $c'$  are estimated with multiple regression models and must be established in terms of statistical significance and moderate or strong effect size. Adjustment for all relevant independent variables (as per standard multiple regression techniques) can be included throughout the models in the Four Step Approach. For example, the mediation analysis of Ashiabi (2005) used Baron and Kenny's (1986) strategy and adjusted for the control variables of poverty level, education, gender of child, race and social assistance throughout their models for the Four Step Approach. (90) The exposure variable of food insecurity (X), outcome variable of

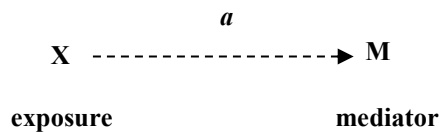
children’s school engagement (Y), and mediator variable of health status (M) from the mediation model of Ashiabi (2005) serve as a useful example in describing the Four Step Approach. (90)



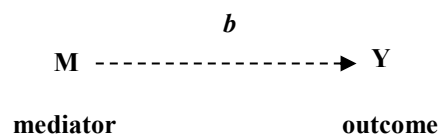
*Step 1 ( $X \rightarrow Y$ ).* It must be established that there is an association between the exposure variable (X) and the outcome variable (Y). The purpose of this step is to show that an effect exists that may be subject to mediation. In the Ashiabi (2005) example, Step 1 would test the association between food insecurity and school engagement while adjusting for the control variables listed above, without considering the influence of health status in this association. This step tests pathway *c* in the mediation model:



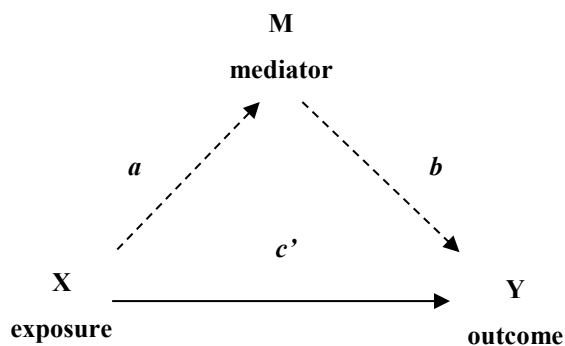
*Step 2 ( $X \rightarrow M$ ).* It must be established that the exposure variable (X) is associated with the mediator variable (M). In this step, the mediator variable is simply treated as an outcome variable. In the Ashiabi (2005) example, Step 2 would test the association between food insecurity and health status while adjusting for the control variables listed above. This step tests pathway *a* in the mediation model:



*Step 3 (M → Y).* It must be established that the mediator variable (M) is associated with the outcome variable (Y), while controlling for the exposure variable (X). In this step, it is necessary to control for the exposure variable because the mediation model presumes that both the exposure and mediator variables are associated with the outcome variable. In the Ashiabi (2005) example, Step 3 would test the association between health status and school engagement while adjusting for the listed control variables as well as food insecurity. This step tests pathway *b* in the mediation model:



*Step 4.* If steps 1-3 have established the existence of relationships,  $X \rightarrow Y$ ,  $X \rightarrow M$ , and  $M \rightarrow Y$ , the fourth step is to establish whether or not *partial* or *complete* mediation exists by testing the association between the exposure variable and the outcome variable, while controlling for the mediator variable. If the predicted model is consistent with complete mediation, the effect will be 0. Otherwise, if the value of the coefficient of the direct effect,  $c'$ , is nonzero but smaller in absolute value than the total effect, partial mediation is occurring. In the Ashiabi (2005) example, Step 4 would test the association between food insecurity and school engagement while adjusting for the listed control variables as well as health status. This step tests pathway  $c'$  in the mediation model, and compares it to  $c$ :



### 2.4.2 Challenges in Mediation Analysis

The core idea of the Four Step Approach to mediation analysis is relatively simple, however, significant challenges arise in its application. Well-known challenges include inconsistent mediation, multicollinearity, and low power as discussed by Kenny and colleagues in subsequent publications after the publication of the Four Step Approach in 1986. (84,91)

Inconsistent mediation occurs when the direct effect ( $c'$ ) is opposite in sign to the indirect effect ( $ab$ ). (84) The indirect effect is most often calculated as the product of the coefficients of pathway  $a$  and pathway  $b$ . In the case of inconsistent mediation, the exposure variable in the presumed mediation model acts as a suppressor variable such that the effect of  $X$  on  $Y$  is negative. A good hypothetical example for inconsistent mediation is the effect of stress ( $X$ ) on mood ( $Y$ ) with coping behaviour as a mediator variable ( $M$ ). In this example, the direct effect of stress on mood is negative ( $c'$ ), where higher levels of stress are associated with decreased mood. For the sake of conceptualization, if more stress leads to an increase in effective coping behaviours ( $a$ ), and an increase in coping leads to an improvement in mood ( $b$ ), this would make the indirect effect ( $ab$ ) in the mediation model positive and opposite in sign to the direct effect ( $c$ ). As a result, the total effect of stress on mood ( $c$ ) may be near to a zero coefficient, making it appear that mediation is not occurring. The Four Step approach to mediation analysis falters here when Step 1 is not met because the result of a very small or zero total effect ( $c$ ) indicates that there is no association to be mediated, when in fact there is an indirect effect that is occurring from exposure to outcome via the mediator variable.

Multicollinearity is another challenge in mediation analysis. (84) When the effect of an exposure variable on the outcome variable exists with mediation, the mediator variable ( $M$ ) is correlated with the exposure variable ( $X$ ). This multicollinearity of the mediator variable with the exposure and outcome variables inevitably affects the precision of the estimates generated in the last step of the Four Step Approach. The stronger the mediation effect is, indicated by a large effect size of  $a$  (Step 2), the smaller the effect sizes of  $b$  (Step 3) and  $c'$  (Step 4) would be. Therefore, with stronger mediation, a larger sample size would be necessary to allow for adequate power to test  $b$  and  $c'$  than in the case of

weaker mediation. Based on the associations between variables in mediation models, multicollinearity is an inevitable challenge in mediation analysis.

The issue of low power across the steps of the Four Step Approach are explored further by Kenny and Judd (2014). (91) The authors show that the tests for the pathways of the total effect ( $c$ ) in Step 1 and indirect effect ( $c'$ ) in Step 4 have relatively low power compared to the test for the indirect effect ( $ab$ ). It is thus common to find a statistically significant indirect effect in Steps 2 and 3 but a statistically insignificant total effect in Step 1. (84) In cases of partial mediation where the direct effect ( $c'$ ) is non-zero, the power of the test of the indirect effect is often still greater than that of the total effect ( $c$ ). As discussed, if inconsistent mediation exists, it is likely that there is even less power in Step 1 for testing pathway  $c$  than in testing the indirect effect ( $ab$ ).

Due to the aforementioned and other issues that arise with The Four Step Approach of Baron and Kenny, more contemporary approaches to mediation analysis have since been developed. They focus on the indirect effect ( $ab$ ) instead of the direct effect ( $c'$ ) in establishing the existence of mediation in a predicted model. (84) Furthermore, some researchers make the recommendation to avoid making claims of partial or complete mediation due to the low power of Step 4 for testing the direct effect. (84,91–94) Contemporary approaches to test the indirect effect in predicted mediation models include: the Joint Significance test of pathway  $a$  and  $b$  (84,88), the Sobel test (95), Bootstrapping (96,97), and the Monte Carlo Method (98).

## **2.5 GAPS IN THE LITERATURE**

There is a supporting body of literature for associations between household food insecurity and poor diet quality (4,5,30,51–54), between poor diet quality and poor academic performance (61–63,67,68,71–73), and between good diet quality and good academic performance (62–70). Yet there is a gap in the literature in studying the pathways between these variables using the analytical approach of mediation analysis. Much of the literature discussing the role of diet quality in the association between household food insecurity and academic performance among children is theoretical, without the use of statistical methods to test the hypothesized mechanisms for why this association occurs.

(28–30) This study addresses this gap in the literature by investigating *what* relationships exist between household food insecurity, diet quality, and academic performance, but also *why* these relationships exist.

### **CHAPTER 3. RESEARCH QUESTIONS**

1. Is household food insecurity associated with the academic performance among grade 4-6 students of the Tri-County Regional School Board in Nova Scotia?
2. Is diet quality a mediator in the association between household food insecurity and student academic performance?

## CHAPTER 4. METHODS

### 4.1 SETTING

The setting of this study is the former Tri-County Regional School Board (now Tri-County Regional Centre for Education) that serves three large counties in Nova Scotia: Digby County, Yarmouth County, and Shelburne County. Collectively referred to as the “Tri-County Region”, Digby, Yarmouth, and Shelburne County comprise largely rural townships and make up a population of approximately 60,000 people. (99)

The Tri-County Regional School Board is one of eight school boards in Nova Scotia and was officially formed in August 2004. (99) It serves approximately 6,100 students and covers over 7,000 square kilometers. (99) Representing a bilingual area, the Tri-County Regional School Board provides French Immersion and French Second Language programs. The governing board of the Tri-County Regional School Board is made up of eleven members who also sit on the Education Committee, a standing committee of the governing board. (99) The Board is responsible for 28 schools: 17 elementary schools, 6 high schools, 1 middle school, 2 elementary/high schools, and 2 adult high schools.

Demographics for the Tri-County Region, Nova Scotia, and Canada provided below in Table 1 show how the study setting compares to the greater population. The Tri-County Region represents about 6% of the Nova Scotia population. Table 1 shows that the Tri-County Region has lower education and income compared to the population of Nova Scotia and Canada. Although the findings of this study are not generalizable to Nova Scotia and Canada, this study provides information for a setting where household food insecurity is likely a serious issue and are therefore applicable in policy development for populations who are making lower than average incomes and likely affected by household food insecurity.



Table 1. Descriptive demographics for Tri-County Region, Nova Scotia, and Canada (2011)

	Shelburne	Digby	Yarmouth	Tri-County Region	Nova Scotia	Canada
<b>Population</b>	14,496	18,036	25,275	57,807	921,727	33,476,688
<b>Median Age</b>	47.2	48.7	45.9	NA	43.7	40.6
<b>Mean Age</b>	44.1	45.4	43.1	44.2	Not reported	Not reported
<b>Median Income</b>	\$21,715	\$21,338	\$23,977	NA	\$27,570	\$29,878
<b>Mean Income</b>	\$28,334	\$27,465	\$30,976	\$28,925	\$35,478	40,650
<b>Education Less Secondary</b>	53.1%	47.1%	42.8%	46.7%	38.5%	37.2%
<b>Household Food Insecurity</b>	NA	NA	NA	NA	17.5%	12.6%

## 4.2 DATA AND STUDY POPULATION

This study is a secondary analysis of a cross-sectional survey conducted in Nova Scotia in 2014 on the Influence of Comprehensive School Health on School Culture and Health Behaviors Among Children. The sampling frame included all students in the 18 Tri-County Regional School Board elementary schools attending grades 4 to 6 ( $n=1457$ ). All students and parents of students attending grades 4 to 6 in schools of the Tri-County Regional School Board that had agreed to participate in a study received invitation to take part in the survey in Spring 2014.

Participating schools received packages with sealed envelopes containing an information letter for parents, a consent form for parents to consent to their child's participation in the survey, and a parental survey with a return envelope to the school. Grade 4 to 6 homeroom teachers were asked to hand out these envelopes to their students to take home with the request that it be filled out by their parents and returned to school. A team of two trained project assistants visited the participating schools. They collected the returned envelopes, created a list of students for whom parental consent was received, and invited these students to participate in the survey. The same procedures were used for data collection during the 2011 Children's Lifestyle and School Performance Study (CLASS) II. (6) Consenting parents and students received different surveys. Parent surveys contained questions regarding socio-demographic factors, home environment, neighbourhood characteristics, child's health, and household food insecurity. The student survey included

questions regarding quality of life, eating behaviours at school and at home, food intake, and physical activity. The response rate was 46%, and a total of 670 student-parent pairs participated in the survey. After dropping 80 students due to missing relevant data or responses of energy intakes <500 kcal or >5000 kcal, this study used data from 590 students.

## **4.4 VARIABLES**

### **4.4.1 Exposure Variable**

Household food insecurity was assessed using the abbreviated six-item Food Security Scale (HFSSM-6SF). Food security and food insecurity scores were derived from the number of affirmative responses to the six included survey items. Any missing values for individuals with three or fewer missing responses were imputed by following the procedure outlined in the HFSSM documentation. (26) As a standard practice in the literature, as described in the background section, based on an overall score using ordinal numbers, households were then classified as having high food security (score 0), marginal food insecurity (score 1), moderate food insecurity (score 2-4), or severe food insecurity (score 5-6). These outcomes were used for binary classification of households as “food secure” or “food insecure”, where a score of 0 is for “food secure” and a score of 1, 2-4, or 5-6 is for “food insecure”. The six-item short form survey is included in Appendix I. Table 2 below shows the distributions of household food insecurity levels in the study sample.

Table 2. Distribution of the study sample across household food insecurity levels (as defined according to the HFSSM-6SF)

Level of HFI	Frequency	Dichotomization
High food security	499 (74%)	<i>Food secure</i>
Marginal food insecurity	55 (8%)	<i>Food insecure</i>
Moderate food insecurity	71 (11%)	
Severe food insecurity	40 (6%)	
Missing	5 (1%)	
<b>Total</b>	670 (100%)	

#### 4.4.2 Outcome Variable

This study uses two binary variables of academic performance (“good” vs. “poor”) based on school reported grades in English Language Arts (Reading, Speaking, and Writing) and Mathematics (Probability, Geometry, Measurement, Numbers and Operations, and Patterns and Relationship). Participating students’ grades were provided by term (Terms 1-3) and were coded as A, B, C, D, or N/A, when a subject was not taken by the student for a given term. Students were required to have at least 2 out of 3 grades for either subject over the school year. Letter grades were translated to numbers (A=1, B=2, C=3, D=4) to calculate a student’s average score for a subject taken for more than one term. “Good” vs. “poor” academic performance was assigned to each student for each subject, where a score of <2.5 was interpreted as “good” and a score of  $\geq 2.5$  was interpreted as “poor”. Students’ overall average score across different subjects was also calculated using the same coding. Table 3 below shows the distributions of school grades in the study sample.

Table 3. Distribution of the study sample across school grades

School Grade	English Language Arts	Mathematics	Dichotomization
<b>A</b>	294 (50%)	212 (36%)	<i>Good academic performance</i>
<b>A/B</b>	1 (<1%)	67 (11%)	
<b>B</b>	232 (39%)	215 (36%)	
<b>B/C</b>	1 (<1%)	26 (4%)	
<b>C</b>	52 (9%)	57 (10%)	<i>Poor academic performance</i>
<b>C/D</b>	0 (0%)	4 (1%)	
<b>D</b>	1 (<1%)	1 (1%)	
<b>Missing</b>	9 (2%)	8 (1%)	
<b>Total</b>	590 (100%)	590 (100%)	

#### 4.4.3 Mediator Variable

This study uses two overall diet quality measures, the Diet Quality Index-International (DQI-I) and the Youth Healthy Eating Index (YHEI). (32,35) Both of these measures were constructed according to participating students' responses for the Harvard Youth/Adolescent Food Frequency Questionnaire (YAQ) and by linking these responses to information provided in the Canadian Nutrient File. (39,43)

Approximate daily intake of nutrients from various foods were estimated from the responses provided in the YAQ by using information laid out in the Canadian Nutrient File in order to obtain the necessary nutrient information for foods included in the questionnaire. Intake of particular nutrients were calculated as the sum of the products of the specific frequency of foods eaten and the nutrient composition for the corresponding foods, i.e.,  $\text{sum}(\text{daily freq}(\text{food } x) * \text{nutrient content}(\text{food } x))$ . (43) Food group intake was assessed based on guidelines set out in Canada's Food Guide (44) by determining if students were meeting the daily recommended values across different food groups (yes/no) for fruits and vegetables ( $\geq 6$ ), milk products ( $\geq 3$ ), grain products ( $\geq 6$ ), and meat products ( $\geq 1$ ). (33) Based on the energy requirement guidelines in Canada's Food Guide, food intakes were standardized to an energy intake of 2,000 kcal/day. (100) Overall diet quality was then assessed by computing DQI-I scores, which range from 0 (poorest) to 100 (highest), by following the scoring criteria for this index that considers nutrient and food group intakes. A DQI-I score is calculated as the sum of scores for the categories of dietary variety, adequacy, moderation, and balance. (32) Directions for computing DQI-I scores from dietary information (found first through application of the YAQ and Canadian Nutrient File) are included in Appendix II.

In addition, a YHEI score was calculated as the sum of scores for the thirteen components included in this dietary index. (35) YHEI scores, as for the DQI-I scores, range from 0 (poorest) to 100 (highest), and are similarly derived by following the scoring criteria for this index. The dietary requirements to achieve maximum scores across the components of the YHEI tool are included in Appendix III.

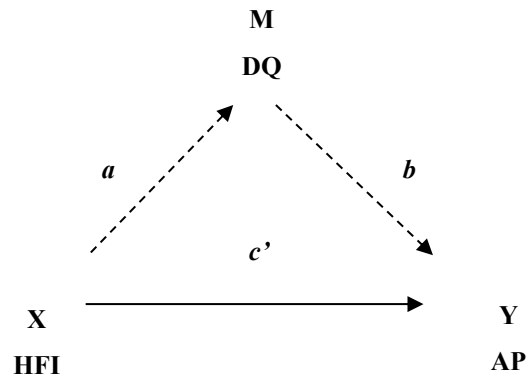
#### **4.4.4 Potential Confounders**

Other variables included in the analysis were: sex (male vs. female), household income (\$0–40,000, >\$40,000, or missing), highest household education (secondary school or lower vs. college or university), number of household members (2-4 vs. >5 persons), and area of residence (urban vs. rural). The area of residence variable is based on the second character of the Forward Sortation Area in the Canadian postal code indicated by rural postal codes containing 0 as the second character. (6,101) All other variables are self-reported.

#### **4.5 ANALYSIS**

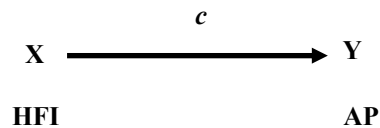
The analysis first described sample characteristics using means and standard deviations (continuous variables) or proportions (categorical variables). To answer the two research questions, we followed the Four Step Approach of Baron and Kenny (1986) and ran a series of regression models. These multiple regression models included school as the random effect. Random intercept models were used to correct the standard errors for the correlation (non-independence) of student observations within each school using hierarchical linear modelling. To determine best-fit models, we started with adjustments for sex, household income, household education, number of household members, and area of residence based on a priori assumptions about confounding, next for household income and household education, and then for household education only. Due to the challenge of collinearity and to avoid over-adjustment, we chose household education as the only adjustment variable in our mediation model for its strongest relationship with the outcome variables among all other potential confounder variables considered. Regression models in the analysis that included diet quality were also adjusted for energy intake, while students with energy intakes <500 kcal or >5000 kcal were excluded from the analysis all together based on plausibility of misreporting. (102)

The specific mediation model following the Four Step Approach of Baron and Kenny (1986) used for the analysis is as follows:

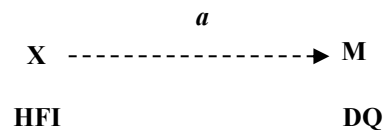


Diet quality (DQ) (measured by DQI-I and YHEI) is hypothesized to mediate the relationship between household food insecurity (HFI) and academic performance (AP) (measured by English Language Arts and Mathematics).

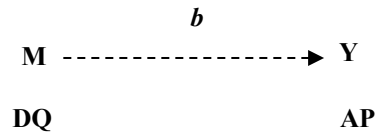
Analysis to answer the first research question of whether household food insecurity is associated with the academic performance corresponds to Step 1 of the Four Step Approach. Step 1 tested pathway *c* in the mediation model using logistic regression: an association between household food insecurity and academic performance.



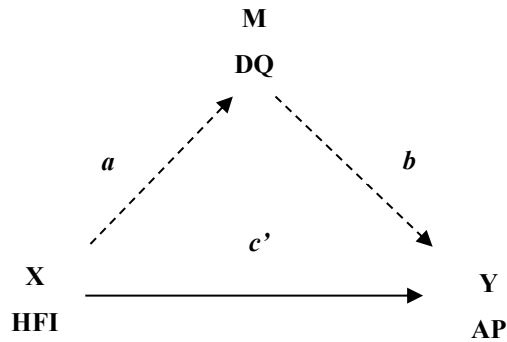
Analysis to answer the second research question of whether diet quality mediates the association between household food insecurity and academic performance corresponds to Steps 2-4 of the Four Step Approach. Step 2 tested pathway *a* using linear regression: an association between household food insecurity and children's diet quality.



Step 3 tested pathway *b* using logistic regression: an association between diet quality and academic performance.



Step 4 was to test pathway *c'* using logistic regression and compare it to *c* to assess if diet quality mediates the relationship between household food insecurity and academic performance. This was to be achieved by testing the association between household food insecurity and academic performance while controlling for diet quality:



We performed all statistical analyses using Stata/SE 12 (Stata Corp., College Station, TX, US) and considered  $p < 0.05$  as statistically significant.

#### 4.6 RESEARCH ETHICS CONSIDERATIONS

Permission for collection of the original data that this study used was granted by the Tri-County Regional School Board and Dalhousie Health Sciences Research Ethics Board. The original survey ensured that appropriate consent was received from participants at all levels involved in the study, from schools, parents, and students. Furthermore, confidentiality of all survey participants was respected by including no names or other identifiers were included in the study dataset. Results were reported in such a way that

individuals could not be inadvertently identified. This thesis obtained an additional research ethics approval from the Dalhousie University Research Ethics Board.



## **CHAPTER 5. RESULTS**

### **5.1 SAMPLE CHARACTERISTICS**

Table 4 reports sample characteristics. The sample of 590 students had a mean score of 59.8 for DQI-I and a mean score of 61.1 for YHEI. Prevalent characteristics are: income greater than \$40,000, college or university education, 4 household members, and rural residence. A substantial proportion of household (21%) was missing income information.

Table 4 also shows sample characteristics stratified by household food insecurity. Children from food insecure households were statistically significantly more likely to come from households with lower income (less than \$40,000) and lower education (secondary school or less). There were no statistically significant differences between the food secure and insecure groups in terms of sex, household size, or area of residence. The mean score of DQI-I in the food secure and insecure groups were not statistically significantly different, but the mean score of YHEI was. The mean scores of DQI-I and YHEI reported in Table 4 were without adjustment for caloric intake, unlike those in subsequent results described below.

Table 4. Sample characteristics by household food insecurity

	<b>All (n = 590)</b>	<b>Food Secure (n = 447)</b>	<b>Food Insecure (n = 143)</b>	<b>P value*</b>
<b>Sex</b>				0.847
Male	275 (47%)	207 (46%)	68 (48%)	
Female	315 (53%)	240 (54%)	75 (52%)	
<b>Household Income</b>				<0.001
\$ 0–40,000	151 (26%)	73 (16%)	78 (55%)	
\$ > 40,000	315 (53%)	272 (61%)	43 (30%)	
Missing	124 (21%)	102 (23%)	22 (15%)	
<b>Household Education</b>				<0.001
Secondary school or less	149 (26%)	91 (21%)	58 (41%)	
College or university	425 (74%)	343 (79%)	82 (59%)	
<b>Number Household Members</b>				0.237
2	33 (6%)	20 (4%)	13 (9%)	
3	126 (22%)	93 (21%)	33 (23%)	
4	247 (42%)	193 (44%)	54 (38%)	
5	121 (21%)	94 (21%)	27 (19%)	
> 5	59 (10%)	43 (10%)	16 (11%)	
<b>Area of Residence</b>				0.554
Urban	200 (34%)	155 (35%)	45 (31%)	
Rural	390 (66%)	292 (65%)	98 (69%)	
<b>DQI-I</b>				0.891
	Mean 59.8	Mean 59.8	Mean 59.7	
	SD 11.2	SD 11.1	SD 11.3	
<b>YHEI</b>				0.002
	Mean 61.1	Mean 61.8	Mean 58.9	
	SD 10.0	SD 10.1	SD 9.5	

\* Calculated from Fisher’s exact test for sex, income, education, number of household members, and area of residence, and from t-tests for DQI-I and YHEI.

Percentages are for columns.

*DQI-I* Diet Quality Index-International, *SD* standard deviation, *YHEI* Youth Healthy Eating Index.

Table 5 reports the sample characteristics by academic performance in English Language Arts and Mathematics. There was no statistically significant difference between female and male for poor academic performance in English Language Arts or Mathematics. On the other hand, there was a statistically significant difference in poor academic performance in English Language Arts or Mathematics by income and education. Higher percentages in poor academic performance for both subjects were found for lower household income and education.

There was no statistically significant difference across numbers of household members with poor academic performance in English Language Arts but there was with poor academic performance in Mathematics. The greatest percentage of children with poor academic performance in Mathematics was found for >5 household members. There was no statistically significant difference between urban and rural residence in poor academic performance in Mathematics but there was in poor academic performance in English Language Arts. A higher percentage of children with poor performance in English Language Arts was found for the rural residence.

Table 5 also reports means and standard deviations of DQI-I and YHEI scores by academic performance. The mean score of YHEI was statistically significantly lower among children with poor English Language Arts and Mathematics, while the mean score of DQI-I was statistically significantly lower only among children with poor English Language Arts.

Table 5. Sample characteristics by academic performance

	<b>ELA Poor</b>	<b>ELA Good</b>	<b>P value*</b>	<b>Math Poor</b>	<b>Math Good</b>	<b>P value*</b>
<b>Sex</b>			0.248			0.592
Male	29 (11%)	241 (89%)		31 (11%)	240 (89%)	
Female	24 (8%)	287 (92%)		31 (10%)	280 (90%)	
<b>Household Income</b>			<0.001			<0.001
\$ 0–40,000	26 (18%)	122 (82%)		30 (20%)	117 (80%)	
\$ > 40,000	16 (5%)	294 (95%)		17 (5%)	296 (95%)	
Missing	11 (9%)	112 (91%)		15 (12%)	107 (88%)	
<b>Household Education</b>			<0.001			0.001
Secondary school or less	26 (18%)	121 (82%)		26 (18%)	121 (82%)	
College or university	24 (6%)	394 (94%)		32 (8%)	387 (92%)	
<b>Number Household Members</b>			0.182			0.007
2	4 (12%)	29 (88%)		6 (18%)	27 (82%)	
3	14 (12%)	107 (88%)		18 (15%)	104 (85%)	
4	15 (6%)	230 (94%)		15 (6%)	230 (94%)	
5	12 (10%)	107 (90%)		12 (10%)	107 (90%)	
> 5	8 (14%)	51 (86%)		11 (19%)	48 (81%)	
<b>Area of Residence</b>			0.033			0.778
Urban	11 (6%)	188 (94%)		20 (10%)	180 (90%)	
Rural	42 (11%)	340 (89%)		42 (11%)	340 (89%)	
<b>DQI-I</b>			0.014			0.513
	Mean 56.1	Mean 60.1		Mean 58.9	Mean 59.8	
	SD 12.6	SD 10.9		SD 10.9	SD 11.2	
<b>YHEI</b>			0.004			0.045
	Mean 57.3	Mean 61.5		Mean 58.7	Mean 61.4	
	SD 9.7	SD 9.8		SD 8.5	SD 10.0	

\* Calculated from Fisher’s exact test for sex, income, education, number of household members, and area of residence, and from t-tests for DQI-I and YHEI.

Percentages are for rows.

*DQI-I* Diet Quality Index-International, *ELA* English Language Arts, *SD* standard deviation, *YHEI* Youth Healthy Eating Index

## **5.2 HOUSEHOLD FOOD INSECURITY AND ACADEMIC PERFORMANCE**

Tables 6 and 7 present the results for the first research question, “Is household food insecurity (“food secure” or “food insecure”) associated with the academic performance among grade 4-6 students of the Tri-County Regional School Board in Nova Scotia?” These results pertain to Step 1 of the Four Step Approach, where we tested pathway *c* in the mediation model.

After adjusting for household education, children from food insecure households had an odds ratio of 1.93 (95% CI: 0.97, 3.81) to have poor performance in English Language Arts relative to children from food secure households, but this result was not statistically significant. Children from food insecure households were significantly more likely to have poor academic performance in Mathematics (OR 1.92, 95% CI: 1.06, 3.46) compared to their peers in households that were food secure.

Table 6. Association between household food insecurity and poor academic performance in English Language Arts

	<b>Unadjusted OR [95% CI]</b>	<b>Adjusted* OR [95% CI]</b>
<b>Household Food Insecurity</b>		
Food Secure	1.00 (Ref)	1.00 (Ref)
Food Insecure	2.37 [1.26, 4.44]	1.93 [0.97, 3.81]
<b>Sex</b>		
Female	1.00 (Ref)	
Male	1.36 [0.75, 2.45]	
<b>Household Income</b>		
\$ 0–40,000	1.00 (Ref)	
\$ > 40,000	0.23 [0.11, 0.46]	
Missing	0.41 [0.18, 0.91]	
<b>Household Education</b>		
Secondary school or less	1.00 (Ref)	1.00 (Ref)
College or university	0.25 [0.13, 0.49]	0.28 [0.14, 0.55]
<b>Number Household Members</b>		
2	1.00 (Ref)	
3	1.13 [0.32, 3.97]	
4	0.46 [0.14, 1.56]	
5	0.84 [0.24, 2.99]	
> 5	1.30 [0.33, 5.00]	
<b>Area of Residence</b>		
Urban	1.00 (Ref)	
Rural	1.93 [0.73, 5.14]	

\* Adjusted for household education

OR: odds ratio

Table 7. Association between household food insecurity and poor academic performance in Mathematics

	<b>Unadjusted</b>	<b>Adjusted*</b>
<b>Household Food Insecurity</b>		
Food Secure	1.00 (Ref)	1.00 (Ref)
Food Insecure	2.22 [1.28, 3.86]	1.92 [1.06, 3.46]
<b>Sex</b>		
Female	1.00 (Ref)	
Male	1.17 [0.69, 1.98]	
<b>Household Income</b>		
\$ 0–40,000	1.00 (Ref)	
\$ > 40,000	0.22 [0.12, 0.42]	
Missing	0.55 [0.23, 1.07]	
<b>Household Education</b>		
Secondary school or less	1.00 (Ref)	1.00 (Ref)
College or university	0.38 [0.22, 0.67]	0.43 [0.24, 0.77]
<b>Number Household Members</b>		
2	1.00 (Ref)	
3	0.78 [0.28, 2.17]	
4	0.29 [0.10, 0.82]	
5	0.50 [0.17, 1.47]	
> 5	1.03 [0.34, 3.10]	
<b>Area of Residence</b>		
Urban	1.00 (Ref)	
Rural	1.11 [0.63, 1.95]	

\* Adjusted for household education

### 5.3 DIET QUALITY AS A MEDIATOR

Tables 8-11 report results for the second research question, “Is diet quality a mediator in the association between household food insecurity and student academic performance?” The results reported in Tables 8-9 pertain to Step 2 of the Four Step Approach, where we tested pathway *a* in the mediation model, and results reported in Tables 10-11 pertain to Step 3 of the Four Step Approach, where we tested pathway *b* in the mediation model.

Table 8 presents the results for the unadjusted and adjusted linear regression models that examined the association between household food insecurity and diet quality measured by the DQI-I. For both the unadjusted and adjusted models, children from food insecure households tended to have a slightly lower DQI-I score than children from food secure households, but the association was not statistically significant.

Table 9 presents the results for the unadjusted and adjusted linear regression models that examined the association between household food insecurity and diet quality measured by the YHEI. The association between household food insecurity and YHEI was statistically significant: children from food insecure households had 3.57 and 3.31 points lower YHEI scores than children from food secure households in the unadjusted and adjusted model, respectively.

Table 10 presents the results for the analysis examining the association between diet quality, measured by DQI-I and YHEI, and poor academic performance in English Language Arts, and Table 11 presents the results for the analysis examining the association between diet quality, measured by DQI-I and YHEI, and poor academic performance in Mathematics. The associations between diet quality, measured both by the DQI-I and YHEI, and poor academic performance both for English Language Arts and Mathematics were statistically significant, but the effect sizes were small. For every unit increase in diet quality, on a 100-point scale for both the DQI-I and YHEI, the odds of poor academic performance in English Language Arts and Mathematics decrease by 5 and 3%, respectively.

The prerequisites for performing a mediation analysis (86) were not met because: (1) there was no consistent total effect of household food insecurity on academic performance (Table 6 and 7); (2) there was no consistent and moderate or strong



association between household food insecurity and diet quality (Table 8 and 9); (3) there was no consistent and moderate or strong association between diet quality and academic performance (Table 10 and 11). The mediation analysis was therefore discontinued.

Table 8. The association between household food insecurity and diet quality measured by DQI-I

	<b>Unadjusted*</b>	<b>Adjusted**</b>
<b>Household Food Insecurity</b>		
Food Secure	1.00 (Ref)	1.00 (Ref)
Food Insecure	-1.84 [-3.76, 0.08]	-1.78 [-3.78, 0.22]

\* With exception of adjusting for calorie intake

\*\* Adjusted for household education

Table 9. The association between household food insecurity and diet quality measured by YHEI

	<b>Unadjusted*</b>	<b>Adjusted**</b>
<b>Household Food Insecurity</b>		
Food Secure	1.00 (Ref)	1.00 (Ref)
Food Insecure	-3.57 [-5.46, -1.68]	-3.31 [-5.23, -1.36]

\* With exception of adjusting for calorie intake

\*\* Adjusted for household education

Table 10. The association between diet quality and poor academic performance in English Language Arts

	<b>Unadjusted*</b> <b>OR [95% CI]</b>	<b>Adjusted**</b> <b>OR [95% CI]</b>
<b>DQI-I</b>		
	0.95 [0.92, 0.98]	0.95 [0.92, 0.98]
<b>YHEI</b>		
	0.95 [0.92, 0.98]	0.95 [0.92, 0.99]

\* With exception of adjusting for calorie intake

\*\* Adjusted for household education

Table 11. The association between diet quality and poor academic performance in Mathematics

	<b>Unadjusted*</b> <b>OR [95% CI]</b>	<b>Adjusted**</b> <b>OR [95% CI]</b>
<b>DQI-I</b>		
	0.97 [0.94, 0.99]	0.97 [0.94, 1.00 <sup>a</sup> ]
<b>YHEI</b>		
	0.96 [0.94, 0.99]	0.97 [0.94, 1.00 <sup>b</sup> ]

\* With exception of adjusting for calorie intake

\*\* Adjusted for household education

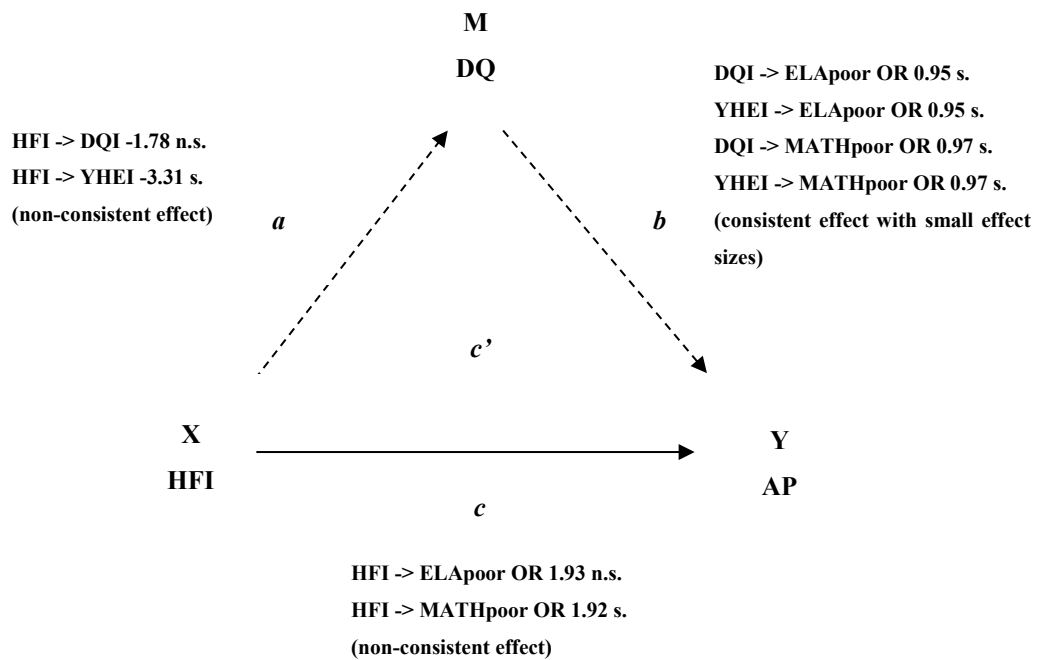
<sup>a</sup> Exact value: 0.998

<sup>b</sup> Exact value: 0.997

## 5.4 SUMMARY OF RESULTS

Applying the Four Step Approach to mediation analysis, this thesis project found pathway *c* (household food insecurity to academic performance) was statistically significant for one of the two subject outcomes for academic performance, pathway *a* (household food insecurity to diet quality) was statistically significant for one of the two diet quality measures, and pathway *b* (diet quality to academic performance) was statistically significant for both diet quality measures and for both subjects but with small effect sizes. Given that there was no consistent total effect of food security on academic performance (pathway *c*), no consistent and moderate or strong association between

household food insecurity and diet quality on one side (pathway *a*), and between diet quality and academic performance on the other side (pathway *b*), the prerequisites for proceeding with the Four Step Approach to mediation analysis (86) were not met. The analysis was therefore concluded after step 3 and did not proceed to complete Step 4 to test pathway *c'* in the mediation model.



## **CHAPTER 6. DISCUSSION**

### **6.1 OVERVIEW**

This study used a population-based cross-sectional survey conducted in the Tri-County Region of Nova Scotia, Canada to investigate the association between household food insecurity and academic performance of children with diet quality as a potential mediator. This study found that 24.2% of children in the sample were living with household food insecurity in 2014, higher than the prevalence of 22% of children in Nova Scotia and 15.6% of children in Canada concerning households with children under the age of 18. (3) This study found that household food insecurity was associated with poor academic performance in Mathematics but was not statistically significantly associated with academic performance in English Language Arts. Further, this study found an association between household food insecurity and diet quality and between diet quality and poor academic performance in English Language Arts and Mathematics; however, prerequisites for mediation analysis were not met and the results were inconclusive for diet quality as a mediator in the association between household food insecurity and academic performance. This thesis project shows a need for further study of diet quality as a mediator in the association between household food insecurity and academic performance, which would help to support the role and development of school nutrition programs for improving the academic performance of children, especially those living with household food insecurity.

This chapter discusses some of the key findings, pertaining to the lack of consistent statistically significant associations between household food insecurity and academic performance and the lack of consistent role of diet quality as a mediator in the association between household food insecurity and academic performance, as well as strengths and limitations and policy implications.

### **6.2 INCONSISTENT ASSOCIATIONS BETWEEN HOUSEHOLD FOOD INSECURITY AND ACADEMIC PERFORMANCE**

This study found that food insecurity was statistically significantly associated with poor academic performance in Mathematics (OR 1.92, 95% CI: 1.06, 3.46), but not in

English Language Arts (OR 1.93, 95% CI: 0.97, 3.81). Previous studies show that household food insecurity is negatively associated with academic performance among children across school subjects. (7,8,14,31,83,103–106) Comparison of the results from this thesis project with those in the literature requires careful attention to differences in study design, population, sample size, measurement of key variables, and analytical approaches. The most closely comparable study is the recent study by Faught et al. (2017) that examined the association between household food insecurity and school performance using data from the Children’s Lifestyle and School Performance Study II (CLASS II). CLASS II included all grade 5 students (ages 10-11 years old) attending public schools in Nova Scotia ( $n=5913$ ), and the survey this thesis project used had been in part modeled after the CLASS II study. (83) Faught et al. measured the academic performance of grade 5 students using standardized test scores in Reading, Writing, and Mathematics. (83) Test scores for grade 5 students were provided by the Nova Scotia Department of Early Education and Child Development that administered provincial mandatory standardized exams in these subjects. (83) Test scores were provided and subsequently coded as “meeting expectations” or “not meeting expectations” based on standardized provincial rubric criteria. (83) Household food insecurity was classified as high food security, low food security, or very low food security, and was prospectively linked to children’s grade 6 standardized test scores obtained one year later in the same subjects. (83) Faught et al. found that in the unadjusted models household food insecurity was strongly and negatively associated with academic performance in all three subjects, while in the adjusted models controlling for household income and education, children with very low food security were less likely to meet expectations in Reading and Mathematics. (83)

The lack of a statistically significant association between household food insecurity and academic performance in English Language Arts found in this thesis project compared to a statistically significant finding in the study by Faught et al. is likely attributable to a few important factors. First, the sample size for the study by Faught et al. was much larger ( $n=4105$ ) than that for this thesis project ( $n=590$ ). The larger sample size gave greater statistical power to detect significant associations in the study by Faught et al. Further, the larger sample size in the study by Faught et al. allowed for three levels of household food insecurity classification as opposed to two in this thesis project. This is an important

difference because Faught et al. identified an association between household food insecurity and academic performance for very low (i.e., severe) household food insecurity, while they did not find a statistically significant association between household food insecurity and academic performance in any of the three subjects for low (i.e., intermediate level) household food insecurity. (83) In this thesis project, due to a much smaller sample size, children with severe and intermediate levels of household food insecurity were classified and coded as “food insecure” in the dichotomization of household food insecurity. Second, academic performance was measured differently between the study by Faught et al. and this thesis project. Faught et al. used standardized test scores rather than school grades and may have provided a more objective assessment of children’s academic performance. (107)

Lastly, adjustments were different. The final models of this thesis project only adjusted for household education, whereas Faught et al. in addition adjusted for household income and a number of other variables including diet, body weight, physical activity, sleep and screen time, sex, and region of residency. (83) In their fully adjusted models, Faught et al. found independent statistically significant associations for household income, household education, and diet quality with academic performance. (83) Although adjustments for these potential confounders in the final models of their study would have attenuated the association between household food insecurity and academic performance toward the null, their study still found a strong negative association between household food insecurity and academic performance both in Reading and Mathematics. (83) The authors explained that they had adjusted for diet quality to evaluate the association between food insecurity and academic performance outside of the potential role of diet quality as a mediator in this association. They acknowledged that there was risk of over-adjustment bias in their analysis. (83) This has important relevance for the second research question of our study, which is discussed below. Considering potential over-adjustment bias in the results of Faught et al., the difference in results found by this study (an association between household food insecurity and Mathematics but not for English Language Arts) and by Faught et al. (an association between household food insecurity and both Reading and Mathematics) should be attributed to the differences regarding sample sizes and measures of academic performance as discussed above.

Larger sample sizes and alternative measures of household food insecurity and academic performance indeed appear to be important differences between this thesis and other studies that found an association between household food insecurity and academic performance among children. For example, a cross-sectional study by Roustit et al. found an association between household food insecurity, measured by the Radimer/Cornell Questionnaire, and self-reported measures of academic performance in French and English among adolescents ( $n=2356$ ) aged 13-16 years. (8) Alaimo et al. (2001) used a cross-sectional study design and found an association between household food insecurity, measured by responses from the NHANES III family survey, and academic performance according to standardized test scores for Reading and Mathematics, number of days absent from school, and having had to repeat a school year among children aged 6-11 years ( $n=3286$ ). (14) Winicki et al. (2003) and Jyoti et al. (2005), who also found an association between household food insecurity and academic performance in longitudinal studies, used standardized testing to assess academic performance and the full 18-item HFSSM rather than the abbreviated HFSSM-6SF to assess household food insecurity. (7,31) The latter is noteworthy difference because the full 18-item HFSSM captures food security status at the household and individual level, whereas the HFSSM-6SF only captures food security status at the household level and cannot determine whether a child is experiencing the same level of food insecurity as other household members. (25) Furthermore, the HFSSM-6SF has a lower sensitivity than specificity, especially for households with children compared to all households. As such, use of the HFSSM-6SF in this thesis project could have generated slightly less accurate results by being better at identifying food secure households than identifying food insecure households (25) in comparison to Winicki et al. and Jyoti et al., who measured food security with the full 18-item HFSSM.

Of note, like the aforementioned study by Faught et al. and this thesis project, many of these studies struggle with confounding of household income in the relationship between household food insecurity and academic performance. For example, Winicki et al. found a statistically significant association between household food insecurity and Mathematics, but not when income was added to their model. (31) In the study of Alaimo et al., after adjusting for income and other potential confounders such as age, gender, region, and household education, household food insecurity was statistically significantly associated

with Mathematics, but was no longer so with Reading. (14) In this thesis project, we found a significant association between household food insecurity and poor academic performance in Mathematics in the model that controlled for household education, but not in the model that additionally controlled for household income (data not shown). Household income and household food insecurity are highly correlated, and adjustment for income will remove any effect of household food insecurity on the outcome almost entirely. Therefore, we considered the addition of income to the adjusted models to be an over-adjustment, and reported only the results of the models that controlled for household education. (108)

### **6.3 INCONSISTENT ROLE OF DIET QUALITY AS A MEDIATOR**

The second research objective of this thesis project was to assess the potential role of diet quality as a mediator in the association between household food insecurity and academic performance by following steps 2-4 of Baron and Kenny's (1986) Four Step Approach. The second step of the Four Step Approach found the association between household food insecurity and diet quality measured by DQI-I was not statistically significant: children from food insecure households scored 1.78 points lower on the DQI-I scale than children from food secure households. However, the association between household food insecurity and diet quality measured by YHEI was statistically significant: children from food insecure households had 3.31 points lower YHEI scores than children from food secure households.

This lack of the consistent relationship between household food insecurity and diet quality depending on the measure of diet quality as compared to findings in the literature is most likely due to our small sample size and analytical approach to variable management. A study by Kirk et al. (2014) found that children living with moderate and severe food insecurity had statistically significantly lower DQI-I scores compared to food secure children. (6) Furthermore, Kirk et al. found that marginal, moderate, and severe food insecurity was associated with a lesser likelihood to meet the recommendations in Canada's Food Guide for fruit and vegetables and milk products compared to food secure children. (6) The study by Kirk et al. had a much larger sample size ( $n= 5853$ ) than this thesis project



and therefore had greater statistical power to detect a statistically significant association between household food insecurity and DQI-I. (6) In addition, Kirk et al. categorized household food insecurity into four levels, high food security, marginal food insecurity, moderate food insecurity, and severe food insecurity, rather than the dichotomization between food secure and food insecure used in this thesis project. (6) Similar to the aforementioned study of Faught et al., a larger sample size of the study of Kirk et al. allowed for granular household food insecurity categories and may have better captured the relationship between household food insecurity and diet quality if it is more predominant with severe levels of household food insecurity. (6,83) For example, Kirk et al. did not find an association between moderate food insecurity and DQI-I. (6)

The third step of the Four Step Approach found statistically significant associations between diet quality and academic performance with both measures of diet quality (DQI-I and YHEI) and for both study subjects (English Language Arts and Mathematics) but the effect sizes were small. Specifically, for every unit increase in diet quality in the 100-point scale both for DQI-I and YHEI, the odds of poor academic performance in English Language Arts and Mathematics decreased by 5 and 3%, respectively. These effect sizes were small compared to findings in the literature for this association. The lack of a consistent moderate or strong relationship between diet quality and academic performance in this study is most likely, once again, due to small sample size, differences in variable measurement, and analytic approach to variable management. While the study of Faught et al. found a strong independent association between diet quality and academic performance using the DQI-I, their larger sample size had greater statistical power to detect associations and could be attributed to their greater effect sizes in comparison to this study. (83) Their study found that children in the high tertile of the DQI-I had odds ratios of 1.76, 1.66, and 1.53 to meet expectations on standardized tests in the respective subjects of Reading, Writing, and Mathematics, respectively, relative to children in the low tertile. (83) Other studies that identified strong associations between diet quality and academic performance measured specific components within diet quality, such as the intake of certain micronutrients (61,67–70) and levels of fast food consumption. (63,71–73) This is an important difference in comparison to this study, which measured diet quality with the composite summary scores of the DQI-I and YHEI. These scales both encompass a much

wider range of diet quality, including both healthful and unhealthful eating behaviours. (32,35) The many different ways that diet quality has been assessed in the literature highlights the challenge of measuring diet quality. Diet quality is a highly nuanced and multifaceted variable. (61,109) This makes it challenging to make cross-study comparisons of effect sizes in the association between diet quality and academic performance and could attribute to differences in findings.

In addition, the study of McIsaac et al. used both the DQI-I and YHEI for measurement of diet quality but found stronger effect sizes than this study: children in the low tertiles for the DQI-I and YHEI had odds ratios of 4.26 and 3.22, respectively, to have poor academic performance in English Language Arts relative to children in the high tertiles for these scales. (77) However, careful attention is necessary in comparing the effect sizes. The unit used for DQI-I and YHEI in this study was a single unit change on the 100-point scales, while the unit used in studies by McIsaac et al. and Faught et al. were tertiles on the 100-point scales. (77,83) Therefore, interpretation of effect sizes must consider how the diet quality variable was constructed and which analytical approach was used.

In conclusion, although the results of our mediation analysis were inconclusive, contextualizing them with the relevant literature, they still point to the potential mediating role of diet quality in the relationship between household food insecurity and academic performance. Future investigation of diet quality as a mediator in the association between household food insecurity and academic performance can benefit from careful attention to adequate sample size and analytic approach to handling variables in the predicted mediation model, such as using more than two levels for household food insecurity, and consistency in assessment of diet quality.

## **6.4 STRENGTHS AND LIMITATIONS**

Key limitations of this thesis project are: the use of cross-sectional data, small sample size, potential selection bias, potential for systematic error with the use of school grades as the measurement of academic performance, potential for biases with the use of self-reported data for the exposure and mediator variables, challenges of interpreting meaningful differences in diet quality scores for real-life settings, and the potential

challenges with Baron and Kenny's (1986) Four Step Approach as compared to contemporary approaches to mediation analysis.

First, a cross-sectional study does not allow for causal inference on the associations studied. Cross-sectional studies capture a snapshot in time, and unlike cohort studies, cannot infer temporality between the cause and effect (one of the prerequisites for causal inference). However, in this thesis project, the association is most likely unidirectional. Household food security is unlikely to be influenced by diet quality or academic performance of students but is rather likely to depend on factors typically influenced by parents, such as household income, improper allocation of household funds, and geographical location. (20) Another difficulty with investigating the association between household food security and academic performance in a cross-sectional study is that in measuring these variables at one point of time, we cannot distinguish short and long-term effects of household food insecurity. This is a notable drawback for studying causal pathways that most likely occur with a long duration of time (89) and has particular relevance to this study. Individuals with household food insecurity suffer from insufficient cognitive development as a result of malnutrition starting as early as in utero with cumulative effects over time. (28,61,110) Although mediation analyses commonly use cross-sectional data, longitudinal data are more appropriate for studying the effects of household food insecurity on academic performance and a potential mediating role of diet quality among children developing over time. (89)

Second, the small sample size of this study resulted in the lack of statistical power and a risk of type II error (where the null hypothesis of no association is accepted when there is an association). The result of no consistent total effect of household food insecurity on academic performance, with an odds ratio of 1.93 (95% CI: 0.97, 3.81) for the association between household food insecurity and poor academic performance in English Language Arts and an odds ratio of 1.92 (95% CI: 1.06, 3.46) for the association between household food insecurity and poor academic performance in Mathematics, is likely the result of type II error. The small sample size also created constraints in the measurement of key variables. With a larger sample size, we might have considered using all four levels of household food insecurity instead of only two, especially considering that the associations between household food insecurity with diet quality and academic

performance have been found at the more severe levels of household food insecurity. (6,83) In addition, due to the small sample size in this study, academic performance was dichotomized according to “good” vs. “poor”, rather than using more than two categories. The decision to dichotomize grades was primarily based on the common practice in the literature, particularly the measurement used in the CLASS II survey. (8,77)

Third, the overall response rate for the school survey used in this thesis project was 46%, and selection bias might have affected the representativeness of the sample. The lower response was likely, at least in part, the result of poor response from some schools and teachers after the collection of consent forms from students. While the non-response in this case might be non-differential, there is a potential underrepresentation of children with household food insecurity in our sample, which could have biased our results toward the null.

Fourth, the use of school grades for the measurement of academic performance has the risk of systematic error if the underlying assumption is incorrect that course grades are designated to students objectively and consistently within one teacher and across different teachers and schools. Standardized testing, although not without its own challenges, has potential advantages of cross-study comparability and greater generalizability of results, especially where marking is based on objective rubric criteria. (83)

Fifth, the measurement of the exposure and mediator variables in this study relied on self-reported data. Self-reported data for the exposure variable to determine household food insecurity may be at risk of social desirability bias, which would bias the result toward the null if families with household food insecurity are answering according to what they believe to be more socially acceptable (being food secure). With self-reported data for the mediator variable of diet quality, there is the risk of recall bias by having to rely on participants to recollect what they ate over a long period of time. The risk of these biases may have introduced systematic error in our results. However, these self-reported measures had advantages of minimal respondent burden and reduced time and costs.

Sixth, interpretation of meaningful differences in diet quality scores for real-life settings is challenging when differences between groups are very small on 100-point scales of the DQI-I and YHEI. For example, a DQI-I score of 60 is defined as the cut-off for good diet quality (32), but it is difficult to conclude, for example, that individuals with DQI-I

scores of 58 versus 62 differ in a meaningful way in their overall diet quality despite being classified as “poor” and “good” diet quality, respectively. However, assessing diet quality as a categorical variable has a similar challenge for interpreting study results in the real-life setting because scores in tertiles do not have a clearly defined health-related reference point. For example, in a population with a mean score around 65 with a very small variability in the score, the difference between scores in the lowest and highest tertile may not represent a difference that has real-life practical implications.

Finally, the mediation analysis based on Baron and Kenny’s (1986) Four Step Approach has a number of known limitations. (84,91) Inconsistent mediation, multicollinearity, and low power have been discussed as challenges with the Four Step Approach by Kenny and colleagues, which can lead to the false finding that there is no association to be mediated between exposure and outcome when in fact there is an indirect effect that is occurring from exposure to outcome via the mediator variable. (84,91) More contemporary approaches to mediation analysis focus on studying the indirect effect (*ab*) in establishing the existence of mediation in a predicted model because of the challenges with the approach of Baron and Kenny that focuses on studying the pathway of the direct effect (*c'*). (84) However, because The Four Step approach has been applied in previous literature using cross-sectional data with similar variables of study (90), The Four Step Approach was chosen as the most feasible and appropriate mediation analysis method for this study.

Key strengths of this study include: the measurement of the exposure, mediator, and outcome variables, and the analytical framework informed by Baron and Kenny’s Four Step Approach (1986).

This study used validated questionnaires for measuring household food insecurity (HFSSM-6SF) and diet quality (YAQ) and measured academic performance with school grades based on data from three time points under one school board. The advantage of measuring household food insecurity with the HFSSM-6SF is that the HFSSM has been widely used in the research of outcomes associated with household food insecurity, and therefore, its use facilitates cross-study comparisons. (20,23) A systematic review of the measurement tools for household food insecurity shows that the HFSSM and the HFSSM-6SF are the most thoroughly assessed instruments for measuring household food insecurity

and have been evaluated internationally with the most aspects of reliability and validity established. (23) The advantage of using the YAQ to assess diet quality is that this questionnaire asks for frequencies of a comprehensive list of food items eaten over the past year, which offers greater representativeness of an individual's typical food consumption than other dietary assessments, such as shorter term 1-3 day food records or recall questionnaires that assess a limited number of food items. (46) Measurement of academic performance with school grades based on data from three time points is a strength of this study because it captures long-term performance of students as compared to academic performance measured at one time point. The use of school grades collected under one school board has the advantage of consistency in curriculum across different schools.

Furthermore, the analytical framework used for this study informed by Baron and Kenny's Four Step Approach (1986) can be applied to future studies that test for the potential role of diet quality as a mediator in the association between household food insecurity and academic performance among children. The findings of this investigation add to the body of literature that investigates the association between household food insecurity and children's academic performance, relevant at a local level and in a Canadian setting, where most investigations of this nature in the Western context have taken place in the United States.

## **6.5 IMPLICATIONS FOR FUTURE STUDIES AND POLICY**

Despite the inconclusive result, future research should continue to explore the association between household food insecurity and academic performance among children with diet quality as a potential mediator because although the existing body of literature supports associations between these variables, (4,5,30,51–54,61) there is still a gap in the literature in studying these stepwise associations within a mediation model. Lessons learned from this study point to key features that future studies may wish to consider. Future investigation of this mediated pathway should consider using the full-item HFFSM, as it can infer food security status at both the household and individual level and is the most valid, reliable, and widely used method of measurement for household food insecurity (23), and employing a longitudinal study design with a larger sample size, where time and

resource constraints allow. In addition, future studies should consider using more contemporary approaches to mediation analysis than the Four Step Approach that focus on the indirect effect ( $ab$ ) instead of the direct effect ( $c'$ ) in establishing the existence of mediation. (84,85,95–98)

The rate of household food insecurity in Nova Scotia is the highest among the provinces, and there have been no improvements in rates of household food insecurity across Canada and Nova Scotia in the last five years. (1–3) This thesis project provides a picture of the extent to which children in the Tri-County Regional School Board are affected by household food insecurity and how household food insecurity may relate to diet quality and academic performance. It is important to understand these relationships to develop policies that can break the perpetual cycle of household food insecurity. The success of school nutrition programs that have been evaluated for hunger prevention, correction of nutritional deficiencies, and improvement in school attendance and standardized testing results (30,74,75) may provide a starting point for developing future initiatives that have the potential to mitigate the negative consequences of household food insecurity for children in Nova Scotia.

## **CHAPTER 7. CONCLUSION**

In studying the relationships between household food insecurity, diet quality, and academic performance, this thesis project identified an association between household food insecurity and poor academic performance in Mathematics, an association between household food insecurity and diet quality measured by YHEI, and an association between diet quality measured both by DQI-I and YHEI and poor academic performance both in English Language Arts and Mathematics. Our findings were inconclusive about the potential role of diet quality as a mediator in the association between household food insecurity and academic performance because prerequisites were not met to complete Baron and Kenny's Four Step Approach for the mediation analysis in this study. Step 1 did not find a consistent total effect of food insecurity on academic performance, Step 2 did not find a consistent moderate or strong association between food insecurity and diet quality; and Step 3 did not find a consistent moderate or strong association between diet quality and academic performance. Although the mediation analysis was inconclusive, the results of this study in context with the literature still suggest the potential mediating role of diet quality in the relationship between household food insecurity and academic performance. Given the high prevalence of household food insecurity in Nova Scotia and the known consequences for children with household food insecurity, future study of how and why these associations exist is necessary so that we can better understand them as we create initiatives to mitigate the negative consequences of household food insecurity for children in Nova Scotia.



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## APPENDICES

### Appendix I.

#### U.S. Household Food Security Survey Module: Six-Item Short Form

July 2008

**Revision Notes:** The food security questions in the 6-item module are essentially unchanged from those in the original module first implemented in 1995 and described previously in this document.

**July 2008:**

- Wording of resource constraint in AD2 was corrected to, "...because there wasn't enough money for food" to be consistent with the intention of the September 2006 revision.

**January 2008:**

- Corrected user notes for coding AD1a.

**September 2006:**

- Minor changes were introduced to standardize wording of the resource constraint in most questions to read, "...because there wasn't enough money for food."
- Question numbers were changed to be consistent with those in the revised Household Food Security Survey Module.
- User notes following the questionnaire were revised to be consistent with current practice and with new labels for ranges of food security and food insecurity introduced by USDA in 2006.

**Overview:** The six-item short form of the survey module and the associated Six-Item Food Security Scale were developed by researchers at the National Center for Health Statistics.

**Background:** The six-item short form of the survey module and the associated Six-Item Food Security Scale were developed by researchers at the National Center for Health Statistics in collaboration with Abt Associates Inc. and documented in "The effectiveness of a short form of the household food security scale," by S.J. Blumberg, K. Bialostosky, W.L. Hamilton, and R.R. Briefel (published by the *American Journal of Public Health*, vol. 89, pp. 1231-34, 1999). ERS conducted additional assessment of classification sensitivity, specificity, and bias relative to the 18-item scale.

If respondent burden permits, use of the 18-item U.S. Household Food Security Survey Module or the 10-item U.S. Adult Food Security Survey Module is recommended. However, in surveys that cannot implement one of those measures, the six-item module may provide an acceptable substitute. It has been shown to identify food-insecure households and households with very low food security with reasonably high specificity and sensitivity and minimal bias compared with the 18-item measure. It does not, however, directly ask about children's food security, and does not measure the most severe range of adult food insecurity, in which children's food intake is likely to be reduced.

**[Begin Six-Item Food Security Module]**

**Transition into Module :**

These next questions are about the food eaten in your household in the last 12 months, since (current month) of last year and whether you were able to afford the food you need.

**NOTE:** If the placement of these items in the survey makes the transition/introductory sentence unnecessary, add the word “Now” to the beginning of question HH3: “Now I’m going to read you....”

**FILL INSTRUCTIONS:** Select the appropriate fill from parenthetical choices depending on the number of persons and number of adults in the household.

HH3. I’m going to read you several statements that people have made about their food situation. For these statements, please tell me whether the statement was often true, sometimes true, or never true for (you/your household) in the last 12 months—that is, since last (name of current month).

The first statement is, “The food that (I/we) bought just didn’t last, and (I/we) didn’t have money to get more.” Was that often, sometimes, or never true for (you/your household) in the last 12 months?

- Often true
- Sometimes true
- Never true
- DK or Refused

HH4. “(I/we) couldn’t afford to eat balanced meals.” Was that often, sometimes, or never true for (you/your household) in the last 12 months?

- Often true
- Sometimes true
- Never true
- DK or Refused

AD1. In the last 12 months, since last (name of current month), did (you/you or other adults in your household) ever cut the size of your meals or skip meals because there wasn't enough money for food?

- Yes
- No (Skip AD1a)
- DK (Skip AD1a)

AD1a. [IF YES ABOVE, ASK] How often did this happen—almost every month, some months but not every month, or in only 1 or 2 months?

- Almost every month
- Some months but not every month
- Only 1 or 2 months
- DK

AD2. In the last 12 months, did you ever eat less than you felt you should because there wasn't enough money for food?

- Yes
- No
- DK

AD3. In the last 12 months, were you every hungry but didn't eat because there wasn't enough money for food?

- Yes
- No
- DK

**[End of Six-Item Food Security Module]**



## User Notes

### **(1) Coding Responses and Assessing Households' Food Security Status:**

Responses of “often” or “sometimes” on questions HH3 and HH4, and “yes” on AD1, AD2, and AD3 are coded as affirmative (yes). Responses of “almost every month” and “some months but not every month” on AD1a are coded as affirmative (yes). The sum of affirmative responses to the six questions in the module is the household’s raw score on the scale.

Food security status is assigned as follows:

- Raw score 0-1—High or marginal food security (raw score 1 may be considered marginal food security, but a large proportion of households that would be measured as having marginal food security using the household or adult scale will have raw score zero on the six-item scale)
- Raw score 2-4—Low food security
- Raw score 5-6—Very low food security

For some reporting purposes, the food security status of households with raw score 0-1 is described as food secure and the two categories “low food security” and “very low food security” in combination are referred to as food insecure.

For statistical procedures that require an interval-level measure, the following scale scores, based on the Rasch measurement model may be used:

Number of affirmatives	Scale score
0	NA
1	2.86
2	4.19
3	5.27
4	6.30
5	7.54
6 (evaluated at 5.5)	8.48

However, no interval-level score is defined for households that affirm no items. (They are food secure, but the extent to which their food security differs from households that affirm one item is not known.)

**(2) Response Options:** For interviewer-administered surveys, DK (“don’t know”) and “Refused” are blind responses—that is, they are not presented as response options but marked if volunteered. For self-administered surveys, “don’t know” is presented as a response option.

**(3) Screening:** If it is important to minimize respondent burden, respondents may be screened after question AD1. Households that have responded “never” to HH3 and HH4 and “no” to AD1 may skip over the remaining questions and be assigned raw score zero. In pilot surveys intended to validate the module in a new cultural, linguistic, or survey context, however, screening should be avoided if possible and all questions should be administered to all respondents.

**(4) 30-Day Reference Period:** The questionnaire items may be modified to a 30-day reference period by changing the “last 12-month” references to “last 30 days.” In this case, items AD1a and AD5a must be changed to read as follows:

AD1a/AD5a. [IF YES ABOVE, ASK] In the last 30 days, how many days did this happen?

\_\_\_\_\_ days

[ ] DK

**(5) Self Administration:** The six-item module has been used successfully in mail-out, take-home, and on-site self-administered surveys. For self-administration, question AD1a may be presented in one of two ways:

- Indent AD1a below AD1 and direct the respondent to AD1a with an arrow from the “Yes” response box of AD1. In a parenthetical following the “No” response box of AD1, instruct the respondent to skip question AD1 and go to question AD2.
- Present the following response options to question AD1 and omit question AD1a:
  - Yes, almost every month
  - Yes, some months but not every month
  - Yes, only 1 or 2 months
  - No

In this case, either of the first two responses is scored as two affirmative responses, while “Yes, only 1 or 2 months” is scored as a single affirmative response.

The two approaches have been found to yield nearly equal results. The latter may be preferred because it usually reduces the proportion of respondents with missing information on how often this behavior occurred.

## Appendix II.

**TABLE 1**  
Components of Diet Quality Index-International (DQI-I) and the percentage of the sample in component subcategories in China and the United States<sup>1,2</sup>

Component	Score	Scoring criteria	China	United States
n			8352	9768
				%
Variety	0-20 points			
Overall food group variety (meat/poultry/fish/eggs; dairy/beans; grain; fruit; vegetable)	0-15 points	=1 serving from each food group/d = 15 Any 1 food group missing/d = 12 Any 2 food groups missing/d = 9 Any 3 food groups missing/d = 6 ≥4 food groups missing/d = 3 None from any food groups = 0	2.4 28.8 43.6 25.0 0.3 0.0	23.3 41.6 26.9 6.9 1.2 0.1
Within-group variety for protein source (meat, poultry, fish, dairy, beans, eggs)	0-5 points	≥3 different sources/d = 5 2 different sources/d = 3 From 1 source/d = 1 None = 0	28.1 28.6 27.0 16.3	68.4 25.1 6.1 0.4
Adequacy	0-40 points			
Vegetable group <sup>3,4</sup>	0-5 points	≥3-5 servings/d = 5, 0 servings/d = 0 ≥100% <100-50% <50%	82.2 14.7 3.1	42.1 37.7 20.2
Fruit group <sup>3,4</sup>	0-5 points	≥2-4 servings/d = 5, 0 servings/d = 0 ≥100% <100-50% <50%	0.4 2.4 97.2	19.6 23.4 57.0
Grain group <sup>3,4</sup>	0-5 points	≥6-11 servings/d = 5, 0 servings/d = 0 ≥100% <100-50% <50%	99.1 0.7 0.2	9.6 59.8 30.7
Fiber <sup>3,4</sup>	0-5 points	≥20-30 g/d = 5, 0 g/d = 0 ≥100% <100-50% <50%	3.9 28.7 67.3	13.9 52.6 33.5
Protein <sup>3</sup>	0-5 points	≥10% of energy/d = 5, 0% of energy/d = 0 ≥100% <100-50% <50%	80.3 19.6 0.1	95.3 4.5 0.1
Iron <sup>3,5</sup>	0-5 points	≥100% RDA (AI)/d = 5, 0% RDA (AI)/d = 0 ≥100% <100-50% <50%	68.3 30.4 1.3	68.9 22.5 8.7
Calcium <sup>3</sup>	0-5 points	≥100% AI/d = 5, 0% AI/d = 0 ≥100% <100-50% <50%	2.9 36.4 60.7	16.0 44.9 39.1
Vitamin C <sup>3,6</sup>	0-5 points	≥100% RDA (RNI)/d = 5, 0% RDA (RNI)/d = 0 ≥100% <100-50% <50%	43.3 37.1 19.6	44.0 27.9 28.1
Moderation	0-30 points			
Total fat	0-6 points	≤20% of total energy/d = 6 >20-30% of total energy/d = 3 >30% of total energy/d = 0	33.7 31.5 34.9	5.5 27.4 67.1
Saturated fat	0-6 points	≤7% of total energy/d = 6 >7-10% of total energy/d = 3 >10% of total energy/d = 0	57.6 24.5 18.0	11.4 27.2 61.4
Cholesterol	0-6 points	≤300 mg/d = 6 >300-400 mg/d = 3 >400 mg/d = 0	77.2 8.2 14.6	66.4 14.4 19.2
Sodium	0-6 points	≤2400 mg/d = 6 >2400-3400 mg/d = 3 >3400 mg/d = 0	9.5 9.3 81.3	30.9 29.9 39.2
Empty calorie foods	0-6 points	≤3% of total energy/d = 6 >3-10% of total energy/d = 3 >10% of total energy/d = 0	94.5 2.8 2.7	63.7 22.6 13.8

Source: Kim S, Haines PS, Siega-Riz AM, Popkin BM. The Diet Quality Index-International (DQI-I) provides an effective tool for cross-national comparison of diet quality as illustrated by China and the United States. *J Nutr.* 2003;133(11):3476-84.

## Appendix III.

YHEI components	YHEI Scoring Criteria		GUTS YHEI Scores <sup>a</sup>	
	Requirements for maximum score of 10	Requirements for minimum score of 0	Girls	Boys
	← servings per day <sup>b</sup> →		← mean ± standard deviation →	
1. Whole grains	≥ 2	0	2.6 ± 2.8	2.9 ± 3.0
2. Vegetables	≥ 3	0	5.0 ± 2.6	4.7 ± 2.5
3. Fruits	≥ 3	0	5.8 ± 3.0	5.7 ± 3.1
4. Dairy	≥ 3	0	8.0 ± 2.5	8.5 ± 2.2
5. Meat ratio <sup>c</sup>	≥ 2	0	7.2 ± 2.8	7.0 ± 2.7
6. Snack foods <sup>d</sup>	0	≥ 3	4.2 ± 2.8	3.6 ± 2.8
7. Soda and drinks	0	≥ 3	6.0 ± 3.1	5.5 ± 3.2
	Requirements for maximum score of 5	Requirements for minimum score of 0		
8. Multivitamin use	Daily	Never	1.5 ± 1.9	1.5 ± 1.9
9. Margarine and butter	Never	≥ 2 pats/day	4.5 ± 0.7	4.5 ± 0.7
10. Fried foods outside home	Never	Daily	3.8 ± 1.1	3.5 ± 1.1
11. Visible animal fat <sup>e</sup>	None	All	3.1 ± 1.6	3.0 ± 1.6
12. Eat breakfast	≥ 5 times/week	Never	4.2 ± 1.4	4.4 ± 1.2
13. Dinner with family	Daily	Never	3.7 ± 1.3	3.8 ± 1.2
YHEI total (0-100)			59.6 ± 10.8	58.6 ± 10.7

<sup>a</sup>GUTS used a food frequency questionnaire to assess usual dietary intake in 8,807 girls and 7,645 boys from 9 to 14 to years of age.  
<sup>b</sup>Serving sizes are based on definitions in the food frequency questionnaire.  
<sup>c</sup>Total number of servings/day of chicken, fish, eggs, nuts, seeds, soy/tofu, and beans, divided by the total number of servings/day of beef, pork, lamb, and liver.  
<sup>d</sup>Snack foods included salty snacks (eg, potato chips, corn chips, nachos, popcorn, pretzels, and crackers) and snacks with added sugar (eg, cake, snack cake, toaster pastry, sweet roll/Danish/pastry, doughnut, brownie, cookies, pie, chocolate, candy bar with chocolate, candy without chocolate, fruit rollup, popsicle, and flavored gelatin).  
<sup>e</sup>Visible animal fat includes the visible fat on meat and the skin on chicken or turkey.

Source: Feskanich D, Rockett HRH, Colditz GA. Modifying the healthy eating index to assess diet quality in children and adolescents. J Am Diet Assoc. 2004 Sep;104(9):1375–83.