THE ASSOCIATION BETWEEN THE RURAL-URBAN CONTINUUM, SOCIAL CAPITAL, AND NUTRITIONAL RISK IN COMMUNITY-DWELLING OLDER ADULTS IN CANADA:
AN ANALYSIS OF BASELINE DATA FROM THE CANADIAN LONGITUDINAL STUDY ON AGING

by

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Table of Contents

List of Tables

List of Figures

Abstract

Background: High nutritional risk poses a significant threat to the health of older adults. Currently, most research in Canada focuses on nutritional risk in hospital or institutional settings, with little emphasis placed on community-dwelling older adults. Social capital, an increasingly popular concept in the social determinants of health literature, may offer key insights into the mechanisms by which the rural-urban continuum is associated with nutritional risk.

Objectives: (1) Estimate the prevalence of high nutritional risk among community-dwelling older adults in Canada, and how it varies by sociodemographic characteristics; (2) Determine if there is an association between the rural-urban continuum and high nutritional risk among community- dwelling older adults in Canada; (3) Determine if social capital acts as a mediator and/or an effect modifier of the relationship between the rural-urban continuum and nutritional risk

Methods: This study was a secondary analysis of baseline data from the Canadian Longitudinal Study on Aging (CLSA). The CLSA provided measures for nutritional risk [a modified version of the Seniors in the Community Risk Evaluation for Eating and Nutrition (SCREEN-II-AB) nutrition screening tool] and the rural-urban continuum (Statistics Canada's Population Centre and Rural Area Classification). Composite measures of structural and cognitive social capital were created by mapping variables in the CLSA to the Adapted Social Capital Assessment Tool. Simple and multiple logistic regression were used to estimate crude and adjusted associations between the rural-urban continuum and nutritional risk, with adjustment for potential confounders including age, sex, ethnicity, income, education, years lived in the current community, household size, access to food outlets, and province. The role of social capital in explaining the relationship between the rural-urban continuum and nutritional risk was determined using two approaches: (i) assessing the presence of multiplicative interaction (via an interaction term in the logistic regression model) and additive interaction (relative excess risk due to interaction) and (ii) the product of coefficients technique to assess the presence of mediation.

Results: The prevalence of high nutritional risk in community-dwelling older adults was 33.4%. Residents of an urban core had significantly increased odds of high nutritional risk relative to rural residents in both the crude and adjusted models, with an adjusted OR [99% CI] of 1.35 [1.10-1.64]. None of the other categories of the rural-urban continuum were significant in the multivariable model. There was no evidence to suggest that structural social capital acts as an effect modifier or as a mediator. In contrast, the relative indirect effect of urban core on nutritional risk via cognitive social capital was -0.07 (99% CI: [-0.12, -0.02]), providing evidence of mediation.

Implications: In light of Canada's rapidly aging population and the increased hospitalization costs associated with malnutrition, reducing and preventing high nutritional risk in community-dwelling older adults is a key public health priority. This project expanded the discussion of nutritional risk into the broader social determinants of health literature. Identifying the factors associated with nutritional risk is an essential step in developing effective interventions for this population.

Word count: 487

List of Abbreviations and Symbols Used

A-SCAT	Adapted Social Capital Assessment Tool
ADL	Activities of daily living
ANOVA	Analysis of variance
AUC	Area under the curve
CA	Census agglomeration
CCHS	Canadian Community Health Survey
CI	Confidence interval
CIHR	Canadian Institutes of Health Research
CLSA	Canadian Longitudinal Study on Aging
CMA	Census metropolitan area
DoMAP	Determinants of Malnutrition in Aged Persons
GSS	General social survey
HS	High school
ICC	Intraclass correlation coefficient
ICR	Interaction contrast ratio
IQR	Inter-quartile range
MCQ	Maintaining contact questionnaire
MaNuEL	Malnutrition in the Elderly
MIZ	Metropolitan influence zone
MOS-SSS	Medical Outcomes Study Social Support Survey
NFL	Newfoundland
OR	Odds ratio
PCCF	Postal code conversion file
PEI	Prince Edward Island
POPCTR	Population Centre
PSCS	Personal Social Capital Scale
RERI	Relative excess risk due to interaction
RR	Relative risk
SAC	Statistical Area Classification

SCAT	Social Capital Assessment Tool
SCREEN-II-AB	Seniors in the Community: Risk Evaluation for Eating and Nutrition (Version 2, abbreviated)
UNICEF	United Nations Children's Fund
WHO	World Health Organization
$\sum_{j=1}^{k} a_j$	$a_1 + a_2 + a_3 + \cdots a_j$

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The AB SCREEN™ II assessment tool is owned by Dr. Heather Keller. Use of the AB SCREEN™ II assessment tool was made under license from the University of Guelph.

Chapter 1 Introduction

The United Nations' Sustainable Development Goals aim to eliminate all forms of malnutrition by 2030, with a key priority being to address the nutritional needs of older adults.[1] Emphasis is often placed on malnutrition in the hospital setting, as malnourished patients have complicated care needs and may experience longer, more costly stays than well-nourished patients.[2,3] However, malnutrition is frequently present upon hospital admission,[3] suggesting a need to prevent it in the community setting. Hence, a better understanding of malnutrition in community-dwelling older adults can help to address two prominent Canadian health care challenges: supporting healthy aging in the community setting and reducing potential burdens on the health care system.

The study of nutritional risk (the precursor of malnutrition) in the community setting is hindered by a lack of importance placed on nutritional risk within the social determinants of health literature. In particular, although many of the determinants of nutritional risk align with the broader social determinants of health, the two fields of study continue to operate in largely distinct spheres of inquiry. For instance, social capital – an increasingly popular concept in the social determinants of health literature – remains largely unexplored in the study of nutritional risk in community-dwelling older adults. Alternatively, although some nutrition studies have reported rural dwellers to be at increased nutritional risk,[4–6] little consideration has been given to potential social mechanisms of this relationship. In response, this study applies a theory-driven, interdisciplinary approach to investigate whether social capital may help to explain variations in nutritional risk along the rural-urban continuum among community-dwelling older adults in Canada.

The second chapter in this thesis begins by outlining the scope, severity, and current terminology surrounding nutritional risk in older adults. The main contribution of this chapter is the creation of the Broaden framework, a comprehensive approach to conceptualizing the determinants of nutritional risk in community-dwelling older adults, which merges existing frameworks from the fields of nutrition and social determinants of health. From here, Chapter 2 concludes by identifying key gaps emerging from the framework and introducing the concepts of the rural-urban continuum and social capital.

Chapter 3 provides an overview of the methods used in this study, including variable definitions and statistical analyses. This project was a secondary analysis of baseline data from the Canadian Longitudinal Study on Aging (CLSA) – a national research platform on the health of aging Canadians that is unprecedented in its scope and comprehensiveness. Key elements of the third chapter include the creation of a composite variable for measuring social capital and an exploration of techniques for assessing statistical interactions and mediation analysis.

Chapters 4 and 5 present results from the study and situate them within the existing literature. Limitations that impact the interpretation or comparability of the results are discussed, along with hypotheses which may help to explain study findings. Lastly, Chapter 6 summarizes the overall conclusions of the study, exploring implications and proposing directions for future research.

Chapter 2 Background

2.1 Overview of Nutritional Risk in Community-dwelling Older Adults

Addressing malnutrition in the community setting is key to promoting healthy aging and reducing potential burden on the health care system. Malnutrition is defined as "a pathological state resulting from a relative or absolute deficiency or excess of one or more essential nutrients".[7 (p.8)] This nutritional imbalance can be due to low dietary intakes and/or impaired nutrient utilization by the body.[8] By definition, the presence of malnutrition poses a risk for poor health, as the nutritional levels in the body have been deemed insufficient for maintaining optimal functioning.[8] Malnutrition has been identified as a risk factor for frailty, cognitive decline, sarcopenia, decreased immune response, acute hospitalization, and mortality.[9–12] Given that musculoskeletal frailty and cognitive decline are two of the top contributors to the burden of disease in older adults,[13] malnutrition poses a significant threat to the health of this population. Furthermore, malnutrition can have implications for future hospitalizations and length of stay. In a recent multicentre study from the Canadian Malnutrition Task Force, 45% of patients admitted into hospital for at least two days were malnourished upon admission, with the median [interquarile range (IQR)] age upon admission being 66 (54-77) years.[3] The presence of moderate to severe malnutrition upon hospital admission has been linked to a 31 to 38% increase in total hospitalization costs and an 18% increase in length of stay when compared to patients that were well-nourished upon addmission.[2]

The issue of malnutrition in older adults represents an unavoidable public health concern, as the physiological changes of aging pose an inherent risk for malnutrition. Older adults have decreased energy requirements accompanied by increased requirements for certain nutrients.[14] Hence, it becomes difficult to satisfy these increased nutrient needs while simultaneously reducing energy intake. Furthermore, physiological changes of aging include a reduced sense of taste and smell, delayed gastric emptying, changes in hormones that control appetite, and a decreased secretion of gastric acids, all of which place this population at risk of malnutrition.[11] Given that 20% of Canada's population is projected to be over 65 years of age by 2024,[15] the potential impact of age-related malnutrition will remain a national priority for years to come.

Terminology

When discussing malnutrition, it is common to encounter the concept of "nutritional risk". Nutritional risk estimates an individual's position along a continuum between optimal nutritional status and malnutrition.[16] Importantly, unless an in-depth nutritional assessment (which includes physical and biochemical assessments and requires certified training) has been completed, it could be technically inaccurate or premature to label someone as "malnourished".[17] In contrast, there are a number of simple and validated tools that can identify individuals at "high nutritional risk", such as the Seniors in the Community: Risk Evaluation for Eating and Nutrition (SCREEN) tool.[18,19] Unfortunately, inconsistencies in the interpretation and use of the terms "nutritional risk" and "malnutrition" are common in the nutrition literature.[20] In this thesis, the term "malnutrition" is used to describe a diagnosable and pathological state of the body.[7] In contrast, unless an individual has been explicitly diagnosed as malnourished, the term "high nutritional risk" is used. The underlying relationship between high nutritional risk and malnutrition is that once an individual's nutritional risk is sufficiently high, that person will be malnourished; however, in the absence of a nutritional assessment, it is difficult to definitively determine when malnutrition is present. Hence, it is possible that some individuals who are classified as "high nutritional risk" would actually be classified as "malnourished" if they were to undergo a full nutritional assessment.

In its most technical form, malnutrition includes both undernutrition and overnutrition.[7] Undernutrition is characterized by features such as insufficient levels of calories or essential nutrients, weight loss, and muscle wasting.[21,22] In contrast, overnutrition is characterized by excessive caloric intake or levels of essential nutrients and manifests as excessive weight gain and obesity.[21,22] In the present study, malnutrition refers only to undernutrition, which is generally considered to pose a more immediate threat to the health of community-dwelling older adults.[22,I] Additionally, the most commonly used nutritional screening tools for community-dwelling older adults are

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[I] Undernutrition is associated with an increased risk of frailty, decreased immunity, and cognitive decline, whereas overnutrition is linked to chronic diseases such as diabetes and cardiovascular disease.[22]

primarily intended to capture undernutrition rather than overnutrition.[23]

Lastly, it is important to clarify the terminology of "community-dwelling older adults". "Community-dwelling" refers to individuals that do not reside in an institutional setting (i.e., hospital or long-term care facility). In nutrition research, it is important to distinguish community-dwelling from institutionalized or hospitalized older adults, as the determinants of high nutritional risk in the latter population are highly specific to their care setting and health status.[24–26, II] Next, "older adults" refers to individuals who are at least 65 years of age. To understand the nutritional significance of this cut-point, note that a change in nutritional status often coincides with retirement (due to changing dietary patterns, income, and physical activity)[27,28] and 65 remains the approximate average age of retirement for Canadians.[29]

Prevalence and determinants

In Canada, 34% of community-dwelling older adults were estimated to be at high nutritional risk based on the 2008/2009 Canadian Community Health Survey (CCHS).[16] In 2019, a larger prevalence estimate of 46.0% high nutritional risk among community-dwelling older adults in Canada was published by Morrison and colleagues.[30] Both of these Canadian estimates are greater than the estimates reported in a 2016 systematic review of 58 studies from countries in Europe, Asia, Africa, North America, and Australia, which reported a pooled global prevalence of high nutritional risk in community-dwelling older adults of 26.5% (which increased to 30.5% when considering only 33 studies that were regarded as "high quality").[31] In this review, the prevalence of high nutritional risk in community-dwelling older adults was 23.4% in European studies, 29.8% in Asian studies, and 30.2% in studies from "other countries".[31] In terms of malnutrition, obtaining precise prevalence estimates is more difficult given the burden of accurately diagnosing malnutrition in a representative sample of community-dwelling older adults.[5] Accordingly, there is substantial variation in estimates of the global

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[II] Examples of determinants of nutritional risk that are specific to hospital and institutional settings include the provision of oral nutrition supplements, mealtimes and feeding practices, acceptability of food served, surgery schedules, staff capacity, texture-modified diets, and parenteral and enteral feeding.[24–26]

prevalence of malnutrition in community-dwelling older adults, with a systematic review of 28 studies from 118 countries producing a range from 0.8% in Northern Europe to 24.6% in South-East Asia.[5] In this review, the pooled prevalence of malnutrition in North America was estimated at 7.6%.[5]

Sociodemographic characteristics associated with high nutritional risk in Canada have previously been identified using data from the 2008/2009 CCHS.[16] Key findings were that female sex, living alone, low income, lower levels of education, infrequent social participation, and low social support were associated with high nutritional risk.[16] Health-related characteristics including depression, polypharmacy, disability, and poor oral health were also significantly associated with high nutritional risk.[16] Notably, the characteristics identified in the CCHS are consistent with those reported as key determinants of high nutritional risk in a range of studies worldwide.[6,32–35] However, other studies have identified additional determinants of high nutritional risk such as position along the rural-urban continuum, ethnicity, and access to food outlets which were not considered in the CCHS study.[4–6,36,37] Hence, the relationship between these determinants and nutritional risk is not fully understood in the Canadian context. In the following section, I provide a comprehensive overview of the determinants of high nutritional risk in community-dwelling older adults and develop a conceptual framework to guide their investigation.

2.2 Conceptual Framework

Nutritional risk in community-dwelling older adults is a multifaceted outcome produced by an intricate causal web of determinants, operating at both societal and individual levels. When investigating such an outcome, a conceptual framework can provide useful guidance. To this end, in 2020, the European Knowledge Hub Malnutrition in the Elderly (MaNuEL) used a modified delphi process to create a model of Determinants of Malnutrition in Aged Persons (DoMAP).[38] Although this model is comprehensive in its overview of potential determinants at the personal level (e.g. medical conditions, age-related functional decline, and increased metabolic rate),[38] the model does not consider the role that broader societal factors (e.g., food availability,

global circumstances and the socioeconomic and political context) play in the development of malnutrition. In short, the DoMAP is, first and foremost, situated within the specialized field of clinical nutritional, making the framework less applicable to scholars in other fields. Hence, there is currently no widely accepted conceptual framework exploring the determinants of nutritional risk in community-dwelling older adults that incorporates both individual and social factors. From previous studies, it is known that many determinants of nutritional risk in community-dwelling older adults align with the broader social determinants of health.[39,40] Hence, the addition of a social determinants of health perspective to current understandings of the determinants of high nutritional risk may help to expand the study of nutrition into broader fields of health and aging.

In an effort to achieve a more comprehensive understanding of the determinants of high nutritional risk in community-dwelling older adults, I explored two dominant frameworks from the fields of social determiannts of health and nutrition, respectively– Solar & Irwin's framework for the Social Determinants of Health[41] and the United Nations Children's Fund (UNICEF)'s framework for maternal and child undernutrition.[42] Although each framework offers valuable insights, there are significant gaps between the ways in which these two frameworks conceptualize the social determinants of health and nutritional risk. Thus, after discussing the strengths and limitations of these existing frameworks, I present a new framework for conceptualizing the determinants of nutritional risk in community-dwelling older adults. This new framework is intended to help merge the fields of nutrition and social determinants of health.

Existing frameworks

UNICEF framework for maternal and child undernutrition

In the nutrition literature, UNICEF's framework for maternal and child undernutrition (**Figure 1**) has been widely used for nearly three decades.[42,43] The framework divides the causes of undernutrition into three tiers: basic causes (e.g., societal structures and the distribution of power), underlying causes (e.g., access to health care, food, sanitation, and housing), and immediate causes (e.g., insufficient nutrient intake and disease).[42] The recognition of undernutrition as a consequence of both dietary intake and disease-status is a key strength of this framework. The UNICEF framework has been

foundational for work exploring the short, long-term, and inter-generational consequences of child and maternal undernutrition.[44] The framework has been used to guide collaborations between health and agricultural sectors,[45] as well as to estimate the economic impact of policies meant to reduce child stunting.[46]

When the UNICEF framework was developed, it was left purposefully general to facilitate future adaptations in different contexts.[42] Notably, there is one adaptation that focuses on older adults, but this adaptation restricts its focus to the contexts of poverty and food insecurity.[47] Unfortunately, there is an absence of adaptations focusing more broadly on the determinants of nutritional risk in community-dwelling older adults. Such adaptations are needed to expand the focus of the UNICEF framework beyond child and maternal health and to provide a more comprehensive overview of the complex array of determinants of nutritional risk that are specific to older adults (e.g., changing socioeconomic status, multiple chronic conditions, altered physical and cognitive functioning, and changes in nutrient metabolism).

Solar and Irwin's framework for action on the social determinants of health

Solar and Irwin's framework for action on the social determinants of health (**Figure 2**) was a foundation for the World Health Organization (WHO) Commission on the Social Determinants of Health and has received increased attention in the literature on social determinants of health and aging.[41,48,49] The framework was used to identify policy entry points for action on the social determinants of health.[41] It has also been used to guide global evidence synthesis on associations between social determinants of health and health inequities and to inform relevant policies and programmes.[50]

A key feature of the framework is that it divides the social determinants of health into intermediary determinants of health ("social causes of health") and structural determinants of health ("factors that determine the distribution of these social causes").[41 (p.5)] Undeniably, this distinction echoes the three tiers of causation in the UNICEF framework; however, Solar and Irwin take the discussion of structural determinants much further, explicitly considering how socio-economic and political contexts (including governance, values, and policies) can both produce and be influenced by social class, ethnicity, and gender.[41] Solar and Irwin also recognize the complex role played by social capital and social cohesion, with these factors considered as mediators

between the structural and intermediary determinants.[41] Nonetheless, despite its usefulness for conceptualizing the social determinants of health, Solar and Irwin's framework is too general to adequately capture the nuances of nutritional risk in older adults. Nutrition is absent from the visual framework and mentioned in the corresponding report only as an intermediary lifestyle determinant of overall health and well-being.[41]

Limitations of existing frameworks

Although both frameworks take similar tiered approaches when conceptualizing the social determinants of health, significant gaps remain between their conceptualizations of nutritional risk. Firstly, Solar and Irwin consider "nutrition" as a "lifestyle or behaviour".[41 (p.39)] Thus, as is often done outside of the nutrition literature, Solar and Irwin appear to equate "nutrition" with "dietary habits", rather than recognizing nutrition as a broad concept encompassing nutrient needs, nutrient metabolism, and nutrient bioavailability. In this way, Solar and Irwin fail to distinguish dietary intake (a behaviour) from malnutrition (a pathological state of the body[7]). Indeed, the UNICEF framework provides a more accurate representation of high nutritional risk, recognizing it as a consequence of poor dietary intake and altered nutrient metabolism due to disease.[42]

A second conceptual issue emerging from the two frameworks is whether high nutritional risk is a health determinant or a health outcome. Solar and Irwin's framework limits its discussion of nutrition to the intermediary determinants of health,[41] while UNICEF's framework sees high nutritional risk (resulting in malnutrition) as an outcome second only to death.[42] Without question, it makes sense to view high nutritional risk as a determinant of health, as it has been linked to an increased risk of numerous negative health outcomes including sarcopenia and cognitive decline.[10,11] Conversely, the presence of high nutritional risk (such that a person is truly malnourished) can be conceptualized as a health outcome, as it constitutes a pathological state in which levels of essential nutrients are inadequate in the body.[7] Thus, it is difficult to achieve and maintain physical wellbeing (and hence overall health) in the presence of malnutrition.[III] Essentially, the choice to regard high nutritional risk as a health outcome or health determinant

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[III] Although less common in developed countries, being malnourished can directly lead to death via mechanisms such as insufficient tissue oxygenation, disturbed fluid/electrolyte imbalance, and insufficient provision of energy to vital organs.[52]

constitutes a common division between the nutrition literature and the social determinants of health literature. Nonetheless, there is merit to both perspectives, suggesting that the most useful conceptualization of high nutritional risk would recognize its dual role as both a determinant of health and a health outcome. Hence, high nutritional risk may be viewed as an *intermediate health outcome*, representing an important pathological change that often leads to other health outcomes.[51]

In short, the concept of nutritional risk in Solar and Irwin's framework is significantly over-simplified, making the framework less appealing to scholars of nutrition. Still, the nutrition literature could benefit from the in-depth overview of social determinants of health provided by Solar and Irwin. Consequently, I have created a new conceptual framework for nutritional risk among community-dwelling older adults that is adapted from these two frameworks. This new framework is presented in the following section.

The Broaden framework

I have created the Broaden framework to provide a unified and comprehensive conceptualization of the determinants of nutritional risk in community-dwelling older adults. There are four key elements of the Broaden framework, (i) *global circumstances*, (ii) *socioeconomic and political context*, (iii) *structural and intermediary determinants*, and (iv) *dual role of nutritional risk* (**Figure 3**). The first three elements provide an overview of the determinants of nutritional risk, ranging from most distal to most proximal. The fourth element recognizes that high nutritional risk may be conceptualized as both a health determinant and a health outcome. The term "to broaden" means to "expand to encompass more people, ideas, or things".[53 (p.219)] This aligns with the framework's purpose, which is to foster an understanding of nutritional risk that encompasses all four elements and how they work together.

(i) Global circumstances

The Broaden framework begins by recognizing the role of global circumstances as an underlying driver of nutritional risk. Nutritional risk is inextricably tied to global circumstances that affect food production and availability. Such circumstances include regional effects of climate change, population shifts, famines, war, epidemics, and other

global events. In a recent report from the Lancet Commission, undernutrition, obesity and climate change were identified as a global syndemic representing the most pressing challenge to human health in this century.[54] Indeed, improving global circumstances are the keystone of major efforts to reduce nutritional risk around the world.[55] Community-dwelling older adults are especially vulnerable to changes in food production and availability, due to the social dynamics related to how food is distributed within communities and families, the unique dietary needs of older adults, and the impact of health conditions on the ability of older adults to acquire and prepare foods.[56]

Global events are one of the most powerful drivers behind policy change. For example, rapidly aging populations in regions such as Japan and Europe are influencing societies' attitudes towards older adults and shaping policy priorities for health care and community programmes.[57] In the context of nutrition, global trends in dietary patterns (e.g., shifts towards more processed foods) have been influential in shaping the nutritional status of the population.[58] Global circumstances play a vital role in initiating or reversing economic downturns and affecting government attitudes towards pro-poor policies and social programmes.[55] In essence, global circumstances provide the foundation from which all other determinants of nutritional risk arise and shape the contexts in which these determinants are prioritized and addressed.

(ii) Socioeconomic and political context

The second component of the Broaden framework is the socioeconomic and political context. As defined by Solar and Irwin, this context includes governance, policies (macroeconomic, social, and public), as well as cultural and societal values.[41] At this foundational level, nutritional risk in older adults is influenced by issues such as government funding for age-friendly communities, the provision and conditions of health insurance and pensions, the presence of ageism, and the value which a society places on youthfulness versus old age.[59] Within the nutrition field, the importance of the socioeconomic and political context tends to be well acknowledged. For instance, the UNICEF framework recognizes that economic structure and political and ideological superstructure influence the distribution of resources needed to prevent undernutrition.[42] Additionally, in recent years, an increasing number of professional organizations such as

the American Dietetic Association have attempted to integrate discussions of governance and policy in their position papers on nutrition and aging.[60]

Unfortunately, outside of the nutrition field, the connection between the socioeconomic and political context and nutritional risk is not always emphasized. For example, aging strategies are increasingly guiding public policies and spending related to health care and community interventions.[61–63] However, in many of these strategies, nutritional risk remains absent or under-acknowledged.[61–63] Ultimately, whether or not aging and nutrition are prioritized in the socioeconomic and political context determines the extent to which older adults are exposed and vulnerable to the more proximal determinants of nutritional risk.

(iii) Structural and intermediary determinants

The socio-economic and political context does not directly lead to high nutritional risk; instead, it acts through the mechanisms of structural and intermediary determinants. In addition to the structural determinants outlined by Solar and Irwin (i.e., education, gender, income, and ethnicity),[41] the Broaden framework also identifies age, position along the rural-urban continuum, and family structure as key structural determinants of nutritional risk. To understand why these three factors can be considered as structural determinants, note that structural determinants are factors that play a role in social stratification and modify an individual's exposure and/or vulnerability to the intermediary determinants.[41] Apart from the biological aging process,[64] age often plays a role in social stratification, as social position may decrease or increase with age, depending on societal values regarding youthfulness and the provision of care for older adults.[57] Next, although variations in social class exist within rural and urban areas, an area's degree of rurality has been associated with the employment, education, and income levels of individuals residing in that area.[65] Differences in availability of health care services and community infrastructure have been observed between rural and urban areas,[66–69] potentially magnifying the impact of social stratification. Furthermore, residing in an area with a greater degree of rurality has been associated with nutritional risk factors such as depression, polypharmacy, decreased cognition, and decreased physical activity.[70–73] Lastly, family structure of older adults has been associated with an income gradient,[74] suggestive of material social stratification, while the death of a spouse can contribute to

feelings of loneliness and isolation, suggestive of subjective social stratification.[75] Family structure also plays a role in the distribution of the social and financial resources needed to support optimal nutritional status.[76]

After considering the structural determinants, the Broaden framework goes on to outline the intermediary determinants of high nutritional risk. Unlike the structural determinants (which are seen as indirect causes of high nutritional risk), the intermediary determinants have a more direct influence on impaired dietary intake, reduced diet quality, or altered nutrient metabolism. Based on the relevant nutrition literature, the Broaden framework identifies the following five domains of intermediary determinants. Key examples are provided for each domain.

- Physical: disability, mobility, frailty [9,33,34,39,77]
- Psychological: depression, loneliness, grief, cognitive status, stress [16,32,33]
- Medical: oral health, chronic conditions, swallowing difficulties, polypharmacy [16,32,33,78]
- Environmental: access to food outlets or meal delivery services, transportation, walkability [36,79–81]
- Behavioural: physical activity, alcohol consumption [82,83]

Undeniably, the structural intermediary determinants reflect the complex and multifaceted nature of nutritional risk. In a simplified interpretation, the intermediary determinants can be seen as a single step along the causal pathway of nutritional risk. In this interpretation, the structural determinants first increase exposure and vulnerability to the intermediary determinants, and in turn, the intermediary determinants give rise to changes in dietary intake and nutrient metabolism. However, the intermediary determinants may act sequentially and influence each other (e.g., certain chronic conditions may lead to reduced swallowing ability or disability may impact physical activity). Similar relationships may occur between the structural determinants (e.g., the persisting relationship between gender and income). In this way, the structural and intermediary determinants constitute a complex series of interacting determinants.

(iv) Dual role of high nutritional risk

Structural and intermediary determinants can eventually lead to high nutritional risk through two direct causes: reduced dietary intake or quality and impaired nutrient

metabolism. For example, intermediary determinants such as depression or poor oral health may facilitate changes in appetite or avoidance of certain foods,[78,84] while disease status (e.g., chronic conditions) may influence an individual's ability to absorb and utilize nutrients from the foods consumed.[85] In other instances, an individual may consume adequate quantities of food, but depending on the type and variety of foods consumed, the diet quality (i.e., the nutritional composition of the foods consumed) may be reduced.[86] By recognizing that there are multiple direct causes of high nutritional risk, the Broaden framework avoids the common misconception that high nutritional risk is purely due to reduced dietary intake.

After considering direct causes, the Broaden framework arrives at its final component: high nutritional risk. Notably, some degree of reverse causality may be present between high nutritional risk and many of the intermediary determinants. For this reason, the Broaden framework includes a bidirectional arrow between the intermediary determinants and high nutritional risk (and its direct causes). Here, the intention is to recognize the dual role of nutritional risk as both a health determinant and a health outcome. If the arrow is followed from the intermediary determinants to high nutritional risk, high nutritional risk is conceptualized as a health outcome. From this perspective, the presence of high nutritional risk (such that a person is truly malnourished) constitutes a pathological state in which levels of essential nutrients are inappropriate to support optimal functioning of the body.[7] Conversely, if the arrow is followed from high nutritional risk to the intermediary determinants, nutritional risk is conceptualized as a determinant of other negative health outcomes. This bidirectional relationship can contribute to a downward spiral in the health of older adults. For example, high nutritional risk can contribute to the development of frailty in older adults, which in turn may exacerbate nutritional risk. Conversely, improvement in an intermediary determinant such as oral health may enhance dietary intake and improve nutritional status, thereby lessening the risk of other intermediary determinants such as functional decline.

Gap emerging from conceptual framework

One of the main opportunities provided by the Broaden framework is the potential to identify gaps in our understanding of nutritional risk in older adults. Additionally, the

Broaden framework invites us to situate existing nutrition studies within current approaches to the social determinants of health. Indeed, when existing studies are compared to this framework, it becomes clear that most research has focused on identifying intermediary determinants of nutritional risk, with structural determinants primarily being considered as potential confounders.[5,6,16,32–35,82,87] Consequently, a closer examination of many of the structural determinants may be warranted. Without such an examination, we are left with a limited understanding of the contexts in which the intermediary determinants of nutritional risk have the largest impact and of the contexts which may be most amenable to interventions. In particular, the rural-urban continuum is a structural determinant that has received relatively little attention. However, position along this continuum has been associated with the distribution of other structural determinants such as ethnicity, occupation, and age.[65] Hence, the rural-urban continuum provides a proxy indicator for multiple structural determinants. Therefore, it represents an ideal candidate for examining how structural determinants produce variations in nutritional risk.

2.3 Rural-Urban Continuum, Social Capital, & Nutritional Risk

Rural-urban continuum as both a geographic and social concept

To adequately incorporate the rural-urban continuum into discussions of nutritional risk, it must be recognized that the concept of "rural versus urban" has both geographic and social interpretations.[88–90] From a geographic perspective, rural and urban areas are often defined as regions with a specific population size and density.[90] For example, Statistics Canada offers a "rural area" classification that includes all persons *not* living in areas with at least 1000 people and at least 400 people per square kilometer.[91,92] In contrast, social perspectives are more concerned with the symbolic social spaces created through shared attitudes, "ways of life", relationships, and experiences.[88,89]

Mechanisms by which a person's position along the rural-urban continuum might influence their nutritional risk include both geographic and social factors. For instance, position along the rural-urban continuum is associated with geographically-determined factors such as access to food outlets, distance to a dietitian or other health professionals,

availability of fresh food, and ease of access to public transit or meal delivery services.[66,93–95] Position along the rural-urban continuum is also associated with socially-determined factors such as dietary norms (e.g. meal times and dietary preferences) and food sharing practices.[94,96–98] Each of these geographic and social factors play a role in determining nutritional risk. Furthermore, when considering both geographic and social factors, it is apparent that residing in either a rural or an urban area will likely have both positive and negative influences on an individual's nutrition risk. For example, some rural areas may have higher levels of food sharing but decreased access to public transit. Alternatively, some urban areas may have easier access to a dietitian but the frequent consumption of highly processed foods (in place of homemade items) may be more socially accepted. Hence, identifying a clear trend between the rural-urban continuum and nutritional risk is difficult, especially if only geographic mechanisms are considered.

The limitations of using geographic criteria to define categories along the rural-urban continuum without considering social contexts are increasingly being recognized in the field of rural health research. For instance, some studies have found that the social determinants of health may have different effects in geographically-defined frural and urban areas.[99,100] That is, the effect of place on health may be less attributable to specific characteristics of the geographic location and more attributable to how the social determinants operate in specific contexts.[99,101,102] Furthermore, an additional limitation of the geographic concept of "rural versus urban" is that the variation *within* rural and urban areas is often greater than the variation *between* rural and urban areas.[101] As nutrition research begins to consider the role of the rural-urban continuum, there is a growing need to explore social contexts which may contribute to heterogeneity within and between geographic areas.

In spite of the limitations of using geographic criteria to define categories along the rural-urban continuum, there are numerous advantages to using such crtieria. These include the widespread availability of geographic information in large secondary data sources such as Statistics Canada's CCHS, the ability to make comparisons with previous studies, the potential to influence policy decisions in geographically defined regions, and the lack of a widely accepted comprehensive measure that captures both geographic and social dimensions of the rural-urban continuum.[101] Thus, at this time, it would be

unrealistic to advise nutrition studies to avoid using geographic measures. In contrast, it would be more realistic for studies that use geographic measures to incorporate additional variables to explore social contexts which may help to explain associations between geographically-defined rural-urban continuum and nutritional risk.

In short, geographic measures will likely remain commonplace in discussions of nutrition risk and the rural-urban continuum for years to come. Nonetheless, it is not advisable to attribute associations between the rural-urban continuum and nutritional risk solely to the geographic criteria used to define an individual's placement along the continuum. Instead, it would be more meaningful to consider how these associations may be explained by the social contexts related to how people organize their lives, interact with others, and exchange social resources.

Introducing the concept of social capital

One way that studies using geographic criteria to define categories along the rural-urban continuum can incorporate social contexts is by exploring the concept of social capital. Social capital has received increasing attention in the field of social determinants of health, with Health Canada now recognizing social capital as a social determinant of health and Solar and Irwin explicitly highlighting the role of social capital in their conceptual framework.[41,103] The number of articles published in PubMed with "social capital" in the title has grown from virtually zero in 1997 to over 100 per year from 2012 onward.[104] In contrast, social capital has rarely been incorporated into nutrition studies, particularly in the context of community-dwelling older adults.[IV] Thus, social capital represents yet another opportunity to bridge the gap between the fields of social determinants of health and nutrition.

There are several different perspectives regarding the precise definition of social capital. Robert Putnam, a prominent social capital scholar, has defined the concept as "features of social organization, such as networks, norms and social trust, that facilitate

[IV] A 2012 systematic review identified 30 studies investigating the relationship between social capital and nutrition, of which most were focused on highly specific subpopulations of adolescents or low-income individuals.[108] Only one study looked at social capital and nutrition in older adults, and this study was primarily interested in ethnic and gender differences among older adults in Alabama.[109]

coordination and cooperation for mutual benefit".[105 (p.67)] This definition aligns with the communitarian perspective, in which social capital is seen as the "social infrastructure" that promotes the exchange of social resources.[106] Alternatively, some scholars favour the network approach, in which social capital is seen as the resources that may be accessed and shared through social networks.[106] To further complicate the concept, there are numerous ways of subdividing social capital. Perhaps the most common distinction is between *bonding social capital* (social networks and/or resources that exist within relatively homogenous social groups) and *bridging social capital* (social networks and/or resources that exist between groups with different socioeconomic status) [106]Additionally, *linking social capital* is a distinct subset of bridging social capital which exists between groups with different positions of power along the social gradient, usually referring to interactions between citizens and institutions or government.[106,107] Next, another increasingly popular distinction is that of *structural social capital* (an objective concept related to a person's type and amount of social engagement) versus *cognitive social capital* (a subjective concept related to a person's perceptions of their relationships and connections with others).[110]

Social capital may be especially important in studies with an aging perspective. For instance, older adults rely on social networks and resources to allow them to continue living independently throughout the aging process.[107] Moreover, evidence suggests that when older adults are in good health, they tend to make significant "investments" in the social capital of their community (via volunteerism and participation in community activities).[111,112] According to social capital theory, such "investments" are expected to translate into benefits for other members of the community. Thus, a social capital lens suggests that promoting successful aging may be a key step in improving the overall health of the general population. Therefore, this lens could be helpful in advocating for the importance of addressing high nutritional risk in community-dwelling older adults.

Social capital represents a potentially important gap in nutrition research. First, it has been well established that social support is an important determinant of nutritional risk.[16,32,35] However, social capital is a broader concept than that of social support, as social capital includes membership in social networks, social norms, and feelings of social trust[105](and each of these factors may exist without the explicit receipt of social

support). Therefore, social capital may provide additional insight into variations in nutritional risk which extend beyond those that have been explained by social support. Indeed, social capital proponents argue that it is unique and valuable in its ability to explain variations in health.[41,107] Accordingly, protective associations have been reported between high levels of social capital and numerous health outcomes, including mortality, cancer, and coronary heart disease.[107, V] Taken together, the existing evidence on the association between nutritional risk and social support combined with emerging results linking social capital to a range of health benefits suggests that a closer investigation of the relationship between social capital and nutritional risk is warranted. A more detailed discussion of mechanisms by which social capital may influence nutrition risk is provided in the following section.

How social capital may enhance investigations of the rural-urban continuum and nutritional risk

Previous studies have reported rural-dwellers to be at increased nutritional risk compared to urban-dwellers.[4–6] Unfortunately, there are three key issues surrounding studies that report this association: (i) they perpetuate the "deficit-perspective" of rural areas, in which negative associations between rural residence and health are emphasized above potential benefits;[114] (ii) minimal attention is paid to the mechanisms by which position along the rural-urban continuum may impact nutritional risk (meaning that no areas for intervention are identified); and (iii) they have not considered how different aspects of rural/urban residence may impact nutritional risk differently. Social capital may help to address all three of these issues.

Although overall or "net" associations suggest an increased nutritional risk in rural areas, this does not mean that rural areas are devoid of features that protect against nutritional risk. For example, some rural areas have been linked to increased levels of gardening or food-sharing amongst neighbours.[96] Furthermore, social capital may be a feature of rural areas that protects against nutritional risk. For instance, studies have reported that rural-dwellers often have higher levels of social capital (most often, this

[V] In certain contexts, high levels of social capital may actually be harmful, rather than beneficial. An example is that of "behavioural contagion", in which harmful behaviours such as smoking can spread through groups with high levels of social capital.[113]

association is observed for bonding social capital).[115–118] In turn, social capital has been purported to decrease the risk of numerous intermediary determinants of high nutritional risk, such as poor oral health, depression, loneliness, and disability.[119–122] Moreover, social capital may protect against high nutritional risk through increasing support for shopping and preparing foods; increasing involvement in group activities such as congregate dining; promoting dietary norms; and improving access to food sharing, health care, or nutrition education.[108,123] Thus, social capital may be a feature of rural areas that provides a protective mechanism against nutritional risk, meaning that social capital may offer an alternative to the deficit-approach in rural health research. It is also possible that social capital is an effect modifier of the relationship between the rural-urban continuum and nutritional risk, with the association between rural residence and high nutritional risk being stronger for individuals with lower levels of social capital than for those with higher levels of social capital.

Existing evidence related to the rural-urban continuum and social capital has largely focused on bridging versus bonding social capital.[117,118] In general, findings suggest that bonding social capital is greater in rural areas than urban areas, while the opposite has been reported for bridging social capital.[117,118] In contrast, there is a paucity of evidence regarding associations between structural and cognitive social capital and the rural-urban continuum. However, it could be hypothesized that certain aspects of rural/urban areas could produce different levels of structural and cognitive social capital. For example, social interactions at the family level have been identified as a key determinant of cognitive social capital in older adults, while socioeconomic status is a stronger determinant of structural social capital.[124] Hence, it follows that areas in which older adults live closer to family may be associated with increased cognitive social capital, while areas with increased socioeconomic status may have greater structural social capital. Furthermore, it is possible that structural social capital may be more closely related to geographic aspects of the rural-urban continuum (as participation in organizations or volunteer activities depends on geographic proximity to such opportunities), while cognitive social capital may be more closely related to social aspects of the rural-urban continuum (as perceptions of social connectivity will likely be influenced by the shared attitudes of individuals residing in a particular area). In short,

distinguishing between structural and cognitive social capital may provide clues as to which aspects of the rural-urban continuum are more strongly associated with high nutritional risk and which aspects may be protective against high nutritional risk.

To understand how structural and cognitive social capital may differentially relate to nutritional risk, prior studies of social capital and health provide a useful starting point. Although studies have found protective associations between both types of social capital and various aspects of health,[125] available systematic reviews suggest that cognitive social capital is more strongly associated with mental health,[120,125,126] while structural social capital is more preventive against chronic disease.[125,127] Extrapolating these results suggest both types of social capital may play a role in nutritional risk, as nutritional risk is determined by both mental and physical health. Indeed, based on the nature of structural and cognitive social capital, it is possible to make some preliminary hypotheses regarding how each type of social capital may translate into nutritional benefits. For instance, structural social capital ("what people do" [107 (p.51)]) may be more linked to material benefits (e.g., the creation of social connections that result in food sharing or support for shopping and preparing food). In contrast, cognitive social capital ("how people feel" [107 (p.51)]) may be more likely to translate into psychosocial benefits (e.g., the creation of social norms related to dietary preferences and meal frequency or improved appetite emerging from feelings of social connectivity). Of course, empirical evidence regarding nutritional risk and structural and cognitive social capital is needed to clarify these relationships.

Social capital measurement considerations

List generating approaches have often been used to measure social capital. In particular, the name, position, and resource generators — developed in 1978, 1986, and 2005, respectively — represent three of the most widely used approaches to measuring social capital (at least in previous decades).[128] Briefly, the name generator requires respondents to list individuals with whom they have certain social ties (e.g., someone with whom they could discuss their emotions or who would lend them money), provide attributes (such as gender and age) of those individuals, and then identify any relationships that exist between the individuals listed.[104,128] In a similar manner, the

position generator provides a list of occupations and asks respondents to list all individuals they know with these occupations.[128] Thirdly, the resource generator provides respondents with a list of resources and asks them to list which they are able to access and the type of social tie (e.g., family, colleague, friend, etc.) through which this access is facilitated.[104] Although these list generating approaches tend to be conducted using in-person interviews, the resource-generator is often administered as a questionnaire and completed independently by the respondent.[128]

More recently, researchers have tended to move away from the historical list generating approaches and focus more on the creation of specific measurement tools. Although many measurement tools exist, a key challenge in choosing an appropriate tool is the lack of an accepted "gold standard". The concept of social capital is theoretically based, with competing perspectives regarding what constitutes social capital. Hence, it can be difficult to assess the validity and reliability of social capital measurement tools.[107] Nonetheless, the vast body of research surrounding social capital measurement has produced certain tools that are more commonly used and accepted.

In 2000, the World Bank undertook a detailed investigation of social capital measurement issues, resulting in the creation of the Social Capital Assessment Tool (SCAT).[129] This 60-item questionnaire was intended to capture cognitive and structural social capital, appeal to a multi-disciplinary and multi-sectoral audience, and apply in a range of cultures and nations.[128,129] The SCAT has been the starting-point for a range of other social capital measurement tools including the Adapted Social Capital Assessment Tool (A-SCAT), the Personal Social Capital Scale (PSCS), and the PSCS-16 and 18.[128] Although the A-SCAT distinguishes between cognitive and structural capital, the PSCS, PSCS-16, and PSCS-18 focus on bonding and bridging social capital.[128]

Aside from these popular tools, many studies employ social capital measurement tools that have been developed for specific use within that study.[107] Criticisms of these types of tools include: limited consideration of theoretical definitions when creating the tools, a lack of consensus regarding whether social capital should be measured at the individual or group level, and the use of single scores which fail to distinguish between different types of social capital (such as cognitive and structural or bridging and bonding).[107,110] Given its complexity, it is understandable that studies face challenges

when incorporating a concept as multifaceted as social capital. For this reason, it is essential that future studies turn to current social capital theory and pre-existing tools to inform their own measurement of social capital.

2.4 The Way Forward

High nutritional risk is a multifaceted condition which poses a significant threat to the health of Canada's aging population. Outside of the specialized field of nutrition, nutritional risk in community-dwelling older adults continues to be misunderstood and under-emphasized. In response, the Broaden framework provides a conceptualization of nutritional risk that situates the discussion within current social determinants of health literature. Furthermore, the Broaden framework reveals that a closer investigation of structural determinants of nutritional risk is warranted. In particular, the rural-urban continuum represents an ideal candidate for closer examinations of how structural determinants produce variations in nutritional risk.

To accurately understand associations between the rural-urban continuum and nutritional risk, such associations cannot be attributed solely to geography but instead should account for the social contexts which are at play along the rural-urban continuum. In this effort, social capital provides a useful starting point. Additionally, considering ways in which social capital may decrease the association between rural-dwellers and high nutritional risk provides an alternative to the "deficit perspective" that is often pervasive in rural health research. Of course, as much as possible, a strong theoretical foundation for the measurement of social capital should be used to mitigate current measurement issues in the field. Ultimately, social capital and the rural-urban continuum offer exciting opportunities for better understanding high nutritional risk in community-dwelling older adults in Canada.

2.5 Figures

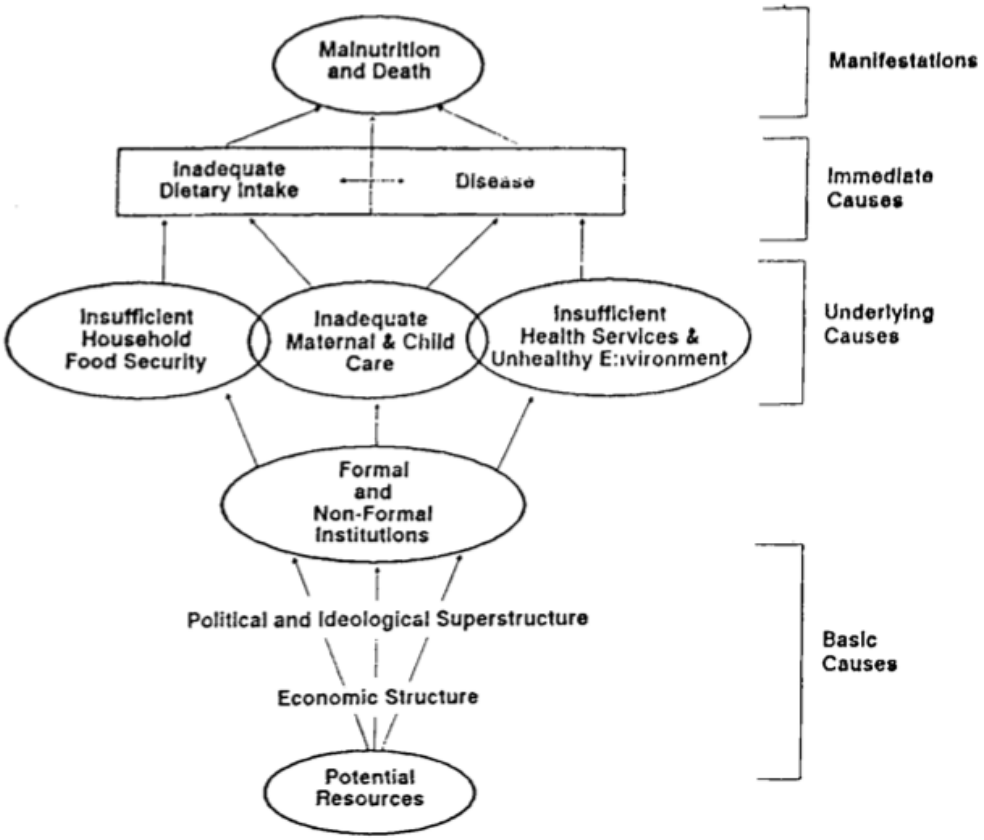

Figure 1. UNICEF framework for maternal and child undernutrition

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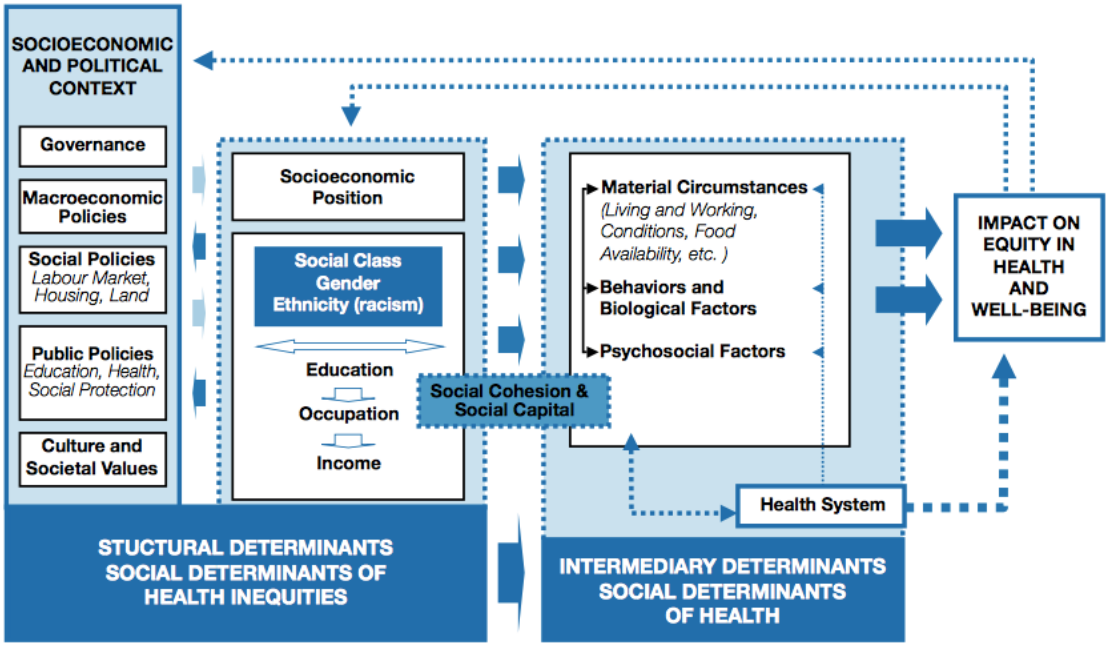

Figure 2. Solar and Irwin's Framework for Action on the Social Determinants of Health

Reprinted from A conceptual framework for action on the social determinants of health. Social Determinants of Health Discussion Paper 2 (Policy and Practice), Solar O., Irwin A., Figure A, page 6, Copyright 2010.[41]

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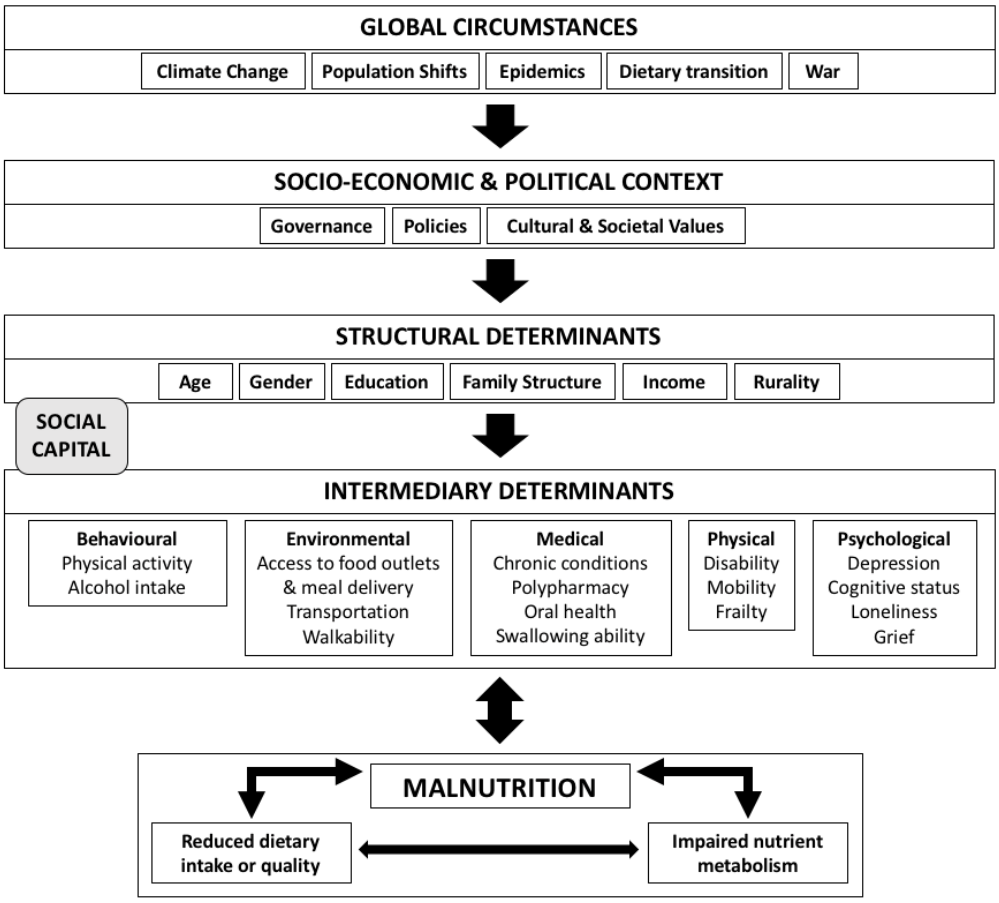

Figure 3. The Broaden framework

Chapter 3 Methods

3.1 Objectives

The overarching aim of this study was to examine potential associations between the rural-urban continuum and nutritional risk in community-dwelling older adults in Canada, and to explore whether social capital can help to explain such associations. Specific objectives were to:

1) Estimate the prevalence of high nutritional risk among community-dwelling older adults (aged ≥ 65 years) in Canada, and how it varies by sociodemographic characteristics.

2) Determine if there is an association between the rural-urban continuum and high nutritional risk among community-dwelling older adults in Canada.

3) Determine if social capital acts as a mediator and/or an effect modifier of the relationship between the rural-urban continuum and nutritional risk

3.2 Data & Study Population

The purpose of the CLSA is to shed light on factors that promote or detract from successful aging.[130] The CLSA has a total sample size of 51,338 Canadians aged 45 to 85 years at baseline.[131,132] Baseline data were collected from 2011 to 2015 and participants will be followed until 2033 or death.[131] The baseline sample excluded individuals living in the three territories, persons residing on a federal First Nations reserve or other First Nations settlement, Canadian residents with temporary visas, and full-time members of the Canadian Armed Forces.[132] Persons living in institutions at baseline were also excluded, meaning that all participants were community-dwelling at baseline.[132] The CLSA sample is comprised of two cohorts:

- Tracking: 21,241 participants completed computer-assisted telephone interviews related to a core set of variables.[131,132] Core variables provided data on demographics, income, health status, lifestyle, psychosocial characteristics, and health care utilization.[132]
- Comprehensive: 30,097 participants completed computer-assisted in-home personal interviews on core variables.[131,132] This cohort also visited one of 11 data collection

centres, where they completed additional in-depth personal interviews and on-site assessment of physical measurements and laboratory data.[131,132]

Eighteen months following the initial in-person or telephone interviews, participants in both cohorts completed a "maintaining contact questionnaire" via telephone.[133] This questionnaire provided additional information on variables related to health status, health care utilization, and environment.[133] Responses to both the initial telephone/in-person interviews and the maintaining contact questionnaire are included in the baseline data provided by the CLSA.

The Tracking cohort was selected using the multi-stage stratified cluster sampling strategy developed for the CCHS-Healthy Aging. To select the Comprehensive cohort (and to supplement the Tracking cohort), provincial healthcare registration databases and random digit dialing were used.[132] Additionally, the Quebec Longitudinal Study on Nutrition and Aging (NuAge) was used to recruit participants from Quebec in the 75 to 85-year-old age group of the Comprehensive cohort.[132] Participants in the comprehensive cohort were required to live within a 25-50 km radius of the 11 CLSA data-collection centres.[132] The CLSA provides sample weights to account for disproportionate sampling, errors in the sampling frame, and non-response.[87]

The present study included both the Tracking and Comprehensive cohorts, as the variables of interest were available for each cohort. Notably, this introduced a potential for misclassification bias, as baseline variables were collected differently for each cohort (in-person for Comprehensive and telephone interviews for Tracking).[134,135] However, the questions used to measure these variables were the same for both cohorts and both were interviewer-administered, mitigating the risk of misclassification bias. [134,135] When restricted to participants at least 65 years of age, the CLSA provided 21,491 participants eligible for inclusion in the present study: 8,845 from the Tracking cohort and 12,646 from the Comprehensive cohort.

3.3 Variables of Key Interest

(i) Nutritional risk

In the CLSA, nutritional risk is measured using a modified version of the Seniors in the Community: Risk Evaluation for Eating and Nutrition, Version 2, abbreviated (SCREEN-II-AB).[132,136] The CLSA module consists of 11 questions which assess: appetite, frequency of cooking, attitude towards cooking, attitude towards meals prepared by others, fluid intake, consumption of fruits and vegetables, meal sharing, meal skipping, swallowing ability, and weight changes in the past six months (see Appendix A).[133] Each item is given a numerical score (ordinal or interval when appropriate) and the scores for each question are summed to give an overall nutritional risk score. This produces a continuous variable that ranges from 0 to 48. The present study used this continuous variable when testing for mediation. In all other models, nutritional risk was considered as a binary variable. Individuals scoring below 38 were labelled as "high nutritional risk", while scores of 38 and above (up to a maximum of 48) were considered "not at high nutritional risk".[19,137] This cut-point was determined by the creators of SCREEN-II-AB.[19] Using nutritional assessment by a registered dietitian as a gold standard, SCREEN-II-AB was determined to have good sensitivity and specificity (area under the curve (AUC)=78%), adequate test-retest reliability (intraclass correlation coefficient (ICC)=0.84), adequate inter-rater reliability (ICC=0.79), and adequate intra-rater reliability (ICC=0.85).[19] Coding for nutritional risk, the dependent variable in this study, is shown in **Table 1**. Note that some participants that are labelled as "high nutritional risk" may actually be malnourished; however, the CLSA does not include a full nutritional assessment as part of its data collection process. Hence, classifications were limited to "high nutritional risk" versus "not at high nutritional risk", rather than "malnourished" versus "not malnourished".

(ii) Social capital

Mapping of CLSA variables to a pre-existing social capital measurement tool

Although the CLSA does not use any pre-existing social capital measurement tools, it provides numerous indicators that can be used as proxy measures to assess different elements of social capital. However, without a pre-established tool, selecting an

appropriate combination of variables to measure social capital can be challenging.[107] Thus, rather than arbitrarily selecting variables, I opted to conduct a "mapping" between a pre-existing social capital measurement tool and the CLSA variables. To do this, I considered whether variables available in the CLSA aligned with the collection of variables measured by a pre-existing tool. When choosing a pre-existing tool, I noted that the PSCS, PSCS-16, and the PSCS-18 focus on bonding versus bridging social capital.[128] In contrast, the SCAT and the A-SCAT focus on structural and cognitive social capital.[128] Previous studies on social capital and the rural-urban continuum have paid substantially more attention to bonding versus bridging rather than cognitive versus structural social capital.[117,118] Given that the the intention of my thesis was to investigate under-explored aspects of the rural-urban continuum which may protect against nutritional risk, focus was limited to the SCAT and the A-SCAT. Of these, the questions included in the A-SCAT appear to align most closely with the variables available in the CLSA.

The A-SCAT distinguishes between structural and cognitive social capital, with 7 and 11 elements related to each concept, respectively (**Table 2**).[110] Its developers qualitatively concluded that the A-SCAT has good face and content validity.[110] Construct validity was confirmed using principal component analysis.[138,139] Compared to other social capital measurement tools, the A-SCAT has been identified as one of the most comprehensive.[138] Furthermore, due to its ability to distinguish between structural and cognitive social capital while remaining relatively brief, the A-SCAT has been specifically recommended for use in nutrition studies.[108]

The A-SCAT is consistently identified as one of the more widely-accepted measurement tools.[107,108,110,128,138] However, in practice, the A-SCAT tends to be further modified (e.g., shortened or culturally adapted) before being applied to a specific population.[120,140–144] These modified measurement tools generally assign dichotomous values (high=1 and low=0) to cognitive social capital and assess structural social capital by counting the frequency of participation or membership (see Appendix B for an example).[142] In short, researchers usually choose to modify the A-SCAT because they require a tool that is short enough to be incorporated into a larger survey or because they want specific questions to be more culturally appropriate.[120,140–144] In contrast, the goal in the current study was to select a measurement tool that provided a comprehensive

theoretical treatment of the concept of social capital. Hence, I opted to use the original A-SCAT (rather than a modification) to inform the measurement of social capital in this study.

When conducting the "mapping" between the A-SCAT and the questions in the CLSA, I began by considering the 18 elements of social capital that comprise the A-SCAT (**Table 2**). Next, I explored the variables available in the CLSA to see which most closely aligned with the elements of the A-SCAT. **Table 3**and **Table 4Error! Reference source not found.** present the CLSA questions that were identified during this process, each grouped with the corresponding element of the A-SCAT. This process generated a battery of potential CLSA variables which could be used to measure certain aspects of social capital. Next, taking advantage of the fact that the A-SCAT distinguishes between elements of structural and cognitive social capital, I selected groups of CLSA variables to capture each of these elements. Furthermore, I considered how each CLSA variable was measured, hoping to group together variables that were measured using a similar scale (e.g., yes/no, Likert scale, count variables, etc.). Lastly, although CLSA variables comprising the Medical Outcome Study Social Support Survey (MOS-SSS) corresponded to elements of cognitive social capital in the A-SCAT, social support has already received significant attention in the field of nutrition.[16,32,35] Therefore, I chose not to explore the MOS-SSS in this study, instead opting to focus on less-explored dimensions of social capital. Taking all of this into consideration, I arrived at the following groups of variables:

- Group A- structural social capital: *frequency of participation in religious activities, frequency of participation in volunteer or charity work, frequency of participation in association activities, frequency of participation in clubs or fraternal organization activities, frequency of participation in educational or cultural activities*
- Group B- cognitive social capital: *most people in local area can be trusted, most people in local area are friendly, feel a part of local area, often feel lonely living in local area, people in local area will take advantage of you, lots of people in local area who would help if in trouble*

Creation of composite variables for structural and cognitive social capital

To explore the validity of the groups of variables obtained in the mapping process, I calculated a Cronbach alpha for the variables within each group. The value obtained was compared to a Cronbach alpha of 0.7.[145] If the value was below 0.7, I created a correlation matrix showing the correlation between each variable in the group, and also calculated the alpha value that would be obtained if each item was removed. Notably, Cronbach alpha was primarily used for exploratory purposes. That is, it was used to inform (rather than dictate) the selection of variables for this study.

After exploring the Cronbach alpha, I created composite variables for each of structural and cognitive social capital. Group A variables (structural social capital) asked participants about their involvement in various types of activities over the 12 months prior to data collection. Possible responses included: at least one time per day (score of 4), at least one time per week (score of 3), at least one time per month (score of 2), at least one time per year (score of 1), or never (score of 0). Participants' responses to each of these questions were summed, giving a total score between 0 and 20. This total score was then standardized according to a normal distribution with a mean of zero and a standard deviation of one. This standardized score was used as a continuous variable when testing for mediation in Objective 3. In all other analyses, the variable was divided into categories representing low (one or more standard deviations below the mean), moderate (within one standard deviation of the mean), and high (one or more standard deviations above the mean) structural social capital.

For Group B variables (cognitive social capital), participants provided responses of strongly disagree (score of 0), disagree (score of 1), agree (score of 2), and strongly agree (score of 3). The variables "often feel lonely in the local area" and "most people in local area will take advantage of you" were reverse scored. Before discussing how I combined these variables to create a single score for cognitive social capital, it should be recognized that the statistical analysis of Likert data is a commonly debated methodological issue.[146,147] In particular, it is not always appropriate to combine Likert data into a composite score.[148] In these cases, individual responses are called Likert-type items.[148] Alternatively, there are other instances when it is acceptable to combine responses into a composite score. Such a composite score is referred to as a Likert

Scale.[148] I provide a brief overview of the difference between Likert-type items and Likert scales below. For an example of the difference between Likert-type items and Likert scales, see Appendix C.

- Likert-type items are individual questions that are assessed using Likert responses but are not interrelated and instead measure distinct concepts.[148] Likert-type items should not be combined into a composite score.[148] Likert-type items are considered to be ordinal; therefore, statistical analysis of these items should be restricted to medians, modes, frequencies, Kendall tau, and chi-square statistics.[147,148]
- A Likert scale is a composite measure composed of at least four individual questions assessed using Likert responses.[148] The composite measure is calculated by summing or taking the mean of a participant's responses to these questions.[148] A Likert scale can be calculated from multiple questions that have been purposefully chosen to assess interrelated elements of a single larger concept.[148] This larger concept is often somewhat abstract and cannot be adequately captured by a single question.[146,148] When creating a Likert scale, it is assumed that each question used to calculate the scale is of equal importance and also that a "neutral" response corresponds to a score exactly mid-way between strongly agree and strongly disagree.[149] Likert scales can be considered to be interval and can be used to calculate means, standard deviations, and Pearson correlation coefficients.[147,148] Likert scales can also be used in analysis of variance (ANOVA), t-tests, and regression analyses.[147,148]

Based on the above distinction, it was deemed appropriate to combine Group B variables into a composite Likert scale, as the individual variables assessed interrelated aspects of the somewhat abstract concept of cognitive social capital. The composite score was created by summing the responses to each individual variable, meaning that each participant received a composite score between 0 and 18 for cognitive social capital. This total score was then standardized according to a normal distribution with a mean of zero and a standard deviation of one. This standardized score was used as a continuous variable when testing for mediation in Objective 3. In all other analyses, the variable was divided into categories representing low (one or more standard deviations below the mean), moderate (within one standard deviation of the mean), and high (one or more standard deviations above the mean) cognitive social capital.

(iii) Rural-urban continuum

The CLSA measures the geographic component of the rural-urban continuum using Statistics Canada's Population Centre and Rural Area Classification (POPCTR).[92] In the CLSA, the POPCTR classification was determined using postal code conversion files (PCCF) to link participants' postal codes to dissemination blocks or block-faces (specific geographic areas defined for the census).[91] The POPCTR classification aims to recognize that rural versus urban as a continuum rather than a dichotomous concept.[92] For this reason, it offers five categories that are defined based on population size and population density.[92] These categories are: urban core, secondary core, urban fringe, urban population centre outside census metropolitan areas (CMAs) and census agglomerations (CAs), and rural (see **Table 5** and **Table 6** for specific definitions). These categories are mutually exclusive and comprise the entire country.[92] Notably, the CLSA includes an additional category for individuals with postal codes that could not be linked to a dissemination block or block-face, but instead could only achieve precision at the larger dissemination area level. Hence, this category represents participants for which no rural/urban information was available and was included in the analyses to explore how it compares to the other categories.

Although the use of PCCF in geocoding is common in health research, it is essential to note that it is vulnerable to misclassification.[150,151] In particular, a concern with the PCCF is the fact that some postal codes may link to more than one dissemination block or block-face.[152] This is particularly common in rural areas, where rural routes and community postal boxes often span or service multiple postal codes.[152] In such cases, the PCCF provides a single link indicator, which reports the census area classification that is most commonly linked to a certain postal code.[152] Still, Statistics Canada cautions that "only a partial correspondence between the postal code and other geographic areas is achieved when using the single link indicator."[152 (p.9)] Finally, another concern is that the address of a community postal box or post office (which is used in the PCCF linkage) may not represent the address where an individual resides.[152] Ultimately, the use of PCCF represents a limitation of the CLSA data, as this is the only data provided for discerning participants' position along the geographic rural-urban continuum.

A comment about rural-urban classification approaches used in Canada

As discussed above, the CLSA uses Statistics Canada's POPCTR approach, which provides five categories: urban core, secondary core, urban fringe, urban population outside of CMAs or CAs, and rural. The other commonly used classification system in Canada is Statistic Canada's Statistical Area Classification (SAC), which provides eight categories: urban (levels 1, 2, 3), rural metropolitan influence zones (MIZ) (strong, weak, moderate, or none), and remote.[153] Both the POPCTR and SAC approaches consider CMAs and CAs; however, the SAC considers all regions within CMAs and CAs as urban and all regions outside of CMAs and CAs as rural/remote.[153] In contrast, when using the POPCTR approach, both CMAs and CAs contain a mix of rural and urban areas.[153] A comparison of the categories provided by each approach are outlined in **Table 7**. Notably, urban areas in the SAC could be classified as rural using the POPCTR approach, and vice versa. In short, findings in the present study must be interpreted within the context of the POPCTR classification and may not be comparable to studies which use the SAC or other similar classification systems.

(iv) Potential confounders

As shown in the Broaden framework, there are numerous determinants of nutritional risk in community-dwelling older adults, many of which may play a role in the associations between the rural-urban continuum, social capital, and nutritional risk. Consequently, there are a range of variables which were considered as potential confounders in this study. Potential confounders included those factors that are associated with (but not definitively caused by) the rural-urban continuum and are also causes of nutritional risk. Of the intermediary determinants in the Broaden framework, distance to food outlets, number of chronic conditions, perceived oral health, and functional impairment were included as potential confounders.[VI]

[VI] Initially, a sensitivity analysis was done by creating models with and without these variables. Also, the correlation between each of these variables and nutritional risk was calculated. Here, the intent was to avoid masking associations by including predictors that were highly correlated with nutritional risk. Including these variables did not significantly change the models, nor were any of the variables highly correlated with nutritional risk. Hence, I chose to include the health status variables in the final models.

This study accounted for the physiological changes of aging by including age as a potential confounder in the statistical models. Other structural determinants considered as potential confounders were sex, education, income, household size, years lived in the current community, and ethnicity. Province was included as a potential confounder, as the distribution of the rural-urban continuum will vary by province.[154] This also ensured that the project aligned with CLSA's recommendation to include a minimum of age, sex, and province as potential confounders in statistical analyses of CLSA data.[87] Measurement for each confounder is shown in **Table 8**.

3.4 Statistical Analyses

In all models, to account for the complex survey design and non-response, I used the sample weights provided by the CLSA[87] and Taylor linearization to calculate measures of variance and standard errors. Due to the large sample size of the CLSA, the significance level was set at 0.01 for all analyses. All analyses were completed in Stata 15.

Objective 1

The prevalence of high nutritional risk among community-dwelling older adults was estimated as the weighted percentage of participants at high nutritional risk. Cross-tabulations were used to determine the distribution of sociodemographic characteristics and health status variables according to level of nutritional risk (i.e., high nutritional risk versus not at high nutritional risk). Results were reported as frequencies and percentages. Sociodemographic characteristics of interest included age, sex, income, education, ethnicity, province, household size, years lived in the current community, access to food outlets, rural-urban continuum, structural social capital, and cognitive social capital. Health status variables of interest included functional impairment, perceived oral health, and number of chronic conditions. Differences in characteristics of interest between high/not high nutritional risk groups were compared using Pearson's Chi-squared statistic. Age was considered as a categorical variable for this objective. Age categories

were 65 to 69, 70 to 74, 75 to 79, 80 to 84, and 85 years and above, which are consistent with the life-cycle groupings recommended by Statistics Canada.[155]

Objective 2

I first estimated the crude association between high nutritional risk and the rural-urban continuum using simple logistic regression. Unadjusted logistic regression models predicting nutritional risk from each of the sociodemographic and health status variables were also created. Then, the adjusted association was estimated using multiple logistic regression to control for age, sex, ethnicity, income, education, household size, years lived in the current community, access to food outlets, province, structural social capital, cognitive social capital, chronic conditions, functional impairment, and oral health. The rural-urban continuum was included in the models as a fixed effect. Goodness of fit was assessed using the Hosmer-Lemeshow test.

Power and sample size considerations: When planning this project, the minimum sample size needed to obtain a power of 0.8 was calculated using the following information:

> The ratio of rural to urban dwellers in the CLSA is approximately 0.17. The prevalence of malnutrition in rural and urban areas was estimated as 9.9% and 5.7%, respectively (based on a 2018 systematic review of the prevalence of malnutrition in older adults in 111 studies from 38 countries[5]). Note that participants identified at "high nutritional risk" will include all those that would be classified as malnourished in a full nutritional assessment, as well as participants that are at high risk but do not meet the diagnostic criteria for malnutrition. Hence, the estimated prevalence of malnutrition is likely a conservative estimate of the prevalence of high-nutritional risk. Next, previous studies have reported that the odds of nutritional risk in rural areas is approximately 1.30 times the odds of nutritional risk in urban areas.[4,6] So, 1.3 was considered as a minimum effect size in the sample size calculation.

Using this information, with a significance level of 0.01, the present study required a minimum sample size of 7,526 participants. After applying exclusion criteria for the current study, the CLSA Tracking and Comprehensive cohorts combine to give a sample size of 19, 377 for this study, far above the minimum size required for a power of 0.8.

Objective 3

Currently, little empirical evidence exists regarding the role of social capital in explaining associations between the rural-urban continuum and nutritional risk. Therefore, this objective was approached from an exploratory (rather than confirmatory) perspective. I aimed to explore potential relationships between social capital and the rural-urban continuum and how they may influence nutritional risk. This was done using two approaches: testing for effect modification and testing for mediation.

(i) Testing for effect modification

Using the model from Objective 2, I added an interaction term between the rural-urban continuum and structural social capital. The statistical significance of the interaction term was used to decide whether or not models would be stratified by level of structural social capital. This process was repeated for cognitive social capital.

The process of fitting an interaction term in a logistic regression model assesses the presence of multiplicative interaction. However, it is increasingly suggested that studies using logistic regression also provide an assessment of additive interaction.[156,157] Additive interaction is preferred from a public health perspective, as it reveals the potential impact of an intervention in one group compared to another (e.g., would increasing social capital in rural areas have a larger impact on nutritional risk than in urban areas?).[156] The multiplicative scale cannot provide such information, because each subgroup has a different baseline odds and the odds ratios are relative to these baseline values.[156] Hence, conclusions about which group would benefit most from an intervention may be inaccurate if the multiplicative scale is used.[156]

I investigated the presence of additive interaction by calculating the relative excess risk due to interaction (RERI). The RERI can also be referred to as the interaction contrast ratio (ICR).[156] The RERI assesses whether, when two exposures are present, the risk of an outcome is increased beyond what would be expected if the risk from the two exposures were simply added together.[156] Given arbitrary exposures A and B, the RERI is calculated using the following equation:

$$RERI = RR_{11} - RR_{10} - RR_{01} + 1. \quad (\text{Eq. } 1)$$

where RR_{11} is the relative risk in those exposed to both A and B, RR_{10} is the relative risk in those exposed to only risk factor A, RR_{01} is the relative risk in those exposed to only risk factor B.[156] See Appendix D for the derivation of the RERI.

Since nutritional risk is not a rare outcome (recall that 34% of community-dwelling older adults were estimated to be at high nutritional risk in the 2008/2009 CCHS[16]), the present analysis could not assume that the odds ratio (OR) obtained from logistic regression approximated the relative risk. Instead, a log-linear regression model was used to provide an estimate of relative risk. Furthermore, to avoid convergence issues in the log-linear model, the five-level rural-urban continuum was dichotomized into rural and urban (urban core, secondary core, urban fringe, and urban population centre outside of CMA or CA) when calculating the RERI.

To calculate the RERI for exposures with more than two categories (such as the social capital variables in the present study, which have low, moderate, and high levels), VanderWeele and Knol recommend running separate analyses for each combination of two categories.[156] Hence, the RERI was calculated for the following three combinations: rural/urban and high/moderate structural social capital, rural/urban and high/low structural social capital, rural/urban and moderate/low structural social capital. In all scenarios, the reference category was that with the lowest nutritional risk (i.e., rural and high social capital in the first two instances, and rural and moderate social capital in the third instance). These reference categories allow us to assess the presence of "excess risk due to interaction" in the other categories. In each scenario, the RERI was calculated with a 99% confidence interval to determine if it was statistically different from zero. The process was repeated for cognitive social capital. Stata code followed the procedure outlined by VanderWeele and Knol.[156]

When RERI values are calculated using relative risks (as was the case in the current project), interpretations are restricted to the sign of the calculated RERI value, with positive values indicating positive interaction, negative values indicating negative interaction (i.e., the risk when exposed to the two risk factors combined is less than their respective risks added together), and zero values indicating no presence of additive interaction (i.e., the risk when exposed to the two risk factors combined is more than their

respective risks added together).[156] In general, the magnitude of the RERI is not used to make inferences about the magnitude of the additive interaction.[156, VII]

(ii) Testing for mediation

Classical mediation analysis techniques were used to explore whether social capital may be a mediator of the relationship between the rural-urban continuum and nutritional risk. A detailed overview of potential sources of bias underlying these techniques can be found in Appendix E. More specifically, I used the product of coefficients technique, which is an extension of Baron and Kenny's causal steps approach to mediation analysis.[158,159] This technique is well established when the mediator and outcome variables are continuous.[160] Conversely, although the causal steps approach can also be applied to dichotomous or categorical mediator or outcome variables, there remains an ongoing methodological debate about the best way to handle such variables (potential options include standardizing regression coefficients or latent variable techniques).[160,161] To circumvent this issue, nutritional risk was considered as a continuous variable for this objective, with values ranging from the minimum SCREEN-II-AB score of 0 to the maximum score of 48. Similarly, structural and cognitive social capital remained as continuous variables rather than being divided into low, moderate, and high categories. Structural social capital ranged from 0 to 20 and cognitive social capital ranged from 0 to 18.

The causal steps approach to mediation analysis divides the total effect of an exposure on an outcome into *direct* and *indirect* effects.[162] The basic understanding behind this approach is demonstrated in **Figure 4** and **Figure 5**, where path *c* is the total effect of the exposure on the outcome, *c′* is the direct effect of the exposure on the outcome, and the indirect effect of the exposure on the outcome is given by *ab*.[162] The indirect effect is the effect that is mediated the mediating variable. Notably, to accurately reflect the specific context of this analysis, the approach must be modified to reflect the fact that the rural-urban continuum is a categorical variable. Andrew Hayes, a leading scholar in the field of mediation analysis, provides useful guidance for applying the

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[VII] An exception is when testing for mechanistic interaction (i.e., sufficient cause interaction), in which the magnitude of the RERI provides insight into the level of evidence for mechanistic interaction.[156] This does not apply in the current study.

product of coefficients approach in such a scenario.[163,164] To demonstrate, suppose that "rural" is defined as the reference category. Then, as shown in **Figure 6** each of the other categories of the rural-urban continuum has a *relative indirect effect* given by $a_j b$, and a *relative direct effect* given by c_j', for values of j equal to *1*,*2*,*3*,or *4*.[163] Building on these basic concepts, I now explain the analysis process in terms of structural social capital; however, note that each step was repeated for cognitive social capital.

To investigate whether structural social capital may be a mediator of the relationship between the rural-urban continuum and nutritional risk, it was necessary to calculate each relative indirect effect, $a_j b$, for $j= 1,2,3,4$. To do this, I first calculated the values for each a_j using a multiple linear regression equation to predict structural social capital from the rural-urban continuum. This is shown in Equation 2,

$$Y_1 = i_1 + \sum_{j=1}^{4} a_j X_j + \sum_{n=1}^{k} g_n c_n + e_1 \quad \text{(Eq. 2)}$$

where Y_1 is structural social capital, i_1 is the intercept, X_j represents the categories of the rural-urban continuum and a_j is the corresponding regression coefficient, $\sum_{n=1}^{k} g_n c_n$ is the sum of the products of each confounder and its corresponding coefficient, and e_1 is the error term. I included age, sex, ethnicity, income, education, household size, province, years spent in current community, cognitive social capital and health status indicators (chronic conditions, functional impairment, and perceived oral health) as potential confounders of the relationship between the rural-urban continuum and structural social capital.

Next, I calculated path *b* using a multiple linear regression equation to predict nutritional risk from structural social capital, this time controlling for the rural-urban continuum as well as all potential confounders. See Equation 3:

$$Y_2 = i_2 + bM + \sum_{j=1}^{4} d_j X_j + \sum_{n=1}^{k} h_n c_n + e_2 \quad \text{(Eq. 3)}$$

where Y_2 is nutritional risk, i_2 is the intercept, M is structural social capital and b is its corresponding regression coefficient, X_j represents the categories of the rural-urban continuum and d_j is the corresponding regression coefficient, $\sum_{n=1}^{k} h_n c_n$ is the sum of the products of each confounder and its corresponding coefficient, and e_2 is the error term.

Confounders included age, sex, ethnicity, income, education, household size, province, years spent in current community, cognitive social capital, access to food outlets, number of chronic conditions, functional impairment, and perceived oral health.

Next, I multiplied each a_j (the coefficient for the rural-urban continuum categories from Equation 2) and b (the coefficient for structural social capital from Equation 3), obtaining the product of coefficients, a_jb. This product provided an estimate of the relative indirect effect for each category in the rural-urban continuum on nutritional risk.

The next step in the product of coefficients technique is to determine if each relative indirect effect, a_jb, is different from zero. Historically, the standard error of the relative indirect effect was calculated using the delta method which assumes a normal distribution.[162] More recently, recognition that the relative indirect effects often follows a skewed distribution has led to recommendations that bootstrapping be used to estimate the standard error or the relative indirect effects.[162] However, the CLSA does not provide bootstrap weights that address the influence of its complex survey design on variance estimation. Instead, the CLSA provides sampling weights for population inferences and sampling information to account for the complex survey design. Since my intention was to make inferences about community-dwelling older adults in Canada, these sampling weights were applied in my analysis. This necessitated that I use the delta method to estimate the standard error of the relative indirect effects, rather than bootstrapping. To explore the potential impact of using the delta method instead of bootstrapping, two supplementary analyses were conducted without the use of the CLSA sampling weights: (i) I calculated the standard error of the relative indirect effects using a bootstrap approach that assumed random sampling (technically inappropriate for the CLSA because it is not a random sample) and (ii) I once again calculated the standard error of the relative indirect effects using the delta method. Results from these two analyses were compared to gain insight into whether the standard errors obtained using the delta method differ greatly from the those obtained using a bootstrapping approach.

The final step in the product of coefficients technique is to assess whether the effect of the rural-urban continuum on nutritional risk is mediated by structural social capital. (Of course, such as assessment is only preliminary, as conclusions about causality are not possible within the cross-sectional nature of this study). The simplest way to do

this is to consider structural social capital to be a mediator if any of the relative indirect effects are significantly different from zero.[164] However, Hayes has cautioned that conclusions may depend on the choice of reference group for the categorical independent variable.[164] Hence, in the present study, if no evidence of mediation was observed with the rural category as the reference, I conducted sensitivity analyses by testing for mediation using the other categories as a reference. Lastly, note that more advanced methods for omnibus tests assessing the presence of mediation using a categorical independent variable with the product of coefficients technique are still undergoing development by Hayes and colleagues.[165]

As a final comment, note that the product of coefficients technique used in the present project differs from Baron and Kenny's original causal steps to mediation analysis, in which each step of the analysis should only proceed if the prior step revealed statistical significance.[162] Because statistical significance will depend on a combination of effect size and sample size, significance testing has been discouraged due to its potential to misrepresent the presence (or absence) of a mediating effect.[162]

3.5 Tables

Table 1. Name, variable categorization, and additional information for the dependent variable used in all analyses (nutritional risk)

Dependent Variable	Variable Categorization	Additional information
Nutritional Risk	0 = not at high nutritional risk 1= high nutritional risk	This is a derived variable in the CLSA dataset that is determined from the score obtained from the modified SCREEN-II-AB. Scores from 0 to <38 correspond to "high nutritional risk", while scores from 38-48 correspond to "not high nutritional risk".[137] When testing for mediation in objective 3, the continuous version of this variable was used, with scores ranging from 0 to 48.

SCREEN-II-AB = Seniors in the Community: Risk Evaluation for Eating and Nutrition (Version 2, abbreviated)

Table 2. Seven dimensions of structural social capital and eleven dimensions of cognitive structural capital that are assessed by the A-SCAT

Structural social capital[110]	**Cognitive social capital**[110]
○ *Participation in organizations* ○ *Institutional linkages (connections to services, facilities, institutions)* ○ *Frequency of general collective action* ○ *Specific collective action (e.g., whether people would get together to address named hypothetical situations)* ○ *Degree of citizenship (e.g., whether the respondent has voted/campaigned/taken part in other neighbourhood or city-wide activity)* ○ *Links to groups with resources (such as local government of aid agencies)* ○ *Links to parallel groups (namely other communities)*	○ *General social support* ○ *Emotional support (enabling people to 'feel' things)* ○ *Instrumental support (enabling people to 'do' things* ○ *Informational support (enabling people to 'know' things)* ○ *Trust* ○ *Fellow-feeling (interest in the fortune of others)* ○ *Reciprocity and cooperation* ○ *Social harmony* ○ *Sense of belonging* ○ *Perceived fairness (e.g., would others in the community take advantage of people)* ○ *Perceived social responsibility (e.g., would others in the community return lost items)*

Italics indicate that wording of the A-SCAT dimensions are unchanged from the original source

A-SCAT= Adapted Social Capital Assessment Tool

Table 3. Mapping showing all variables in the CLSA which correspond to each dimension of structural social capital assessed in the A-SCAT

Dimension of the A-SCAT* [110]	**Related variables in the CLSA** [215]
Participation in organizations	• Frequency of participation in volunteer or charity work (past 12 months) • Frequency of participation in religious activities (past 12 months) • Frequency of participation in association activities (past 12 months) • Frequency of participation in clubs or fraternal organization activities (past 12 months) • Frequency of participation in educational or cultural activities (past 12 months)
Institutional linkages (connections to services, facilities, institutions)	
Frequency of general collective action	
Specific collective action (whether people would get together to address named hypothetical situations)	
Degree of citizenship (whether the respondent has voted/campaigned/taken part in other neighbourhood or city-wide activity)	• Voted in last election • Reads a daily newspaper
Links to groups with resources (such as local government of aid agencies)	
Links to parallel groups (namely other communities)	

Italics indicate that wording of the A-SCAT dimensions are unchanged from the original source

A-SCAT= Adapted Social Capital Assessment Tool; CLSA = Canadian Longitudinal Study on Aging

Table 4. Mapping showing all variables in the CLSA which correspond to each dimension of cognitive social capital assessed in the A-SCAT

Element of the A-SCAT* [110]	**Related variables in the CLSA** [215]
General social support	• Tangible Social Support – MOS-SSS Subscale***
Emotional support (enabling people to 'feel' things)	• MOS-SSS scale: Support availability through wanted advice • MOS-SSS scale: Support availability for advising about a crisis • MOS-SSS scale: Support availability if need to confide • Affection score – MOS-SSS Subscale • MOS-SSS scale: Support availability having a good time • MOS-SSS scale: Support availability through hugs • MOS-SSS scale: Support availability by love and making participant feel wanted • MOS-SSS scale: Support availability if need to talk • MOS-SSS scale: Support availability for understanding problems • MOS-SSS scale: Support availability through get togethers for relaxation • MOS-SSS scale: Support availability to share fears • MOS-SSS scale: Support availability showing love and affection • MOS-SSS scale: Support availability for suggestions with a personal problem • Received non-professional companionship and emotional support
Instrumental support (enabling people to 'do' things	• MOS-SSS scale: Support availability with daily chores • MOS-SSS scale: Support availability if confined to bed • MOS-SSS scale: Support availability if unable to prepare meals • MOS-SSS scale: Support availability through distraction activities • MOS-SSS scale: Support availability if need to go to doctor • Received non-professional assistance with activities • Received non-professional assistance with mobility

Element of the A-SCAT* [110]	**Related variables in the CLSA** [215]
	• Received non-professional assistance with meal preparation
Informational support (enabling people to 'know' things)	• MOS-SSS scale: Support availability providing information
Trust	• Most people in local area can be trusted
Fellow-feeling (interest in the fortune of others)	
Reciprocity and co-operation	
Social harmony	• Most people in local area are friendly
Sense of belonging	• Feel a part of local area • Often feel lonely living in local area
Perceived fairness (would others in the community take advantage of people)	• People in local area will take advantage of you
Perceived social responsibility (would others in the community return lost items)	• Lots of people in local area who would help if in trouble

Italics indicate that wording of the A-SCAT dimensions are unchanged from the original source

A-SCAT= Adapted Social Capital Assessment Tool; CLSA = Canadian Longitudinal Study on Aging; MOS-SSS = Medical Outcome Study Social Support Survey

Table 5. Definitions for geographic concepts that must be understood prior to defining Statistics Canada's Population Centre and Rural Area Classification

Relevant Concepts[91,92]	**Definition**[91,92,216]
Population Centre	• Population ≥ 1000 AND • Population density ≥ 400 per km^2
Census metropolitan area (CMA)	• "Formed by one or more adjacent municipalities centred on a population centre"[216] • Population ≥ 1000,000 • ≥50,000 persons living in urban core
Census agglomeration (CA)	• "Formed by one or more adjacent municipalities centred on a population centre"[216] • ≥ 10,000 persons living in urban core
Rural area	• Any area that is not a population centre

Table 6. Definitions for each of the five categories in Statistics Canada's Population Centre and Rural Area Classification

Categories of Statistics Canada's Population Centre and Rural Area Classification* [91,92]	**Definition**[91,92]
Urban core	• Population centre with the largest population of all population centres within a CMA or CA. If the core is within a CMA, it must have a population ≥50,000. If it is within a CA, it must have a population of ≥ 10,000.
Secondary core	• Population centre • Population ≥10,000 • Inside a CMA or CA
Urban fringe	• Population centre • Population <10,000 • Inside a CMA or CA • Share no common borders with core or secondary core
Urban population centre outside CMA and CA	• Population centre • Not within a CMA or CA
Rural	• All rural areas, both inside and outside CMAs and CAs

*These categories are used by both the CLSA and the present study to define the rural-urban continuum.
CA = census agglomeration; CLSA = Canadian Longitudinal Study on Aging; CMA = census metropolitan area

Table 7. Categories of Statistics Canada's Population Centre (POPCTR) and Rural Area Classification and Statistical Area Classification (SAC) grouped according to whether they lie within a CMA, CA, or any area outside of a CMA or CA

	CMA (Population ≥ 100,000 + contains an urban core with ≥ 50,000)	**CA** (Population ≥ 10,000 + contains an urban core with ≥ 10,000)	**Any area outside of a CMA or CA**
Statistic Canada's POPCTR & Rural Area Classification	• Urban core • Secondary core •Urban fringe • Rural	•Urban core • Secondary core • Urban fringe • Rural	• Urban population centre outside CMA or CA • Rural
SAC	•Urban (level 1)	•Urban (level 2) •Urban (level 3)	•Rural (includes strong, moderate, weak, and no metropolitan influence zones) •Remote (territories outside of CMA or CA)

CA = census agglomeration; CMA = census metropolitan area; POPCTR = population centre; Statistical Area Classification

Table 8. Name, variable categorization, and additional information for all independent variables used in analyses

Independent Variable	**Variable Categorization**	**Notes/additional information**
Rural-urban continuum	0 = urban core 1 = secondary core 2 = urban fringe 3 = urban population outside census metropolitan areas and census agglomerations 4 = rural 9 = No rural/urban information available (postal code linked at dissemination area instead of more detailed block face or dissemination block)	See **Table 5** and **Table 6** for more information
Structural social capital variables	0 = never 1 = at least once a year 2 = at least once a month 3 = at least once a week 4 = at least once a day	Structural social capital variables include: • frequency of participation in volunteer or charity work • frequency of participation in religious activities • frequency of participation in association activities • frequency of participation in clubs or fraternal organization activities • frequency of participation in educational or cultural activities
Cognitive social capital variables	0 = strongly disagree 1 = disagree 2 = agree 3 = strongly agree	Cognitive social capital variables include: • most people in local area can be trusted • most people in local area are friendly • feel a part of local area • often feel lonely living in local area (reverse coded) • people in local area will take advantage of you (reverse coded) • lots of people in local area who would help if in trouble
Age	Continuous variable	During analyses for objective 1, age will be collapsed into the following categories:

Independent Variable	Variable Categorization	Notes/additional information
		0 = 65-69 1 = 70-74 2 = 75-79 3 = 80-84 4 = 85+ These categories reflect the life-cycle groupings recommended by Statistics Canada.[155]
Sex	0 = male 1 = female	
Ethnicity	0 = Non-white 1 = White	
Total household income	0 = <$20,000 1= $20,000 to <$50,000 2 = $50,000 to <$100,000 3 = $100,000 to <150,000 4 = $150,000+	
Highest level of education	0 = Less than high school graduation 1 = High school graduation 2 = Some post-secondary/trade certificate 3 = College/university certificate 4 = Bachelor's degree 5 = University degree or certificate above bachelor's degree	
Household size	1= 1 person, 2 = 2 people 3 = 3 people 4 = 4 people 5 = 5 or more people	This variable will adjust total household income by household size.
Years lived in the current community	0 = Less than 5 1 = 5 or more, but less than 10 2 = 10 or more, but less than 20 3 = 10 or more, but less than 30 4 = 30 or more, but less than 40 5 = 40 or more, but less than 50 6 = 50 or more, but less than 60 7 = 60 or more, but less than 70 8 = 70 or more	
Access to food outlets	0 = no 1 = yes	The variable represents responses to the question "What kind of trip(s) do you typically make in a

Independent Variable	Variable Categorization	Notes/additional information
		week, whether by car, public transit, walking or other means?". Participants that included "grocery shopping" in their response are coded as 1.
Province	0 = Newfoundland and Labrador 1 = Nova Scotia 2 = Quebec 3 = Ontario 4 = Manitoba 5 = Alberta 6 = British Columbia 7 = Saskatchewan 8 = PEI 9 = New Brunswick	
Functional Impairment	0 = No functional impairment 1 = Mild functional impairment 2 = Moderate functional impairment 3 = Severe or total functional impairment	This variable is derived in the CLSA based on the activities of daily living (ADL). Severe and total functional impairment were combined to address cell sizes < 30. Note that meal preparation was not included in the assessment of ADL, as this was assessed as part of the SCREEN-II-AB questionnaire.
Perceived oral health	0 = Excellent 1 = Very Good 2 = Good 3 = Fair 4 = Poor	This variable was coded with "excellent" as the lowest code and "poor" as the highest because we were interested in the effect of "poor oral health" on nutritional risk.
Chronic conditions	0 = None 1 = One 2 = Two 3 = Three 4 = Four 5 = Five 6 = Six 7 = Seven or more	This variable is a sum of how many times a respondent answered "yes" to having ever been told by a medical professional that that they have one of the following conditions: cognitive decline, mood or anxiety disorder, vision problems, thyroid problems, heart disease/ heart attack/ myocardial infarction/ angina/ peripheral vascular disease, arthritis (any type), bowel or intestinal conditions, , high blood pressure or

Independent Variable	Variable Categorization	Notes/additional information
		hypertension, diabetes, cerebrovascular accident, migraine headache, urinary incontinence, cancer, osteoporosis, back pain (excluding fibromyalgia or rheumatoid arthritis) , kidney disease or kidney failure. Participants' responses were summed even if they reported "don't know" / "refused" to some chronic condition questions. Hence, this variable may underestimate the number of chronic conditions. However, it was assumed that someone would report "yes" if they ever had a condition, meaning that responses of "don't know"/ "refused" are likely indicators that the condition was not present.

ADL = activities of daily living; SCREEN-II-AB = Seniors in the Community Risk Evaluation for Eating and Nutrition (Version 2, abbreviated)

3.6 Figures

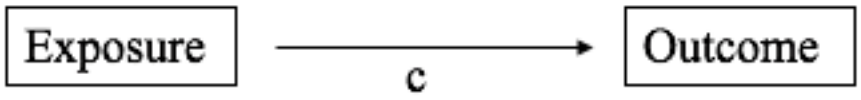

Figure 4. Path diagram showing the total effect (c) of an exposure on the outcome

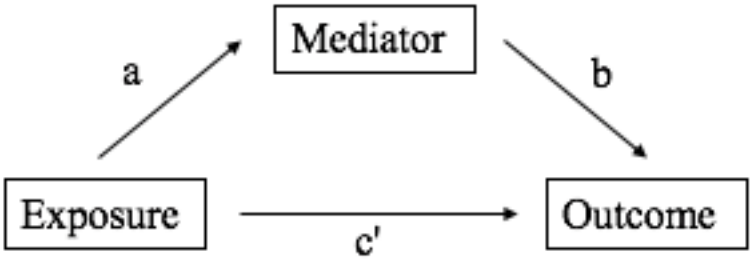

Figure 5. Path diagram showing the direct (c') and indirect (ab) effect of an exposure on the outcome.

The direct effect is the effect of the exposure on the outcome that attributable to the mediator. The indirect effect is the effect of the exposure on the outcome that is mediated by the mediator.

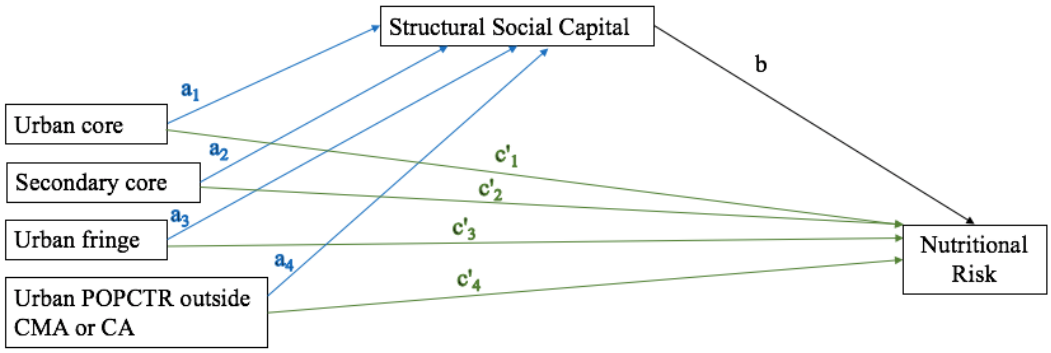

Figure 6. Path diagram showing the relative direct (c_i') and indirect (a_ib) effects of rural-urban continuum categories on nutritional risk.

Rural category is used as the reference category.
CA = census agglomeration; CMA = census metropolitan area; POPCTR = population centre
Note: Figure is based on a similar diagram by Hayes & Preacher, 2013[163]

Chapter 4 Results

4.1 Sample Sizes Available for Analyses

A flow chart detailing the number of participants excluded at each stage in the analysis is shown in **Figure 7**. A general overview of each step in the flow chart is provided below.

The initial CLSA sample had 51,338 participants in the Tracking and Comprehensive cohorts combined. However, participants were only included in the present analysis if they were at least 65 years of age and completed the Maintaining Contact Questionnaire. Notably, nutritional risk, cognitive social capital variables, years lived in the current community, access to food outlets, and oral health were only assessed in the Maintaining Contact Questionnaire. Next, participants were excluded if they had an inconclusive categorical nutritional risk score (as this was the primary outcome of interest). Participants with missing or inconclusive responses to ethnicity, years lived in the current community, household size, functional impairment, perceived oral health, and chronic conditions were excluded, as these variables had less than 1% missing. In contrast, missing/inconclusive categories for the rural-urban continuum, household income, and structural and cognitive social capital were given their own category in Objectives 1 and 2.[VIII] This gave a sample size of 19,377 for the first two objectives.

For the effect modification analysis in objective three, inconclusive categories for the rural-urban continuum and structural/cognitive social capital were excluded, giving a sample size of 16,857. Lastly, mediation analysis was conducted using the continuous (rather than categorical) nutrition risk variable, and so participants missing this variable were excluded. This gave a sample size of 16,473 for the mediation analysis.

At each step when participants were excluded (aside from the exclusion based on age eligibility), a missing case analysis comparing included and excluded participants was completed (Appendix F). In general, whenever there was a significant difference between groups of participants that were included versus excluded, those groups that

[VIII] The number of inconclusive responses to cognitive social capital was ~8% of the sample and so this was included as its own category. Then, for consistency, I kept the inconclusive category for structural social capital, even though it was ~0.5%.

were excluded tended to have a higher percentage of participants with risk factors for high nutritional risk such as lower levels of education, lower total household income, non-white ethnicity, and lower levels of cognitive and structural social capital. Hence, it is possible that the prevalence of high nutritional risk was under-estimated.

4.2 Objective 1

Results for Objective 1 are presented in **Table 9**. The weighted prevalence of high nutritional risk was 33.4%, suggesting that approximately one in three older adults in Canada are at high nutritional risk. All sociodemographic characteristics were significantly associated with nutritional risk except for ethnicity, access to food outlets, and province. The weighted percentage of high nutritional risk was higher in females than in males: 36.7% versus 29.6%.

Along the rural-urban continuum, the weighted percentage of older adults at high nutritional risk was highest in the urban core category (35.4%) and lowest in the rural category (28.2%). The percentages of older adults at high nutritional risk in the secondary core (28.8%) and urban fringe (28.2%) were similar to the proportion in rural areas, while the percentage in the urban population centre outside of a CMA or CA was identical to that in the urban core (35.4%).

As the level of cognitive and structural social capital increased from low to high, the weighted percentage of participants at high nutritional risk decreased from 49.3% to 25.4% and from 39.0% to 28.3%, respectively. Similarly, protective relationships were observed for income and education, with the prevalence of high nutritional risk decreasing overall as income and education increased. For household size, the weighted percentage of high nutritional risk was greatest in participants that live alone (48.9%), and lowest in participants who live with one other person (26.8%). Years lived in the current community displayed a slightly U-shaped association with nutritional risk, with the weighted percentage of high nutritional risk decreasing from 39.0% to 29.9% as years lived in the current community decreased from less than five years to fifty or more years, but less than sixty years, and then increasing to 38.5% as years lived in the current community increased to 70 years or more.

All health status variables were significantly associated with nutritional risk. There was a monotonic increase in the weighted percentage of older adults at high nutritional risk as the number of chronic conditions and the level of their functional impairment increased, and as the level of perceived oral health decreased. In particular, the prevalence of high nutritional risk was greater than 50% in participants reporting fair/poor perceived oral health, moderate/severe/total functional impairment, or six or more chronic conditions.

In a supplementary results table for Objective 1, the distribution of rural-urban continuum, sociodemographic variables, and health status variables within the high nutritional risk group and the not high nutritional risk group is shown in Appendix G. Note that significant results and general relationships observed in this analysis are aligned with those presented in the main analysis. For instance, the high nutritional risk group had a greater percentage of urban participants compared to the not high nutritional risk group (67.3% versus 61.7%), while the not high nutritional risk group had a greater percentage of rural participants compared to the high nutritional risk group (22.8% versus 17.8%).

4.3 Objective 2

Results for Objective 2 are presented in **Table 10**. In the unadjusted model, the odds of high nutritional risk in the urban core and urban POPCTR outside CMA and CA were significantly different from the odds in rural areas, with a 40% increase in the odds observed in both categories (99% confidence interval (CI) of [1.17-1.68] and [1.02-1.92], respectively). After adjusting for confounders, the association with the urban core remained significant, with the odds of high nutritional risk in urban core older adults 1.35 (99% CI: [1.10-1.64]) times the odds of high nutritional risk in rural older adults. No other categories along the rural-urban continuum were significantly different from rural areas in the multivariable model.

Results from the unadjusted logistic regression models for each sociodemographic and health status variable are, in essence, aligned with those from the bivariate analysis (produced by the Pearson Chi-squared statistic) in Objective 1. In the unadjusted logistic

regression models, significant results were obtained for all variables except ethnicity and access to food outlets. In contrast, many sociodemographic characteristics were not significant in the multivariable model: sex, ethnicity, total household income, access to food outlets, years lived in current community, and province.

Age demonstrated a significant association in the multivariable model, with the odds of high nutritional risk decreasing by 2% for each unit increase in age. Similarly, a monotonic decrease in the odds of high nutritional risk was observed with each increasing level of education in the multivariable model; however, only the highest education level (university degree or certificate above a bachelor's degree) was significantly different from the reference group of less than high school graduation (adjusted OR [99% CI] = 0.65 [0.49-0.85]). Compared to living alone, all households with more than one person showed a decrease in the odds of high nutritional risk, with the greatest benefit observed in households with at least five people (adjusted OR [99% CI] = 0.38 [0.20-0.75]).

Both types of social capital displayed decreasing odds of high nutritional risk as the level of social capital increased in the multivariable model; however, this effect was only significant for cognitive social capital. Participants with high cognitive social capital had 48% decreased odds of high nutritional risk compared to those with low cognitive social capital. Notably, participants with inconclusive structural social capital had a significantly decreased odds of high nutritional risk compared to participants with low structural social capital (adjusted OR [99% CI] = 0.32 [0.14-0.75]).

In the multivariable model, a significant increase in the odds of high nutritional risk was observed with worsening outcomes for each of the three health status variables: functional impairment, perceived oral health, and number of chronic conditions. In particular, the odds of high nutritional risk in the categories corresponding to the worst health outcomes (7 or more chronic conditions, severe/total functional impairment, or poor oral health) increased by at least 3 times compared to those categories corresponding to the best outcomes (no chronic conditions, no functional impairment, or excellent oral health), with adjusted OR [99% CI] of 3.21 [2.14-4.81], 3.68 [1.16-11.7], and 3.00 [1.77-5.04], respectively.

4.4 Objective 3

Prior to completing the analyses that tested whether cognitive/structural social capital act as effect modifiers or mediators of the relationship between the rural-urban continuum and nutritional risk, the distribution of high/moderate/low cognitive social capital for each category in the rural-urban continuum was compared (**Table 11**). This was repeated for structural social capital (**Table 12**). The rural-urban continuum was significantly associated with cognitive social capital (p=0.0001), with rural showing the greatest percentage of participants with high cognitive social capital, and the urban core having the lowest. In contrast, the association between the rural-urban continuum and structural social capital was not significant (p=0.5902).

Tests for Effect Modification

When adding an interaction term between structural social capital and the rural-urban continuum to the model from Objective 2, none of the interaction terms were significant. Similarly, when this was repeated for cognitive social capital, none of the interaction terms were significant. In both scenarios, a Wald test was also used to confirm that the interaction terms did not add significantly to the model. Hence, there was no evidence of multiplicative interactions between structural social capital and the rural-urban continuum, nor between cognitive social capital and the rural-urban continuum.

Next, as outlined in the methods chapter, the RERI was calculated for the following three combinations: rural/urban and high/moderate social capital, rural/urban and high/low social capital, rural/urban and moderate/low social capital. For structural social capital, the RERIs and 99% confidence intervals for each scenario were 0.07 (-0.39, 0.53), 0.05 (-.034, 0.46), and 0.01 (-0.32, 0.33) respectively. RERIs for cognitive social capital were -0.34 (-0.99, 0.30), -0.08 (-0.49, 0.32), and -0.15 (-0.59, 0.29), respectively. Notably, each of these confidence intervals contain zero, meaning there was no evidence of additive interaction.

Tests for Mediation

Cognitive Social Capital

Cognitive social capital appeared to mediate the relationship between the rural-urban continuum and nutritional risk. The relative indirect effects and the corresponding 99% confidence interval for each category in the rural-urban continuum are reported in **Table 13**. The 99% confidence interval for the relative indirect effect in the urban core did not include zero, suggesting the presence of mediation. This relative indirect effect can be interpreted as follows: relative to rural residents, older adults living in an urban core had a SCREEN-II-AB score that was 0.07 units lower as a result of the negative effect of living in an urban core on cognitive social capital (this negative effect is based on the negative sign of a_1). Note that this interpretation applies only to the indirect effect of the urban core on nutritional risk (i.e. the effect that is mediated by cognitive social capital), rather than describing the total effect of living in an urban core on nutritional risk. Importantly, a slight rephrasing of the interpretation may help to make the results more intuitive. In particular, we could state that relative to urban core residents, older adults living in a rural area had a SCREEN-II score that was 0.07 units higher as a result of the positive effect of living in a rural area on cognitive social capital, which in turn decreased nutritional risk (based on the positive sign of b). These interpretations of the relative indirect effect are based on guidance provided by Hayes and colleagues.[163] Also, recall that a higher SCREEN-II-AB score is associated with a lower nutritional risk.

An analysis of the residuals for the linear regression models used to generate the above mediation results showed (i) a tendency to overestimate the continuous nutritional risk score for participants with scores below 30 and (ii) a tendency to overestimate the continuous standardized cognitive social capital score for participants with a score below -2. To assess the presence of bias, a sensitivity analysis was completed by excluding those participants for which the models showed a poor fit (n=1350). This analysis produced the same conclusions as the original analysis, although the relative indirect effect in the urban core was -0.05 (rather than -0.07). Hence, the magnitude of the relative indirect effects may have been slightly overestimated.

Structural Social Capital

There was no evidence to suggest that structural social capital mediates the relationship between the rural-urban continuum and nutritional risk. With rural as the reference category, the relative indirect effects and the corresponding 99% confidence interval for each category in the rural-urban continuum are reported in **Table 14**. This analysis was repeated with each category as the reference, and none of the relative indirect effects were ever significantly different from zero.

Standard error estimation

Recall that the 99% confidence intervals reported for the relative indirect effects were calculated using the delta method (i.e., Taylor linearization) and were calculated after applying CLSA sampling weights. For both cognitive and structural social capital, the supplementary analysis that did not apply CLSA sampling weights but instead compared the standard errors obtained using bootstrapping that assumed random sampling and the delta method showed that the difference in standard errors occurred in the second to third decimal place and never changed the conclusions.

4.5 Tables

Table 9. Number and percent of participants at high /not high nutritional risk within each category of sociodemographic and health status variables (Objective 1).

	High nutritional risk		Not high nutritional risk		
	Unweighted n	Weighted % **(row)**	Unweighted n	Weighted % **(row)**	p-value[1]
Total	6,791	33.4	12,586	66.6	
Rural-urban continuum					
Urban core	5,266	35.4	9,363	64.6	<0.0001*
Secondary core	104	28.8	213	71.2	
Urban fringe	108	28.2	211	71.8	
Urban POPCTR outside CA or CMA	264	35.4	480	64.6	
Rural	760	28.2	1,699	71.8	
Rural/urban classification not available	289	31.8	620	68.2	
Age					
65-69 years	2,204	30.8	4,344	69.2	0.0028*
70-74 years	1,545	34.5	2,965	65.5	
75-79 years	1,804	34.7	3,250	65.3	
80-84 years	1,116	36.5	1,812	63.5	
85-89 years	122	35.4	215	64.6	
Sex					
Male	3,090	29.6	6,575	70.4	<0.0001*
Female	3,701	36.7	6,011	63.3	
Ethnicity					
White	6,526	38.8	12,186	61.2	0.0861
Non-white	265	33.2	400	66.8	
Total Household income					
<$20,000	698	51.7	581	48.3	<0.0001*
$20,000 to <$50,000	2,623	38.0	3,933	62.0	
$50,000 to <$100,000	2,065	28.4	4,769	71.6	
$100,000 to <$150,000	491	24.0	1,533	76.0	
≥$150,000	262	24.5	753	75.5	
Don't know/no answer/refused	652	37.5	1,017	62.5	
Household Size					
One	3,024	48.9	3,078	51.1	<0.0001*
Two	3,145	26.8	8,417	73.2	
Three	421	34.0	747	66.0	
Four	131	37.4	204	62.6	
Five or more	70	30.1	140	69.9	
Highest level of education					
<HS graduation	1,028	40.8	1,374	59.2	<0.0001*
HS graduation	1,353	37.4	2,212	62.6	
Some post-2ndary/trade certificate	879	34.4	1,432	65.6	
College/university certificate	1,354	34.5	2,481	65.5	
Bachelor's degree	1,153	29.3	2,421	70.7	
>Bachelor's degree	1,024	24.8	2,665	75.2	
Access to food outlets					
No	1,502	33.2	2,812	66.8	0.7729
Yes	5,289	33.5	9,774	66.5	
Years in current community					
Less than 5	324	39.0	534	61.0	0.0038*
More than 5 but less than 10	512	34.1	833	65.9	
10 or more but less than 20	1,058	34.6	1,854	65.4	

	High nutritional risk		Not high nutritional risk		
	Unweighted n	Weighted % **(row)**	Unweighted n	Weighted % **(row)**	p-value[1]
20 or more but less than 30	886	31.4	1,692	68.6	
30 or more but less than 40	958	31.8	1,903	68.2	
40 or more but less than 50	1,211	32.0	2,538	68.0	
50 or more but less than 60	735	29.9	1,388	70.1	
60 or more but less than 70	523	36.5	872	63.5	
70 or more	584	38.5	972	61.5	
Structural social capital					
Low	1,614	39.0	2,236	61.0	<0.0001*
Moderate	4,280	32.6	8,203	67.4	
High	864	28.3	2,075	71.7	
Inconclusive due to missing responses	33	18.0	72	82.0	
Cognitive social capital					
Low	832	49.3	808	50.7	<0.0001*
Moderate	4,250	32.3	8,172	67.7	
High	1,012	25.4	2,718	74.6	
Inconclusive due to missing responses	697	44.3	888	55.7	
Province					
Nova Scotia	617	31.8	1,207	68.2	0.1416
New Brunswick	165	31.7	332	68.3	
Prince Edward Island	150	32.1	310	67.9	
Newfoundland and Labrador	360	27.4	894	72.6	
Quebec	1,321	34.5	2,253	65.5	
Ontario	1,432	33.0	2,827	67.0	
Manitoba	686	38.7	1,053	61.3	
Saskatchewan	170	33.6	329	66.4	
Alberta	712	33.3	1,175	66.7	
British Columbia	1,178	33.0	2,206	67.0	
Number of chronic conditions					
0	278	19.0	928	81.0	<0.0001*
1	744	24.9	2,128	75.1	
2	1,205	28.7	2,807	71.3	
3	1,307	32.2	2,539	67.9	
4	1,157	36.3	1,913	63.7	
5	865	41.8	1,172	58.2	
6	575	50.0	605	50.0	
7 or more	660	56.0	494	44.0	
Functional impairment					
None	5,381	30.6	11,182	69.4	<0.0001*
Mild	1,274	48.7	1,329	51.3	
Moderate	94	70.7	49	29.3	
Severe or total	42	75.9	26	24.1	
Perceived oral health					
Excellent	1,521	24.3	4,187	75.7	<0.0001*
Very good	2,494	31.1	5,119	68.9	
Good	2,015	41.8	2,687	58.2	
Fair	577	51.3	479	48.7	
Poor	184	60.0	114	40.0	

[1]p-value based on Pearson χ^2 statistic after applying weights to correct for complex survey design

*p<0.01

CA = census agglomeration; CMA = census metropolitan area; HS = high school; POPCTR = population centre

Results correspond to all 19,377 participants included in Objective 1.

Table 10. Odds Ratios and 99% Confidence intervals from unadjusted and adjusted logistic regression models predicting high nutritional risk from the rural-urban continuum, sociodemographic variables, and health status variables (Objective 2)

	Unadjusted Model (OR [99%CI])	Adjusted Model (OR [99%CI])
Rural-urban continuum		
Urban core	**1.40 [1.17-1.68]**	**1.35 [1.10-1.64]**
Secondary core	1.03 [0.64-1.66]	0.87 [0.51-1.47]
Urban fringe	1.00 [0.59-1.71]	0.99 [0.57-1.73]
Urban POPCTR outside CA or CMA	**1.40 [1.02-1.92]**	1.29 [0.92-1.80]
Rural	Reference	Reference
No rural/urban information available	1.19 [0.89-1.60]	1.11 [0.80-1.54]
Age	**1.02 [1.01, 1.03]**	**0.98 [0.97-0.99]**
Sex		
Male	Reference	Reference
Female	**1.38 [1.21, 1.56]**	0.94 [0.80-1.09]
Ethnicity		
White	Reference	Reference
Non-white	1.28 [0.88, 1.84]	1.15 [0.78-1.69]
Total Household income		
<$20,000	Reference	Reference
$20,000 to <$50,000	**0.57 [0.45, 0.73]**	0.97 [0.74-1.27]
$50,000 to <$100,000	**0.37 [0.29, 0.48]**	0.89 [0.66-1.20]
$100,000 to <$150,000	**0.30 [0.21, 0.41]**	0.83 [0.57-1.21]
≥$150,000	**0.30 [0.20, 0.45]**	0.92 [0.59-1.43]
Don't know/no answer/refused	**0.56 [0.41, 0.76]**	0.93 [0.67-1.30]
Highest level of education		
< High school graduation	Reference	Reference
High school graduation	0.87 [0.70, 1.08]	1.02 [0.81-1.30]
Some post-secondary/ trade certificate	**0.76 [0.60, 0.97]**	0.84 [0.65-1.10]
College/University certificate	**0.76 [0.62, 0.95]**	0.88 [0.69-1.12]
Bachelor's degree	**0.60 [0.48, 0.76]**	0.78 [0.61-1.01]
University degree/ certificate > bachelor's	**0.48 [0.38, 0.60]**	**0.65 [0.49-0.85]**
Access to food outlets		
Yes	1.02 [0.88, 1.18]	1.08 [0.92-1.27]
No	Reference	Reference
Household size		
One	Reference	Reference
Two	**0.38 [0.33, 0.44]**	**0.44 [0.37-0.51]**
Three	**0.54 [0.40, 0.72]**	**0.60 [0.43-0.82]**
Four	0.62 [0.37, 1.06]	0.60 [0.35-1.03]
Five+	**0.45 [0.23, 0.87]**	**0.38 [0.20-0.75]**
Years in current community		
Less than 5	Reference	Reference
More than 5 but less than 10	0.81 [0.55, 1.18]	0.94 [0.62-1.42]
10 or more but less than 20	0.82 [0.59, 1.16]	1.01 [0.69-1.47]
20 or more but less than 30	0.72 [0.51, 1.01]	0.85 [0.58-1.25]
30 or more but less than 40	0.73 [0.52, 1.03]	0.92 [0.63-1.35]
40 or more but less than 50	0.74 [0.52, 1.03]	0.95 [0.66-1.38]
50 or more but less than 60	**0.66 [0.46, 0.95]**	0.80 [0.54-1.19]
60 or more but less than 70	0.90 [0.61, 1.32]	1.07 [0.70-1.63]
70 or more	0.98 [0.68, 1.41]	1.01 [0.68-1.53]
Province		
Ontario	Reference	Reference
British Columbia	1.00 [0.84, 1.19]	1.02 [0.84-1.23]
Manitoba	**1.29 [1.06, 1.56]**	1.19 [0.96-1.47]
New Brunswick	0.94 [0.71, 1.26]	0.83 [0.60-1.13]
Newfoundland and Labrador	0.77 [0.58, 1.01]	0.74 [0.55-1.02]
Nova Scotia	0.95 [0.74, 1.22]	0.92 [0.70-1.20]
Alberta	1.02 [0.82, 1.26]	0.96 [0.76-1.20]

	Unadjusted Model (OR [99%CI])	Adjusted Model (OR [99%CI])
Prince Edward Island	0.96 [0.71, 1.30]	0.92 [0.68-1.26]
Quebec	1.07 [0.89, 1.28]	0.96 [0.70-1.20]
Saskatchewan	1.03 [0.78, 1.36]	0.97 [0.72-1.32]
Number of chronic conditions		
0	Reference	Reference
1	1.42 [1.00, 2.00]	1.38 [0.97-1.96]
2	**1.72 [1.24, 2.38]**	**1.52 [1.09-2.12]**
3	**2.02 [1.46, 2.81]**	**1.75 [1.25-2.45]**
4	**2.43 [1.74, 3.39]**	**2.00 [1.43-2.80]**
5	**3.07 [2.16, 4.35]**	**2.29 [1.60-3.28]**
6	**4.28 [2.90, 6.31]**	**3.05 [2.04-4.57]**
7 or more	**5.43 [3.69, 7.98]**	**3.21 [2.14-4.81]**
Functional impairment		
None	Reference	Reference
Mild	**2.15 [1.80, 2.57]**	**1.41 [1.16-1.71]**
Moderate	**5.47 [2.44, 12.24]**	**3.23 [1.47-7.07]**
Severe or total	**7.13 [2.44, 20.87]**	**3.68 [1.16-11.7]**
Perceived oral health		
Excellent	Reference	Reference
Very good	**1.40 [1.19, 1.66]**	**1.31 [1.10-1.56]**
Good	**2.24 [1.87, 2.68]**	**1.86 [1.54-2.24]**
Fair	**3.28 [2.45, 4.37]**	**2.48 [1.82-3.36]**
Poor	**4.66 [2.84, 7.66]**	**3.00 [1.77-5.04]**
Structural social capital		
Low	Reference	Reference
Moderate	**0.76 [0.65, 0.89]**	0.88 [0.75-1.05]
High	**0.62 [0.49, 0.77]**	0.79 [0.62-1.01]
Inconclusive due to missing responses	**0.34 [0.15, 0.81]**	**0.32 [0.14-0.75]**
Cognitive social capital		
Low	Reference	Reference
Moderate	**0.49 [0.40, 0.61]**	**0.62 [0.49-0.78]**
High	**0.35 [0.27, 0.45]**	**0.52 [0.39-0.68]**
Inconclusive due to missing responses	0.82 [0.61, 1.10]	0.88 [0.64-1.20]

Bolded results are significant at the 0.01 level.
CA = census agglomeration; CI = confidence interval; CMA = census metropolitan area; HS = high school; OR = odds ratio; POPCTR = population centre
All variables were included in the adjusted model. Results correspond to all 19,377 participants included in Objective 2.

Table 11. Number and percent of participants for effect modification analysis by level of cognitive social capital and position along the rural-urban continuum

	Cognitive Social Captial					
	Low		Moderate		High	
	Unwtd. n	Wghtd % **(row)**	Unwtd. n	Wghtd. % **(row)**	Unwtd. n	Wghtd. % **(row)**
Urban core	1,217	10.0	9,365	70.4	2,702	19.6
Secondary core	32	15.6	179	62.6	78	21.8
Urban fringe	31	15.1	211	61.8	57	23.1
Urban POPCTR outside CA or CMA	67	8.6	495	71.4	152	19.9
Rural	199	7.9	1,546	66.7	526	25.4

$p = 0.0001$, based on Pearson χ^2 statistic after applying weights to correct for complex survey design
CA = census agglomeration; CMA = census metropolitan area; POPCTR = population centre
Results correspond to all 16,857 participants included in effect modification analyses in Objective 3.

Table 12. Number and percent of participants for effect modification analysis by level of structural social capital and position along the rural-urban continuum

	Structural Social Capital					
	Low		Moderate		High	
	Unwtd. n	Wghtd % **(row)**	Unwtd. n	Wghtd. % **(row)**	Unwtd. n	Wghtd. % **(row)**
Urban core	2,512	21.9	8,716	64.3	2,056	13.9
Secondary core	72	26.0	178	64.1	39	9.9
Urban fringe	53	18.9	199	69.9	47	11.2
Urban POPCTR outside CA or CMA	140	22.8	438	62.2	136	15.0
Rural	478	22.8	1,441	62.4	352	14.8

$p = 0.5902$, based on Pearson χ^2 statistic after applying weights to correct for complex survey design

CA = census agglomeration; CMA = census metropolitan area; POPCTR = population centre

Results correspond to all 16,857 participants included in effect modification analyses in Objective 3.

Table 13. Relative indirect effects with 99% confidence intervals from mediation anaylysis of cognitive social capital (Objectvie 3)

	a_i	b	Relative indirect effect*	99% CI
Urban core	-0.1571144 (a_1)	0.4648053	-0.07	[-0.12, -0.02]
Secondary core	-0.1295591(a_2)		-0.06	[-0.18, 0.06]
Urban fringe	-0.1835521(a_3)		-0.09	[-0.22, 0.06]
Urban POPCTR outside CMA or CA	-0.0994784 (a_4)		-0.05	[-0.12, 0.03]

CA = census agglomeration; CMA = census metropolitan area; POPCTR = population centre

[ai] regression coefficient for each category of the rural-urban continuum in a log-linear model predicting cognitive social capital from the rural-urban continuum, controlling for sociodemographics and health status variables.

[b] regression coefficient for cognitive social capital in a log-linear model predicting nutritional risk from cognitive social capital, controlling for rural-urban continuum, sociodemographics, and health status variables.

*For each category of the rural-urban continuum, the relative indirect effect is the product of a_i and b. The 99% CI for the relative indirect effect was calculated using the delta method.

Results correspond to all 16,473 participants included in mediation analyses in Objective 3. Rural category was used as the reference group.

Table 14. Relative indirect effects with 99% confidence intervals from mediation analysis of structural social capital (Objective 3)

	a_i	b	Relative indirect effect	99% CI
Urban core	-0.0260445 (a_1)	0.2463187	-0.006	[-0.03, 0.02]
Secondary core	-0.1026993 (a_2)		-0.02	[-0.08, 0.03]
Urban fringe	0.0019604 (a_3)		0.0004	[-0.06, 0.06]
Urban POPCTR outside CMA or CA	0.0608981 (a_4)		0.02	[-0.02,0.05]

CA = census agglomeration; CMA = census metropolitan area; POPCTR = population centre

[ai] regression coefficient for each category of the rural-urban continuum in a log-linear model predicting structural social capital from the rural-urban continuum, controlling for sociodemographics and health status variables.

[b] regression coefficient for structural social capital in a log-linear model predicting nutritional risk from cognitive social capital, controlling for rural-urban continuum, sociodemographics, and health status variables.

*For each category of the rural-urban continuum, the relative indirect effect is the product of a_i and b. The 99% CI for the relative indirect effect was calculated using the delta method.

Results correspond to all 16,473 participants included in mediation analyses in Objective 3. Rural category was used as the reference group.

4.6 Figures

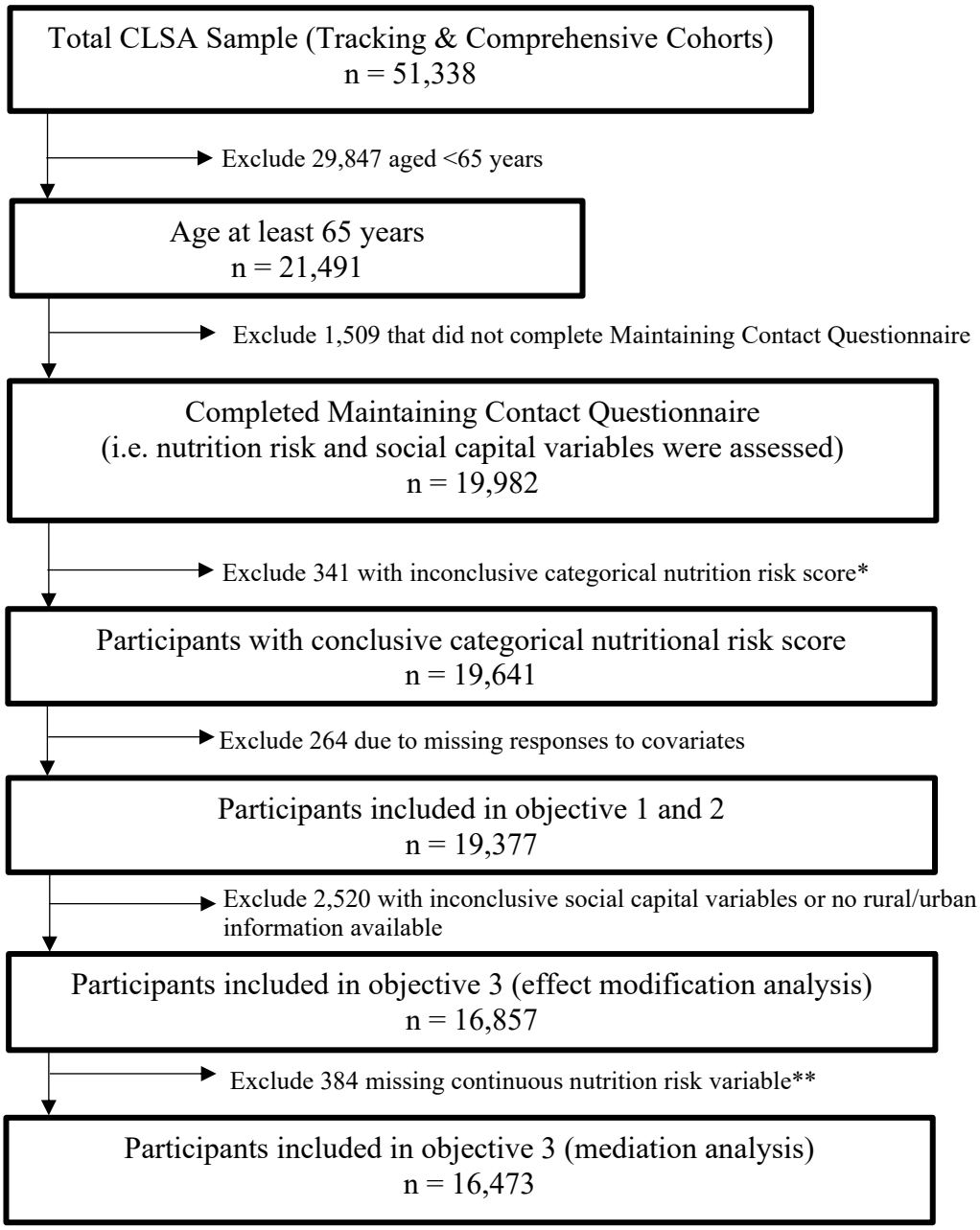

Figure 7. Flow chart of the sample sizes and exclusion rationale for each objective

* 341 participants had an inconclusive categorical nutritional risk score due to missing responses to at least one of the questions AND a total score below 38 (note that if a participant's score was 38 or higher, then the CLSA classified them as "not at high nutritional risk", even if they were missing a response to one of the SCREEN-II-AB questions). **There are more participants missing the continuous variable than the categorical variable. This is because the categorical variable was conclusive if the score

was 38 or greater, even if the participant did not a response for every item. However, the continuous variable is missing is the participant does not have a response for every item.

Chapter 5 Discussion

5.1 Overview of Results

Approximately one-third (33.4%) of community-dwelling older adults in Canada were estimated to be at high nutritional risk. This number is essentially unchanged from the 34% estimate provided by the 2008/2009 CCHS.[16] Thus, given that baseline data for the CLSA were collected from 2011 to 2015, it would appear that little improvement has been made in reducing the number of older adults at high nutritional risk, in spite of the United Nations' Sustainable Development Goal to eradicate malnutrition by the year 2030.[1] This highlights the importance of better understanding the determinants of high nutritional risk in community-dwelling older adults.

Results from the present analysis supported the Broaden framework, with a wide range of structural and intermediary determinants being significantly associated with high nutritional risk in both the bivariate and multivariable analyses. The odds of high nutritional risk were greatest in the urban core, with little variation between the other categories of the rural-urban continuum. This finding did not support the hypothesis that older adults in rural areas would experience higher nutritional risk. Lastly, the ability of social capital to help explain the association between the rural-urban continuum and nutritional risk differed by type of social capital. Strucutural social capital was neither a mediator nor an effect modifier. In comparison, cognitive social capital showed a stronger association with both the rural-urban continuum and nutritional risk, and results suggested that cognitive social capital acts as a mediator. Each of these findings will be further explored in this chapter.

It is important to remember that the present study used the POPCTR approach to classify the rural-urban continuum. In other nutrition studies, the specific criteria used to define rural-urban categories is often not provided. For instance, in a systematic review of geographic variation in protein-energy malnutrition, included studies were simply classified as rural, urban, or mixed, with no explicit criteria provided for these classifications.[5] Hence, it may be difficult to make concrete comparisons between the present analysis and prior nutrition studies with respect to conclusions about the rural-urban continuum. Ultimately, the following discussion should be firmly situated within

the context of the POPCTR criteria used to define categories along the rural-urban continuum.

5.2 Sociodemographic and Health Variables Associated with Nutritional Risk

It is important to note that the present analysis conducted two sets of bivariate analyses (the Pearson Chi-squared test in Objective 1 and unadjusted logistic regression models in Objective 2). The key difference between these two approaches is that the Pearson chi-squared test assesses the presence of an association, while logistic regression requires an assumption about causation via the declaration of a dependent and independent variable. Although I will clearly state which analysis is being referred to throughout this discussion, results from these two approaches are, in essence, the same.[IX]

Women were at a higher nutritional risk than men in both bivariate analyses; however, the association between sex and nutritional risk was not significant in the multivariable analysis. Although some studies have reported women to be at a higher nutritional risk,[5,6,12] there are other studies that have found no difference between men and women.[35,39,82] There are many factors that could account for the results related to sex and nutritional risk. For instance, prior studies have reported that women are more likely than men to have a greater number of chronic conditions and to experience a greater degree of functional impairment.[166–169] Given that these factors were controlled for in the multivariable analysis (and that female participants had significantly higher numbers of chronic conditions and a greater degree of functional impairment), this may explain the present findings.

Age was significantly associated with nutritional risk in both the first and second objectives, with the multivariable analysis indicating that the odds of high nutritional risk decrease by approximately 2% for each unit increase in age. This seems somewhat

[IX]The only exception was province, for which no significant relationship with nutritional risk observed in Objective 1, but a significant difference in the odds of high nutritional risk between Manitoba and the reference category of Ontario were observed in Objective 2.

counterintuitive; however, the 2008/2009 CCHS reported a similar 1-2% decrease in odds of high nutritional risk with each unit increase in age (although this was only significant in females).[16] Survival bias offers a possible explanation, as older participants who have survived long enough to participate in the study may be inherently healthier. Additionally, a 2018 study revealed that Canadians aged 75 and older had a lower odds of food insecurity compared to Canadians aged 65-74 years (OR [95% CI]: 0.322 [0.212–0.419]).[170] This reduction in food insecurity in older Canadians has been observed in other studies and is often attributed to income supplements provided to older adults within Canada.[170–172]

It was not entirely surprising that ethnicity, access to food outlets, and province were not significantly associated with nutritional risk in the bivariate analyses in Objective 1 nor in the multivariable analyses in Objective 2. Firstly, although unique nutritional challenges have been previously reported for certain ethnic groups such as Indigenous Canadians,[173] the CLSA sample was predominantly white, limiting conclusions to white/non-white participants. Secondly, in terms of access to food outlets, note that the present study assessed whether a participant's "typical weekly trips (whether by car, public transit, walking or other means)" included "grocery shopping". This variable was limited in its ability to fully capture accessibility, as it does not distinguish between mode of transportation nor does it assess the difficulty that a participant may have experienced when making such weekly trips. Also, there is likely variation in what types of food outlets participants perceived as "grocery shopping" (e.g., convenience store, supermarket, farmers' market, etc.). Finally, with respect to province, one possible explanation for the nonsignificant results could be the relative uniformity in nutrition policy across the country (e.g., national best practices for meals on wheels programs, the National Seniors Council to guide policy decisions, and federal guidance documents such as Canada's Food Guide).[174]

Higher levels of educational attainment and household income – common markers of socioeconomic status – appeared protective against nutritional risk in the bivariate analyses (Objectives 1 and 2); however, only education was statistically significant in the multivariable analysis. More specifically, only participants with a university degree or certificate above a bachelor's degree had a significantly decreased odds of high

nutritional risk compared to participants without a high school education. Notably, the multivariable analysis adjusted household income by household size, which may explain the difference in significance for income between the bivariate and multivariable analyses. Furthermore, a prior study conducting an investigation of markers of socioeconomic status and nutritional risk also reported no statistically significant associations, leading study authors to postulate that socioeconomic status may be less influential in the development of malnutrition than determinants that are related to lifestyle or biology.[175]

The present study also explored the roles of household size and years lived in the current community. Living in a household with at least one other person was shown to be protective against high nutritional risk. Nutrition studies have commonly reported that living alone is a key determinant of high nutritional risk, operating through potential mechanisms such as loneliness, eating alone, and decreased assistance with meal preparation.[16,32,82] The association between years lived in the current community and nutritional risk was found to be significant in the two bivariate analyses but not in the multivariable model. This is likely partially explained by the fact that the multivariable model adjusted for age, which was unsurprisingly associated with years lived in the current community.

All three health status variables – number of chronic conditions, functional impairment, and perceived oral health – were strongly associated with nutritional risk in both the bivariate (Objectives 1 and 2) and multivariable analysis. This supports a wide body of literature showing that high nutritional risk is often linked to declines in health status.[11,22,64] For instance, multiple chronic conditions can result in polypharmacy, which has been linked to key metabolic changes that increase nutritional risk.[176,177] As another example, greater degrees of functional impairment can interfere with activities such as shopping for food and meal preparation.[178] Finally, poor oral health can lead to difficulty chewing and swallowing, which has been shown to reduce food intake, especially for protein rich foods such as meat products.[78,179]

5.3 Differences in High Nutritional Risk Along the Rural-Urban Continuum

The present study produced unexpected findings regarding nutritional risk along the rural-urban continuum and these could not be fully explained by unique characteristics of the present study. Prior studies have reported rural-dwellers to be at an increased nutritional risk compared to urban-dwellers.[4–6,180,181] In contrast, the present study found older adults residing in the urban core to have a 30% increased odds of high nutritional risk compared to older adults residing in rural areas, after adjusting for sociodemographic and health status variables. The fact that the present analysis differed from prior studies by considering a five-level rural-urban continuum rather than a rural/urban dichotomy did not explain the conflicting findings, as the increased odds of high nutritional risk in urban-dwellers persisted in a sensitivity analysis which dichtomozied the five levels of the rural-urban continuum into rural/urban. [X] Similarly, the unexpected findings cannot be fully attributed to the fact that, to the best of my knowledge, the present study is the first to consider nutritional risk in older adults along the rural-urban continuum in a Canadian context. Certainly, the lower population density of urban centres in Canada compared to those in other countries may partially account for the increased nutritional risk observed in urban-dwellers, as high population density has been linked to nutritional benefits such as an increased availability of resources and increased accessibility.[182–184] Nonetheless, there are other aspects of the Canadian context (such as
the fact that Canada is frequently identified as a global leader in the prioritization of age-friendly cities[185]) that appear inconsistent with the higher rates of nutritional risk observed in urban cores. In short, the increased nutritional risk observed in urban-dwelling older adults may indeed be a novel finding that warrants an increased consideration of the nutritional status of this population.

Older adults in urban areas face unique challenges that may account for their

[X] The rural-urban continuum was dichotomized according to the POPCTR rural/urban labels (i.e. urban = urban core, secondary core, urban fringe, and urban POPCTR outside CMA and CA; rural = rural) and also according to regions within/outside of CMAs/CAs (i.e. urban = urban core, secondary core, urban fringe; rural = urban POPCTR outside CMA and CA, rural).

increased nutritional risk. Urban areas often experience greater food insecurity than rural areas.[186,187,XI] Food insecurity is the culmination of a range of financial, geographic, and cultural challenges, as food security (the opposite state of food insecurity) is present "when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life."[188 (p.9)] Closely linked to the idea of food insecurity is the fact that urban areas tend to have a higher number of food deserts, which are areas in which there is little to no access to grocery stores or affordable fresh food.[189,190] Food deserts are growing increasingly common in urban Canada as supermarkets move away from downtown cores and into the outer boundaries of urban regions.[189] Although food deserts create nutritional risks for the entire population, they present an extra concern for older adults who may already face mobility challenges via physical disability or loss of driving status.[191,192] In addition to food insecurity and food deserts, urban areas also tend to have a higher proportion of nutritionally at-risk populations (e.g. immigrants, refugees, and homeless persons) which could play a role in the increased nutritional risk observed in urban centres.[193,194]

The absence of an observed difference in nutritional risk along the intermediary categories of the rural-urban continuum may have been due to a combination of limited heterogeneity between these geographic areas and small sample sizes. After adjusting for sociodemographic characteristics and health status variables, the odds of high nutritional risk in the secondary core, urban fringe, or urban POPCTR outside of CMA or CA were not significantly different from rural areas. Thus, nutritional risk did not appear to

[XI] It was not possible to fully assess the difference in food insecurity between rural and urban residents in the present study. Food insecurity was only measured for participants in the Tracking cohort. In the sample of 7,660 participants from the CLSA Tracking cohort that were included in the first two objectives, 1.6% were classified as food insecure, with 53% of these residing in an urban core and 21% residing in a rural area. However, this number does not fully capture the difference in food insecurity between rural and urban residents. CLSA participants were dichotomized as food secure/insecure based on responses to the question "In the past 12 months, did you ever eat less than you felt you should because there wasn't enough money to buy food?" In contrast, when ideally measured, food insecurity can be mild (fear or anxiety related to having enough to eat), moderate (compromises in food intake or quality), or severe (insufficient food intake and hunger).[195]

decrease along the continuum from urban to rural. Notably, there is a growing recognition that differences between regions along the rural-urban continuum may be less pronounced than the within-region differences.[101] It follows that there may be little observable variation between categories which are not on the extreme ends of the rural-urban continuum. Indeed, the three middle categories share the common criteria of being population centres which are not urban cores, inevitably creating a degree of similarity. Furthermore, the sample sizes in these middle categories were relatively small, accounting for only 1.6% (secondary core), 1.6% (urban fringe), and 3.8% (urban POPCTR outside CMA or CA) of the total sample, suggesting that the study may have been underpowered to detect what little differences may exist between these categories.

The fact that older adults in rural areas were found to have lower odds of high nutritional risk compared to older adults in urban cores may be attributable to the metropolitan influence experienced by rural participants. A strong MIZ is defined as a region in which at least 30% of the employed population commutes to a CMA core or CA for employment.[153] Recall that participants in the Comprehensive cohort (who comprise 60% of the present study's sample) were required to live within a 25 to 50 km radius of the 11 data-collection centres, suggesting that a certain degree of metropolitan influence was experienced by the majority of rural participants.[132] Accordingly, if the rural participants in the CLSA were primarily residents of a strong MIZ, this could potentially explain their decreased nutritional risk. For example, some studies have shown that when rurality is divided into MIZs, positive health outcomes are observed in areas with a strong metropolitan influence.[196] Residents of rural areas with a strong metropolitan influence may benefit from the increased amenities and more comprehensive health care provisions that often exist in an urban area.[197] At the same time, residents in these areas have access to benefits of living in a rural area such as increased levels of gardening or food-sharing amongst neighbours.[96] In essence, residing in a rural area with a strong MIZ may represent a "best of both worlds" situation, in which an individual has access to protective features of both rural and urban areas. Unfortunately, because the present study used the POPCTR rather than the SAC to classify the rural-urban continuum, it was not possible to divide rural participants according to MIZ. Thus, further research is required

to determine if a strong MIZ is responsible for the nutritional benefit observed in rural-dwelling older adults.

5.4 Can Social Capital Help Explain Variations in Nutritional Risk Along the Rural-Urban Continuum?

Cognitive Social Capital

Cognitive social capital emerged as a promising candidate for explaining associations between the rural-urban continuum and nutritional risk. Cognitive social capital showed a protective association with nutritional risk in both Objectives 1 and 2. Additionally, the rural-urban continuum was significantly associated with cognitive social capital, with levels of cognitive social capital being greatest in rural areas. Lastly, although no evidence of effect modification was observed, there was some evidence of mediation. In particular, findings suggested that rural-dwelling older adults experience a protective benefit against high nutritional risk that is mediated by higher levels of cognitive social capital.

There are a number of limitations to be considered when interpreting the finding that cognitive social capital may act as a mediator. Firstly, although the relative indirect effect in the urban core was statistically different from zero, it is unlikely that a 0.07-unit change in the SCREEN-II-AB score (which ranges from 0 to 48) is clinically meaningful. Furthermore, because the SCREEN-II-AB score is generally dichotomized using 38 as a cut-point, changes in scores that do not result in a crossing of this cut-point may not necessarily indicate a change in nutritional risk (recall that the SCREEN-II-AB score was only considered as a continuous variable to enable the use of well-developed techniques in traditional mediation analyses). Secondly, the sensitivity analysis that excluded participants for which regression models had a poorer fit suggested that the relative indirect effects may have been over-estimated. Thirdly, although results from the supplementary analysis (which did not apply CLSA sampling weights but instead compared the standard errors obtained using bootstrapping that assumed random sampling and the delta method) showed a negligible difference in the standard errors, it is still possible that the delta-method produced different conclusions for the main analysis

(which applied CLSA sampling weights) than would have been obtained from bootstrapped standard errors. Nonetheless, the strong associations between cognitive social capital and each of nutritional risk and the rural-urban continuum suggest that, at the very least, mediation by cognitive social capital warrants further consideration.

Cognitive social capital may be capturing some of the social aspects that define what it means to live in a rural area. For instance, a study using data from Statistics Canada's General Social Survey (GSS) to investigate the social aspects of rural areas in Canada (defined in the study as regions outside of a CMA or CA) reported rural-dwellers to have an increased sense of belonging and a greater trust of their neighbours compared to urban-dwellers.[198] Notably, participants' sociodemographic characteristics did not account for these differences, leading authors to paraphrase social capital scholar Robert Putnam, stating that participants' differences were "because of where they are, not who they are". [198 (p.18)] Indeed, the GSS results are not unique, as a greater sense of belonging, increased social cohesion, and increased social trust have been observed in rural areas both within and outside of Canada.[67,116,199,200]

Although to the best of my knowledge no other study has specifically looked at cognitive social capital and nutritional risk in older adults, numerous studies have reported similar associations between nutritional risk and concepts that are closely related to cognitive social capital. For example, loneliness (a subjective experience that is distinct from the more objective experience of social isolation) may result from lower levels of certain components of cognitive social capital such as social trust and sense of neighbourhood belonging in older adults.[121,201] In turn, loneliness is often reported to be strongly associated with nutritional risk.[32,202] Other studies have found cognitive social capital to be protective against depression and functional impairment in older adults,[203–205] both of which are determinants of high nutritional risk in this population.[16] Finally, the notion that nutritional risk in older adults is mediated via intangible and subjective feelings of social connectivity is not entirely new, as one of the most common predictors of nutritional risk is eating alone.[19] In older adults, commensality (eating together) is believed to produce nutritional benefits via increased enjoyment of meals and establishment of dietary norms surrounding portion sizes and mealtimes.[206,207]

Structural Social Capital

Although the ability of structural social capital to explain associations between the rural-urban continuum and nutritional risk was minimal (it was not significantly associated with nutritional risk in the multivariable model in Objective 2, it was not significantly associated with the rural-urban continuum, and did not appear to be an effect modifier or a mediator of the relationship between the rural-urban continuum and nutritional risk in Objective 3), this should be interpreted within the context of the structural social capital variable used in this study. For instance, the Cronbach alpha for the composite structural capital variable was only 0.5581, and this was not improved upon removal of any variables (for comparison, the Cronbach alpha for cognitive social capital was 0.8084). Furthermore, the individual variables used to create the composite score were only reflective of a single dimension of structural social capital: participation in organizations.

The lack of significant findings related to structural social capital in the present study may be less attributable to the fact that only one dimension of structural social capital was assessed and more attributable to the type of social participation that was considered. Indeed, social participation is one of the most consistently assessed markers of social capital, especially within the public health sphere.[208] Additionally, significant protective associations have been reported between social participation and nutritional risk, making social participation a dimension of structural social capital that warrants investigation.[16,209–211] Hence, the present study is not inherently limited by considering this single dimension of structural social capital. However, the present study considered only formal social participation (i.e., organized gatherings between established groups), rather than informal social participation (i.e., casual gatherings between friends, relatives, or colleagues).[208] Prior studies comparing formal and informal participation reported that informal participation is more strongly associated with happiness, social trust, and older adults' mental wellbeing, each of which may translate into nutritional benefits such as improved appetite and social support.[208,212] In contrast, formal social participation is most often linked to political action, which may provide a less immediate nutritional benefit in older adults.[208] Ultimately, the absence of informal participation in the present study's

composite structural social capital variable may be partially responsible for its' limited ability to explain associations between the rural-urban continuum and nutritional risk.

Because the composite structural social capital variable was created by mapping CLSA variables to the A-SCAT — a tool that was not explicitly designed for nutrition studies — the chosen variables may not adequately capture the mechanisms by which social participation might influence nutritional risk. A narrative review by Vesnaver and colleagues highlights the four main ways in which social participation in older adults may translate into a nutritional benefit: social integration (the desire to conform to dietary norms displayed by others), companionship (feelings of wellbeing), social support (tangible assistance, emotional support, and sharing of information), and commensality (the sharing of meals).[206] The extent to which these four factors are produced by the variables assessed in the present study (religious activities, volunteer/charity work, educational or cultural activities, fraternal organizations, clubs or associations) may depend more on the number and types of social ties a person forms through this participation rather than the participation itself. Therefore, perhaps the study of nutritional risk would benefit more from a social capital measurement approach which provides a more detailed assessment of a person's social relationships (such as list generating approaches).

Whether social participation varies along the rural-urban continuum is likely dependent on how both social participation and the rural-urban continuum are defined. The present study is not the first to find no difference in social participation of older adults along the rural-urban continuum. For example, the Quebec NuAge study found no significant differences in social participation (defined using a range of variables assessing formal and informal participation) across a three-level continuum with categories rural, metropolitan, and urban.[213] The same finding was reported in a second Quebec study by Therrien and Desrosiers that used a 77 item questionnaire to assess a combination of formal and informal participation.[214] In contrast, a nation-wide study comparing participation in volunteer organizations or service clubs/fraternal organizations across the rural-urban continuum (defined using the SAC approach) reported levels of participation to be greatest in rural areas.[198] Thus, the true degree of variation in social participation across the rural-urban continuum in Canada remains unclear.

5.5 Strengths & Limitations

The proposed study aimed to bridge conceptual gaps between the fields of social determinants of health and nutrition. In particular, the conceptual framework that underpins this study draws on the dominant theories from each of these fields and was used to inform the choice of objectives and potential confounders. Nutritional risk was assessed using a validated tool designed in Canada especially for older adults. This project was grounded in a comprehensive interpretation of the rural-urban continuum, complementing the use of a geographic measure with a consideration of social contexts in the form of social capital. The measurement of social capital was theoretically based and informed by a pre-existing measurement tool that recognizes the multi-dimensional nature of social capital by distinguishing between structural and cognitive types. Findings from this study highlighted cognitive social capital as a feature of rurality that may protect against nutritional risk, thereby opposing the deficits-perspective that is often present in rural health research. Lastly, this study was strengthened by using the CLSA as its data source. The CLSA offers a unique opportunity for understanding the health of Canadians, providing a rich source of health information on a national cohort of over 50,000 participants. The longitudinal nature of the CLSA enables future research to expand on the findings in the present study.

Nonetheless, this project had several key limitations. Firstly, because the outcome of interest was nutritional risk rather than malnutrition, I was not able to discern how many participants were actually malnourished. Next, rural-urban continuum classifications were determined using PCCF, which, as discussed throughout the thesis, is vulnerable to misclassification errors.[150] Furthermore, the use of the POPCTR approach to measure the rural-urban continuum limited the comparability of this study. Another limitation of assessing the geographic rural-urban continuum is the subjectivity regarding why an individual may choose to live in a rural or an urban area, representing potential personality differences between rural and urban residents that could not be assessed in the current study.

The use of secondary data prevented me from using a pre-existing and validated tool to measure social capital. Even though I used the A-SCAT to inform the measurement, I was not able to select variables that aligned with each element of the A-

SCAT, nor could I be certain that the chosen variables capture the same latent constructs as those captured by the questions of the A-SCAT. Furthermore, when creating the cognitive social capital variable, I did not consider CLSA questions focusing on social support because of a desire to focus on less commonly explored dimensions of cognitive social capital and also because of differences in the measurement scales used to assess social support variables and other dimensions of cognitive social capital. Consequently, results related to cognitive social capital are not reflective of potential relationships arising from the dimension of social support. Also, results in the present study cannot be compared to previous findings related to the role of social support in nutritional risk. Hence, a more comprehensive understanding of cognitive social capital will require a measurement approach that considers all dimensions of cognitive social capital.

Another limitation was the use of delta standard errors rather than bootstrapped standard errors in the mediation analysis; however, as discussed, the bias resulting from this choice is not anticipated to be significant. Next, the cross-sectional nature of this study limits its conclusions to associations rather than causation. This is especially relevant when interpreting associations between health status variables (i.e., chronic conditions, functional impairment, and oral health) and nutritional risk, as high nutritional risk is both a health outcome and a determinant of health. However, I did conduct sensitivity analyses prior to including health status variables in all models and ensured that they were not highly correlated with nutritional risk. Lastly, the inability to conclude causation is especially important when interpreting results from the mediation analysis. Indeed, there is a potential for reverse causality between nutritional risk and social capital, as an individual's nutritional status (which is part of their overall health status) inevitably influences their type and amount of social relationships.

Chapter 6 Conclusion

6.1 Overall Conclusions & Implications

Preventing malnutrition is a key step in promoting the health of community-dwelling older adults. However, the causes of malnutrition in this population are many and complex, with compounding effects that intersect the fields of nutrition and social determinants of health. In response, this project developed the Broaden framework, a new framework for conceptualizing the determinants of nutritional risk in community-dwelling older adults, which attempts to expand the discussion of nutritional risk into the broader field of social determinants of health. Based on gaps revealed from the Broaden framework, the present study investigated nutritional risk along the rural-urban continuum in community-dwelling older adults in Canada. Furthermore, in recognition that social factors play an important role in the rural-urban continuum, this project explored whether social capital — a popular concept in the social determinants of health literature — could help explain variations in nutritional risk along the rural-urban continuum.

Corroborating prior prevalence estimates,[16] 33.4% of community-dwelling older adults were found to be at high nutritional risk. This number presents a significant concern, as it threatens the health of both community-dwelling older adults and the Canadian health care system. Not only can high nutritional risk lead to a range of negative health outcomes,[9–12] but the presence of malnutrition upon hospital admission creates complex care needs that often require substantially more resources.[2] Reducing the prevalence of high nutritional risk is not a straight-forward task, as this study identified a wide range of sociodemographic and health-status variables that are key determinants of high nutritional risk, including age, education, household size, functional impairment, number of chronic conditions, and perceived oral health. Gaining a better understanding of the determinants of high nutritional risk is a useful first step in developing effective nutrition interventions for this population.

Findings from the current study suggested residents of urban cores experience the highest degree of nutritional risk, thereby challenging previous studies which have reported rural areas to be at the greatest risk.[4–6,180,181] However, differences in

measurement approaches make it difficult to truly compare findings between studies. Instead, the primary insight from the present study is that the nutritional needs of older adults living in urban cores in Canada deserves a closer investigation. Indeed, there are some Canadian studies showing an increase in food insecurity and food deserts in major urban centres,[187,189] representing two potential entry points for interventions aimed at reducing high nutritional risk in community-dwelling older adults.

Lastly, in this exploratory analysis, both types of social capital showed a relatively limited ability to explain associations between the rural-urban continuum and nutritional risk, although results related to cognitive social capital were more promising. In terms of structural social capital, the composite variable used in this study provided an assessment of formal participation. Thus, increasing formal participation may not be an ideal candidate for reducing nutritional risk in older adults; however, such a conclusion is limited by the lack of comparable studies that have specifically considered formal (as opposed to formal and informal) participation. In terms of cognitive social capital, evidence of mediation was observed but was subject to several methodological considerations. Nonetheless, the strong relationships observed between cognitive social capital and both the rural-urban continuum and nutritional risk indicate that a more in-depth examination of cognitive social capital is warranted. In particular, if the importance of cognitive social capital is confirmed in other studies, this could result in increased support for nutrition interventions that are less focused on redistributing financial resources and more grounded in enhancing individuals' feelings of social connectivity, belonging, and trust (e.g., community gardens, congregate dining, inter-generational meals, and social networking groups for sharing nutritional concerns and advice).

6.2 Future Directions

The Broaden framework provides the conceptual foundation that is essential for multidisciplinary progress on nutritional-risk in community-dwelling older adults. Future projects may use the Broaden framework to situate their studies within the complex causal pathway leading to high nutritional risk. The framework may also be used to facilitate new and exciting multidisciplinary hypotheses, revealing key gaps or entry

points for studies on determinants and interventions. Furthermore, the Broaden framework emphasizes the bidirectional relationship between nutritional risk and its determinants, highlighting the need for longitudinal studies to clarify the direction of identified associations.

Because the present study was the first to explore nutritional risk in community-dwelling older adults across the rural-urban continuum in Canada, future studies might consider whether findings change when the SAC classification is used in place of the POPCTR approach. Another option is to consider the use of a hybrid classification approach, such as one proposed by Health Quality Ontario which provides 14 categories based on a consideration of population centres, CMAs, CAs, and MIZs.[153] Furthermore, as methods to simultaneously measure the geographic and social aspects of the rural-urban continuum continue to develop, nutrition researchers can aim to incorporate such measures into their studies. In particular, emerging methods incorporating digital mapping techniques combined with qualitative interviews represent promising approaches.[88] Moreover, the close relationship observed between cognitive social capital and the rural-urban continuum in the present study suggests that cognitive social capital may be capturing some of the social aspects of the rural-urban continuum. Hence, future work might consider whether cognitive social capital can be incorporated into comprehensive measurements of the rural-urban continuum.

The present study advances current knowledge but is not sufficient to draw definitive conclusions regarding the role of social capital in explaining associations between the rural-urban continuum and nutritional risk. In particular, primary studies that use a pre-existing social capital measurement tool would be desirable. Additionally, the role of structural social capital could be reassessed using a more comprehensive measure that includes formal and informal participation as well as other dimensions of structural social capital. Finally, the role cognitive social capital could be further explored using more advanced mediation analysis techniques which incorporate the potential outcomes framework.[162]

6.3 Knowledge Translation

This project has been presented as a Three-Minute Thesis at the Dalhousie Community Health and Epidemiology Departmental Research Day. An abstract has also been accepted for the Dalhousie Department of Medicine Research Day (postponed due to COVID-19). A manuscript entitled "The Broaden framework: A context-based, multidisciplinary approach to studying malnutrition in community-dwelling older adults" has been prepared for submission to the journal *Adv Nutr*. A second publication discussing the study's main findings will also be prepared and submitted to journals such as *Am J Clin Nutr* and *J Nutr Health Aging*.

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Appendices

Appendix A. CLSA Adaption of SCREEN-II-AB

Nutritional Risk (NUR) – Tracking 1-14E/Comprehensive 1-11

The SCREEN™ assessment tool is owned by Dr. Heather Keller. Use of the SCREEN™ assessment tool was made under license from the University of Guelph. This module is a modification of the SCREEN© instrument (Abbreviated version of SCREEN II©) developed by Dr. Heather Keller (University of Guelph, Ontario, Canada).

The next group of questions ask about your weight and eating habits on a typical day.

NUR_1
NUR_GLSWT_MCQ

Compared with 6 months ago, have you gained weight, lost weight, or stayed about the same?

Gained weight	1	**CONTINUE**
Lost weight	2	**CONTINUE**
Stayed about the same	3	**SKIP TO NUR_3/ NUR_SKPMLS_MCQ**
[DO NOT READ] Don't know/No answer	8	**SKIP TO NUR_3/ NUR_SKPMLS_MCQ**
[DO NOT READ] Refused	9	**SKIP TO NUR_3/ NUR_SKPMLS_MCQ**

NUR_2
NUR_WTGL_MCQ

How much weight did you lose/gain in the past 6 months? **READ LIST, CODE ONLY ONE RESPONSE**

More than 10 pounds (More than 4.5 kilos)	1
6 to 10 pounds (2.7 to 4.5 kilos)	2
About 5 pounds (About 2.3 kilos)	3
Less than 5 pounds (Less than 2.3 kilos)	4
[DO NOT READ] Don't know/No answer	8
[DO NOT READ] Refused	9

NUR_3
NUR_SKPMLS_MCQ

In general, how often do you skip meals? **READ LIST, CODE ONLY ONE RESPONSE**

Almost every day	1
Often	2
Sometimes	3
Rarely	4
Never	5
[DO NOT READ] Don't know/No answer	8

[DO NOT READ] Refused 9

NUR_4
NUR_APPTT_MCQ

In general, how would you describe your appetite? Would you say it is…**READ LIST, CODE ONLY ONE RESPONSE**

Very good 1
Good 2
Fair 3
Poor 4
[DO NOT READ] Don't know/No answer 8
[DO NOT READ] Refused 9

NUR_5
NUR_SWLLFD_MCQ

In general, how often do you cough, choke, or have pain when swallowing food or fluid? Would you say…**READ LIST, CODE ONLY ONE RESPONSE**

Often or always 1
Sometimes 2
Rarely 3
Never 4
[DO NOT READ] Don't know/No answer 8
[DO NOT READ] Refused 9

NUR_6
NUR_FRTVEG_MCQ

In general, how many servings of fruits and vegetables do you eat in a day?

INTERVIEWER INSTRUCTION: FRUITS AND VEGETABLES CAN BE CANNED, FRESH, FROZEN, OR 100% NATURAL JUICE.
A SERVING IS…:

- ***125 ml (1/2 cup) OF VEGETABLES***
- ***125 ml (1/2 cup) OF COOKED, LEAFY VEGETABLES***
- ***250 ml (1 cup) RAW LEAFY VEGETABLES***
- ***1 FRUIT OR 125 ml (1/2 cup) OF FROZEN OR CANNED FRUIT OR 125 ml (1/2 cup) OF 100% NATURAL JUICE***

Seven or more 1
Six 2
Five 3
Four 4
Three 5
Two 6
Less than two 7

[DO NOT READ] Don't know/No answer..... 8
[DO NOT READ] Refused 9

NUR_7
NUR_DRKFLD_MCQ

How much fluid do you drink in a day? **READ LIST, CODE ONLY ONE RESPONSE**

INTERVIEWER INSTRUCTION: INCLUDES WATER, TEA, COFFEE, HERBAL DRINKS, 100% NATURAL JUICES, FRUIT FLAVOURED DRINKS, MILK, AND SOFT DRINKS BUT NOT ALCOHOL. A CUP IS 8 OUNCES or 250 ML.

Eight or more cups 1
Five to seven cups 2
Three to four cups 3
About two cups 4
Less than two cups..... 5
[DO NOT READ] Don't know/No answer..... 8
[DO NOT READ] Refused 9

NUR_8
NUR_MLSMN_MCQ

How often do you eat at least one meal each day with someone? **READ LIST, CODE ONLY ONE RESPONSE**

Almost always 1
Often..... 2
Sometimes 3
Rarely 4
Never..... 5
[DO NOT READ] Don't know/No answer..... 8
[DO NOT READ] Refused 9

NUR_9
NUR_CKMEALS_MCQ

Do you usually cook your own meals?

INTERVIEWER INSTRUCTIONS: INCLUDES FRESH, FROZEN, PRE-PACKAGED AND CANNED FOOD

Yes	1	**CONTINUE**
No.....	2	**SKIP TO NUR_11/ NUR_MLPREP_OTH_MCQ**
[DO NOT READ] Don't know/No answer.....	8	**SKIP TO NUR_11/ NUR_MLPREP_OTH_MCQ**

[DO NOT READ] Refused ..... 9 **SKIP TO NUR_11/ NUR_MLPREP_OTH_MCQ**

NUR_10
NUR_MLPREP_MCQ

Which of the following statements best describes meal preparation for you? **READ LIST, CODE ONLY ONE RESPONSE**

I enjoy cooking most of my meals 1
I sometimes find cooking a chore..... 2
I usually find cooking a chore 3
[DO NOT READ] Don't know/No answer..... 8
[DO NOT READ] Refused 9

SKIP TO NUR_12/NUR_FASTFD_NB_MCQ

NUR_11
NUR_MLPREP_OTH_MCQ

Which of the following statements best describes the meals prepared for you? **READ LIST, CODE ONLY ONE RESPONSE**

INTERVIEWER INSTRUCTION: INCLUDES FAMILY MEMBERS, FRIENDS, AND MEAL SERVICES

I'm satisfied with the quality of the food prepared by others 1
I'm not satisfied with the quality of the food prepared by others 2
[DO NOT READ] Don't know/No answer..... 8
[DO NOT READ] Refused 9

Appendix B. Shortened A-SCAT

Structural social capital

Group membership

1. In the last 12 months have you been an active member of any of the following types of groups in your community?

Work-related/ trade union	Religious group
Community association/ co-op	Credit/funeral group
Women's group	Sports group
Political group	

Coding: Member of none, 1 or 2+ groups.

If respondent is a member of a group ask:

2. In the last 12 months, did you receive from the group any emotional help, economic help, or assistance in helping you know or do things?

Social support from individuals and groups

3. In the last 12 months, have you received any help or support from any of the following, this can be emotional help, economic help, or assistance in helping you know or do things?

Family	Politicians
Neighbours	Government officials/civil service
Friends who are not neighbours	Charitable organisations/NGO
Community leaders	Religiousleaders
Other	

Coding: Support from none, 1 or 2+ sources.

Citizenship

4. In the last 12 months, have you joined together with other community members to address a problem or common issue?

5. In the last 12 months, have you talked with a local authority or governmental organisation about problems in this community?

Coding: No involvement, either joined together or talked, joined and talked.

Cognitive social capital

6. In general, can the majority of people in this community be trusted?

7. Do the majority of people in this community generally get along with each other?

8. Do you feel as though you are really a part of this community?

9. Do you think that the majority of people in this community would try to take advantage of you if they got the chance?

Coding: Low cognitive social capital = yes responses to 2 or less questions. High cognitive social capital = yes responses to 3 or 4 questions.

Source: De Silva et al, 2007.[142]

Appendix C. Example of Likert-type Items Versus a Likert Scale

Items (Likert Items)		SD	D	N	A	SA
1	Lecture method of instruction is appropriate in every situation.	1	2	3	4	5
2	Strict discipline is necessary for learning.	1	2	3	4	5
3	Team work is the culture for success.	1	2	3	4	5
4	Distributive leadership is appropriate for the school improvement.	1	2	3	4	5
5	Socioeconomic factor influences student leaning behavior.	1	2	3	4	5
Items (Likert Scale)						
6	My head teacher demonstrates high moral standard.	1	2	3	4	5
7	My head teacher communicates high expectations.	1	2	3	4	5
8	My head teacher demonstrates commitment to the goals.	1	2	3	4	5
9	My head teacher displays enthusiasm and optimism.	1	2	3	4	5
10	My head teacher uses power for personal gain.	1	2	3	4	5

SD = Strongly Disagree, D = Disagree, N = Neutral, A = Agree, SA = Strongly Agree

Source: Subedi, 2016.[217]

Appendix D. Derivation of RERI

Suppose we have an outcome (O) of interest and two exposures, A and B.

Let R_{10} be the risk of O in someone exposed to A alone
R_{01} be the risk of O in someone exposed to B alone
R_{00} be the risk of O in someone exposed to neither A nor B
R_{11} be the risk of O in someone exposed to both A and B

Then, the difference between the risk in someone exposed to both A and B compared to the risk in someone exposed to A added to the risk in someone exposed to B, accounting for the baseline risk R_{00}, is given by:

$$(R_{11} – R_{00}) – [(R_{10} – R_{00}) + (R_{01} - R_{00})] = R_{11} - R_{10} - R_{01} + R_{00}$$

Then, converting risks to relative risks, we obtain the RERI:

$$RERI = (R_{11} - R_{10} - R_{01} + R_{00}) / R_{00} = RR_{11} - RR_{10} - RR_{01} + 1$$

Source: VanderWeele & Knol, 2014 [156]

Appendix E. Potential Sources of Bias in Mediation Analyses

This project used traditional approaches to assess mediation as a form of preliminary and exploratory investigation. It is important to note that these traditional approaches have three potential sources of bias[218]:

1. Mediator-outcome confounding[218]

- In addition to controlling for confounders of the exposure-outcome relationship, mediation analysis should also control for mediator-outcome confounders.[218] In the context of my study, this means that all potential confounders of the relationship between structural/cognitive social capital and nutritional risk should be controlled for. Based on the literature review related to social capital and nutrition, potential confounders identified were years lived in the current community, age, sex, income, education, household size, and health status, all of which were controlled for in the present analysis.

2. Exposure-mediator interaction[218]

- The presence of an exposure-mediator interaction can introduce significant complexity and bias into traditional mediation techniques, leading many researchers to adopt a more modern causal inference approach in such cases.[218] However, as indicated by the results for Objective 3, there was no evidence of an interaction between the rural-urban continuum and structural/cognitive social capital in the present study.

3. Mediator-outcome confounding affected by the exposure[218]

- Bias may occur if a mediator-outcome confounder lies on the causal pathway between the exposure and the outcome.[218] In the present study, potential variables that meet this criterion were chronic conditions, functional impairment, and perceived oral health. Fortunately, Richiardi and colleagues provide the following advice: “To assess the amount of bias that traditional analyses could introduce in the presence of intermediate confounding, the strengths of the associations between the exposure and the mediator-outcome confounder L and between L and

the outcome should be evaluated. If the presence of any of these two associations is more an issue of theoretical discussion rather than a real threat to the analysis, more advanced methods to deal with intermediate confounding will produce estimates similar to standard methods."[218 (p.1517)] In my study, these two associations would be: (1) The association between rural-urban continuum and functional impairment/oral health/chronic conditions; and (2) The association between functional impairment/oral health/chronic conditions and nutritional risk. Furthermore, there was no significant association between rural-urban continuum and functional impairment/oral health/chronic conditions for the 16,473 participants included in the mediation analysis. Hence, the estimates obtained from the traditional mediation techniques used were not expected to be significantly biased.

Appendix F. Missing Case Analyses

Table A- 1. Distribution (number and percent) of sociodemographic and health status variables within groups of participants that completed/did not complete the Maintaining Contact Questionnaire (MCQ).

	Completed MCQ		Did not complete MCQ		
	n	% (column)	n	% (column)	p-value
Total	19,982	100	1,509	100	
Rural/urban classification					
Urban core	15,100	75.6	1,046	69.3	<0.001*
Secondary core	326	1.6	29	1.9	
Urban fringe	332	1.7	17	1.1	
Urban POPCTR outside CA or CMA	766	3.8	90	6.0	
Rural	2,530	12.7	217	14.4	
Rural/urban classification not available	928	4.6	110	7.3	
Age					
65-69 years	6,699	33.5	382	25.3	<0.001*
70-74 years	4,623	23.1	292	19.4	
75-79 years	5,231	26.2	433	28.7	
80-84 years	3,069	15.4	349	23.1	
85-89 years	360	1.8	53	3.5	
Sex					
Male	9,971	49.9	771	51.1	0.371
Female	10,011	50.1	738	48.9	
Ethnicity					
White	19,258	96.5	1,423	94.5	<0.001*
Non-white	705	3.5	83	5.5	
Missing	19	0.1	3	0.2	
Total Household income					
<$20,000	1,338	6.7	198	13.1	<0.001*
$20,000 to <$50,000	6,773	33.9	667	44.2	
$50,000 to <$100,000	7,014	35.1	372	24.6	
$100,000 to <$150,000	2,069	10.4	79	5.2	
≥$150,000	1,031	5.2	33	2.2	
Don’t know/no answer	903	4.5	99	6.6	
Refused	854	4.3	61	4.0	
Household Size					
One	6,362	31.8	594	39.6	<0.001*
Two	11,839	59.3	754	50.2	
Three	1,207	6.0	102	6.8	
Four	347	1.7	26	1.7	
Five or more	218	1.1	25	1.7	
Missing	9	0.05	8	0.5	
Highest level of education					
<HS graduation	2,496	12.5	356	23.6	<0.001*
HS graduation	3,664	18.3	334	22.1	
Some post-2ndary/trade certificate	2,389	12.0	215	14.2	
College/university certificate	3,945	19.7	261	17.3	
Bachelor’s degree	3,682	18.4	179	11.9	
>Bachelor’s degree	3,806	19.0	164	10.8	
Province					
Nova Scotia	1,869	9.4	133	8.8	<0.001*
New Brunswick	513	2.6	66	4.4	
Prince Edward Island	480	2.4	50	3.3	

	Completed MCQ		Did not complete MCQ		
	n	% (column)	n	% (column)	p-value
Newfoundland and Labrador	1,290	6.5	151	10.0	
Quebec	3,668	18.4	274	18.2	
Ontario	4,398	22.0	305	20.2	
Manitoba	1,794	9.0	120	8.0	
Saskatchewan	512	2.6	69	4.6	
Alberta	1,955	9.8	134	8.9	
British Columbia	3,503	17.5	207	13.7	
Number of chronic conditions					
0	1,241	6.2	79	5.2	<0.001*
1	2,945	14.7	197	13.1	
2	4,097	20.5	275	18.2	
3	3,963	19.8	251	16.6	
4	3,165	15.8	247	16.4	
5	2,111	10.6	193	12.8	
6	1,223	6.1	115	7.6	
7 or more	1,205	6.0	145	9.6	
Missing	32	0.2	7	0.5	
Functional impairment					
None	16,895	84.6	1,118	74.1	<0.001*
Mild	2,616	13.1	307	20.3	
Moderate	266	1.3	45	3.0	
Severe or total	69	0.4	21	1.4	
Inconclusive	136	0.7	18	1.2	

*p<0.01
CA = census agglomeration; CMA = census metropolitan area; HS = high school; MCQ = Maintaining Contact Questionnaire; POPCTR = population centre

Table A- 2. Distribution (number and percent) of sociodemographic and health status variables within groups of participants that had conclusive/inconclusive nutritional risk scores.

	Conclusive categorical nutritional risk score		Inconclusive categorical nutritional risk score		p-value
	n	% **(column)**	n	% **(column)**	
Total	19,641	100	341	100	
Rural/urban classification					
Urban core	14,834	75.5	266	78.0	0.514
Secondary core	322	1.6	4	1.2	
Urban fringe	324	1.6	8	2.4	
Urban POPCTR outside CA or CMA	755	3.8	11	3.2	
Rural	2,488	12.7	42	12.3	
Rural/urban classification not available	918	4.7	10	2.9	
Age					
65-69 years	6,612	33.7	87	25.5	<0.001*
70-74 years	4,563	23.2	60	17.6	
75-79 years	5,126	26.1	105	30.8	
80-84 years	2,994	15.2	75	22.0	
85-89 years	346	1.8	14	4.1	
Sex					
Male	9,788	49.8	183	53.7	0.161
Female	9,853	50.2	158	46.3	
Ethnicity					
White	18,939	96.4	319	93.6	0.014
Non-white	684	3.5	21	6.2	
Missing	18	0.1	1	0.3	
Total Household income					
<$20,000	1,310	6.7	28	8.2	<0.001*
$20,000 to <$50,000	6,652	33.9	121	35.5	
$50,000 to <$100,000	6,914	35.2	100	29.3	
$100,000 to <$150,000	2,039	10.4	30	8.8	
≥$150,000	1,021	5.2	10	2.9	
Don't know/no answer/refused	1,705	8.7	52	15.2	
Household Size					
One	6,206	31.6	156	45.8	<0.001*
Two	11,686	59.5	153	44.9	
Three	1,186	6.0	21	6.2	
Four	342	1.7	5	1.5	
Five or more	212	1.1	6	1.8	
Missing	9	0.05	0	0	
Highest level of education					
<HS graduation	2,436	12.4	60	17.6	0.02
HS graduation	3,611	18.4	53	15.5	
Some post-2ndary/trade certificate	2,338	11.9	51	15.0	
College/university certificate	3,888	19.8	57	16.7	
Bachelor's degree	3,624	18.4	58	17.0	
>Bachelor's degree	3,744	19.1	62	18.2	
Access to food outlets					
No	4,404	22.4	98	28.7	0.006*
Yes	15,237	77.6	243	71.3	
Years in current community					
Less than 5	868	4.4	17	5.0	<0.001
More than 5 but less than 10	1,359	6.9	23	6.7	
10 or more but less than 20	2,946	15.0	34	10.0	

	Conclusive categorical nutritional risk score		Inconclusive categorical nutritional risk score		p-value
	n	% **(column)**	n	% **(column)**	
20 or more but less than 30	2,610	13.3	59	17.3	
30 or more but less than 40	2,889	14.7	55	16.1	
40 or more but less than 50	3,787	19.3	53	15.5	
50 or more but less than 60	2,154	11.0	44	12.9	
60 or more but less than 70	1,404	7.2	20	5.9	
70 or more	1,570	8.0	31	9.1	
Don't know/no answer	53	0.3	5	1.5	
Refused	1	0.01	0	0	
Structural social capital					
Low	3,909	19.9	102	29.9	<0.001*
Moderate	12,639	64.4	208	61.0	
High	2,971	15.1	26	7.6	
Inconclusive due to missing responses	122	0.6	5	1.5	
Cognitive social capital					
Low	1,673	8.5	41	12.0	<0.001*
Moderate	12,569	64.0	186	54.5	
High	3,766	19.2	37	10.9	
Inconclusive due to missing responses	1,633	8.3	77	22.6	
Province					
Nova Scotia	1,843	9.4	26	7.6	0.180
New Brunswick	502	2.6	11	3.2	
Prince Edward Island	467	2.4	13	3.8	
NFL and Labrador	1,270	6.5	20	5.9	
Quebec	3,614	18.4	54	15.8	
Ontario	4,315	22.0	83	24.3	
Manitoba	1,765	9.0	29	8.5	
Saskatchewan	508	2.6	4	1.2	
Alberta	1,926	9.8	29	8.5	
British Columbia	3,431	17.5	72	21.1	
Number of chronic conditions					
0	1,220	6.2	21	6.2	0.014
1	2,900	14.8	45	13.2	
2	4,050	20.6	47	13.8	
3	3,887	19.8	76	22.3	
4	3,113	15.8	52	15.2	
5	2,064	10.5	47	13.8	
6	1,196	6.1	27	7.9	
7 or more	1,181	6.0	24	7.9	
Missing	30	0.2	2	0.6	
Functional impairment					
None	16,669	84.9	271	79.5	0.003*
Mild	2,641	13.4	57	16.7	
Moderate	147	0.8	6	1.8	
Severe or total	68	0.4	1	0.3	
Inconclusive	116	0.6	6	1.8	
Perceived oral health					
Excellent	5,767	29.4	89	26.1	<0.001*
Very good	7,682	39.1	107	31.4	
Good	4,765	24.3	104	30.5	
Fair	1,081	5.5	28	8.2	
Poor	303	1.5	4	1.2	
Don't know/ no answer	43	0.2	9	2.6	

*p<0.01

CA = census agglomeration; CMA = census metropolitan area; HS = high school; NFL = Newfoundland; POPCTR = population centre

Table A- 3. Distribution (number and percent) of sociodemographic and health status variables within groups of participants that were excluded/not excluded prior to Objective 1 due to missing covariates.

	Not excluded		Excluded		
	n	% **(column)**	n	% **(column)**	p-value
Total	19,377	100	264	100	
Rural/urban classification					
Urban core	14,629	75.5	205	77.7	0.856
Secondary core	317	1.6	5	1.9	
Urban fringe	319	1.6	5	1.9	
Urban POPCTR outside CA or CMA	744	3.8	11	4.2	
Rural	2,459	12.7	29	11.1	
Rural/urban classification not available	909	4.7	9	3.4	
Age					
65-69 years	6,548	33.8	64	24.2	<0.001
70-74 years	4,510	23.4	53	20.1	
75-79 years	5,054	26.1	72	27.3	
80-84 years	2,928	15.1	66	25	
85-89 years	337	1.7	9	3.4	
Sex					
Male	9,665	49.9	123	46.6	0.289
Female	9,712	50.1	141	53.4	
Ethnicity					
White	18,712	96.6	227	86.0	<0.001*
Non-white	665	3.4	19	7.2	
Missing	0	0.0	18	6.8	
Total Household income					
<$20,000	1,279	6.6	31	11.7	<0.001*
$20,000 to <$50,000	6,556	33.8	96	38.4	
$50,000 to <$100,000	6,834	35.3	80	30.3	
$100,000 to <$150,000	2,024	10.4	15	5.7	
≥$150,000	1,015	5.2	6	2.3	
Don't know/no answer/refused	1,669	8.6	36	13.6	
Household Size					
One	6,102	31.5	104	39.4	<0.001*
Two	11,562	59.7	124	47.0	
Three	1,168	6.0	18	6.8	
Four	335	1.7	7	2.6	
Five or more	210	1.1	2	0.8	
Missing	0	0.0	9	3.4	
Highest level of education					
<HS graduation	2,402	12.4	34	12.9	0.921
HS graduation	3,566	18.4	45	17.0	
Some post-2ndary/trade certificate	2,311	11.9	27	10.2	
College/university certificate	3,835	19.8	53	20.1	
Bachelor's degree	3,574	18.4	50	18.9	
>Bachelor's degree	3,689	19.0	55	20.8	
Access to food outlets					
No	4,314	22.3	90	34.1	<0.001*
Yes	15,063	77.7	174	65.9	
Years in current community					
Less than 5	858	4.4	10	3.8	<0.001*
More than 5 but less than 10	1,345	6.9	14	5.3	
10 or more but less than 20	2,912	15.0	34	12.9	

	Not excluded		Excluded		
	n	% **(column)**	n	% **(column)**	p-value
20 or more but less than 30	2,578	13.3	32	12.1	
30 or more but less than 40	2,861	14.8	28	10.6	
40 or more but less than 50	3,749	19.4	38	14.4	
50 or more but less than 60	2,123	11.0	31	11.7	
60 or more but less than 70	1,395	7.2	9	3.4	
70 or more	1,556	8.0	14	5.3	
Don't know/no answer	0	0.0	53	20.1	
Refused	0	0.0	1	0.4	
Structural social capital					
Low	1,640	8.5	33	12.5	<0.001*
Moderate	12,422	64.1	147	55.7	
High	3,730	19.3	36	13.6	
Inconclusive due to missing responses	1,585	8.2	48	18.2	
Cognitive social capital					
Low	3,850	19.9	59	22.4	<0.001*
Moderate	12,483	64.4	156	59.1	
High	2,939	15.2	32	12.1	
Inconclusive due to missing responses	105	0.5	17	6.4	
Province					
Nova Scotia	1,824	9.4	19	7.2	0.259
New Brunswick	497	2.6	5	1.9	
Prince Edward Island	460	2.6	7	2.6	
NFL and Labrador	1,254	6.5	16	6.1	
Quebec	3,574	18.4	40	15.2	
Ontario	4,259	22.0	56	21.2	
Manitoba	1,739	9.0	26	9.8	
Saskatchewan	499	2.6	9	3.4	
Alberta	1,887	9.7	39	14.8	
British Columbia	3,384	17.5	47	17.8	
Number of chronic conditions					
0	1,206	6.2	14	5.3	<0.001*
1	2,872	14.8	28	10.6	
2	4,012	20.7	38	14.4	
3	3,846	19.8	41	15.5	
4	3,070	15.8	43	16.3	
5	2,037	10.5	27	10.2	
6	1,180	6.1	16	6.1	
7 or more	1,154	6.0	27	10.2	
Missing	0	0.0	30	11.4	
Functional impairment					
None	16,563	85.5	106	40.1	<0.001*
Mild	2,603	13.4	38	14.4	
Moderate	143	0.7	4	1.5	
Severe or total	68	0.3	0	0.0	
Inconclusive	0	0.0	116	43.9	
Perceived oral health					
Excellent	5,708	29.5	59	22.4	<0.001*
Very good	7,613	39.3	69	26.1	
Good	4,702	24.3	63	23.9	
Fair	1,056	5.4	25	9.5	
Poor	298	1.5	5	1.9	
Don't know/ no answer	0	0.0	43	16.3	

*p<0.01

CA = census agglomeration; CMA = census metropolitan area; HS = high school; NFL = Newfoundland; POPCTR = population centre

Table A- 4. Distribution (number and percent) of sociodemographic and health status variables within groups of participants that were excluded/not excluded prior to Objective 3 due to inconclusive information for the rural-urban continuum or structural/cognitive social capital.

	Not excluded		Excluded		
	n	% (column)	n	% (column)	p-value
Total	16,857	100	2,520	100	
Rural/urban classification					
Urban core	13,284	78.8	1,345	53.4	<0.001*
Secondary core	289	1.7	28	1.1	
Urban fringe	299	1.8	20	0.8	
Urban POPCTR outside CA or CMA	714	4.2	30	1.2	
Rural	2,271	13.5	188	7.5	
Rural/urban classification not available	0	0.0	909	36.1	
Age					
65-69 years	5,737	34.0	811	32.2	0.002*
70-74 years	3,962	23.5	548	21.8	
75-79 years	4,373	25.9	681	27.0	
80-84 years	2,507	14.9	421	16.7	
85-89 years	278	1.6	59	2.3	
Sex					
Male	8,502	50.4	1,163	46.2	<0.001*
Female	8,355	49.6	1,357	53.8	
Ethnicity					
White	16,309	96.8	2,403	95.4	<0.001*
Non-white	548	3.2	117	4.6	
Total Household income					
<$20,000	1,030	6.1	249	9.9	<0.001*
$20,000 to <$50,000	5,614	33.3	942	37.4	
$50,000 to <$100,000	6,068	36.0	766	30.4	
$100,000 to <$150,000	1,829	10.8	195	7.7	
≥$150,000	901	5.3	114	4.5	
Don't know/no answer/refused	1,415	8.4	254	10.1	
Household Size					
One	5,148	30.5	954	37.9	<0.001*
Two	10,200	60.5	1,362	54.0	
Three	1,030	6.1	138	5.5	
Four	298	1.8	37	1.5	
Five or more	181	1.1	29	1.2	
Highest level of education					
<HS graduation	1,990	11.8	412	16.4	<0.001*
HS graduation	3,117	18.5	449	17.8	
Some post-2ndary/trade certificate	2,001	11.9	310	12.3	
College/university certificate	3,336	19.8	499	19.8	
Bachelor's degree	3,146	18.7	428	17.0	
>Bachelor's degree	3,267	19.4	422	16.8	
Access to food outlets					
No	3,597	21.3	717	28.4	<0.001*
Yes	13,260	78.7	1,803	71.6	
Years in current community					
Less than 5	644	3.8	214	8.5	<0.001*
More than 5 but less than 10	1,157	6.9	188	7.5	
10 or more but less than 20	2,504	14.8	408	16.2	

	Not excluded		Excluded		
	n	% (column)	n	% (column)	p-value
20 or more but less than 30	2,268	13.4	310	12.3	
30 or more but less than 40	2,538	15.1	323	12.8	
40 or more but less than 50	3,342	19.8	407	16.2	
50 or more but less than 60	1,851	11.0	272	10.8	
60 or more but less than 70	1,212	7.2	183	7.3	
70 or more	1,341	8.0	215	8.5	
Structural social capital					
Low	3,255	19.3	595	23.6	<0.001
Moderate	10,972	65.1	1,511	60.0	
High	2,630	15.6	309	12.3	
Inconclusive due to missing responses	0	0.0	105	4.2	
Cognitive social capital					
Low	1,546	9.2	94	3.7	<0.001*
Moderate	11,796	70.0	626	24.8	
High	3,515	20.8	215	8.5	
Inconclusive due to missing responses	0	0.0	1,585	62.9	
Province					
Nova Scotia	1,611	9.6	213	8.4	<0.001*
New Brunswick	400	2.4	97	3.8	
Prince Edward Island	410	2.4	50	2.0	
Newfoundland and Labrador	1,004	6.0	250	9.9	
Quebec	3,226	19.1	348	13.8	
Ontario	3,848	22.8	411	16.3	
Manitoba	1,453	8.6	286	11.4	
Saskatchewan	336	2.0	163	6.5	
Alberta	1,582	9.4	305	12.1	
British Columbia	2,987	17.7	397	15.8	
Number of chronic conditions					
0	1,065	6.3	141	5.6	<0.001*
1	2,567	15.2	305	12.1	
2	3,480	20.6	532	21.1	
3	3,362	19.9	484	19.2	
4	2,683	15.9	387	15.4	
5	1,758	10.4	279	11.1	
6	1,002	5.9	178	7.1	
7 or more	940	5.6	214	8.5	
Functional impairment					<0.001*
None	14,506	86.0	2,057	81.6	
Mild	2,187	13.0	416	16.5	
Moderate	112	0.6	31	1.2	
Severe or total	52	0.3	16	0.6	
Perceived oral health					
Excellent	5,099	30.2	609	24.2	<0.001*
Very good	6,654	39.5	959	38.1	
Good	3,988	23.7	714	28.3	
Fair	883	5.2	173	8.9	
Poor	233	1.4	65	2.6	

*p<0.01

CA = census agglomeration; CMA = census metropolitan area; HS = high school; POPCTR = population centre

Table A- 5. Distribution (number and percent) of sociodemographic and health status variables within groups of participants that were excluded/not excluded prior to mediation analysis due to missing continuous nutritional risk score.

	Not excluded		Excluded		
	n	% (column)	n	% (column)	p-value
Total	16,473	100	384	100	
Rural/urban classification					
Urban core	12,982	78.8	302	78.7	0.201
Secondary core	285	1.7	4	1.0	
Urban fringe	296	1.8	3	0.8	
Urban POPCTR outside CA or CMA	701	4.3	13	3.4	
Rural	2,209	13.4	62	16.2	
Age					
65-69 years	5,639	34.2	98	25.5	<0.001*
70-74 years	3,884	23.6	78	20.3	
75-79 years	4,249	25.8	124	32.3	
80-84 years	2,428	14.7	79	20.6	
85-89 years	273	1.7	5	1.3	
Sex					0.973
Male	8,308	50.4	194	50.5	
Female	8,165	49.6	190	49.5	
Ethnicity					
White	15,940	96.8	369	96.1	0.464
Non-white	533	3.2	15	3.9	
Total Household income					
<$20,000	986	6.0	44	11.5	<0.001*
$20,000 to <$50,000	5,482	33.3	132	34.4	
$50,000 to <$100,000	5,955	36.2	113	29.4	
$100,000 to <$150,000	1,792	10.9	37	9.6	
≥$150,000	884	5.4	17	4.4	
Don't know/no answer/refused	1,374	8.3	41	10.7	
Household Size					
One	4,988	30.3	160	41.7	<0.001*
Two	10,013	60.8	187	48.7	
Three	1,004	6.1	26	6.8	
Four	293	1.8	5	1.3	
Five or more	175	1.1	6	1.6	
Highest level of education					
<HS graduation	1,921	11.7	69	18.0	0.001
HS graduation	3,039	18.5	78	20.3	
Some post-2ndary/trade certificate	1,956	11.9	45	11.7	
College/university certificate	3,281	19.9	55	14.3	
Bachelor's degree	3,084	18.7	62	16.1	
>Bachelor's degree	3,192	19.4	75	19.5	
Access to food outlets					
No	3,511	21.3	86	22.4	0.609
Yes	12,962	78.7	298	77.6	
Years in current community					
Less than 5	639	3.9	5	1.3	0.075
More than 5 but less than 10	1,120	6.8	37	9.6	
10 or more but less than 20	2,445	14.8	59	15.4	
20 or more but less than 30	2,218	13.5	50	13.0	
30 or more but less than 40	2,482	15.1	56	14.5	
40 or more but less than 50	3,274	19.9	68	17.8	

	Not excluded		Excluded		
	n	% (column)	n	% (column)	p-value
50 or more but less than 60	1,811	11.0	40	10.4	
60 or more but less than 70	1,178	7.2	34	8.8	
70 or more	1,306	7.9	35	9.1	
Structural social capital					
Low	3,151	19.1	104	27.1	<0.001
Moderate	10,741	65.2	231	60.2	
High	2,581	15.7	49	12.8	
Cognitive social capital					
Low	1,493	9.1	53	13.8	0.003
Moderate	11,531	70.0	265	69.0	
High	3,449	20.9	66	17.2	
Province					
Nova Scotia	1,573	9.6	38	9.9	0.330
New Brunswick	391	2.4	9	2.3	
Prince Edward Island	399	2.4	11	2.9	
Newfoundland and Labrador	988	6.0	16	4.2	
Quebec	3,162	19.2	64	16.7	
Ontario	3,746	22.7	102	26.6	
Manitoba	1,422	8.6	31	8.1	
Saskatchewan	330	2.0	6	1.6	
Alberta	1,554	9.4	28	7.3	
British Columbia	2,908	17.7	79	20.6	
Number of chronic conditions					
0	1,045	6.3	20	5.2	0.586
1	2,507	15.2	60	15.6	
2	3,411	20.7	69	18.0	
3	3,289	20.0	73	19.0	
4	2,620	15.9	63	16.4	
5	1,708	10.4	50	13.0	
6	978	5.9	24	6.2	
7 or more	915	5.6	25	6.5	
Functional impairment					
None	14,209	86.3	297	77.3	<0.001*
Mild	2,111	12.8	76	19.8	
Moderate	107	0.6	5	1.3	
Severe or total	46	0.3	6	1.6	
Perceived oral health					
Excellent	4,984	30.3	115	30.0	<0.001*
Very good	6,529	39.6	125	32.6	
Good	3,888	23.6	100	26.0	
Fair	845	5.1	38	9.9	
Poor	227	1.4	6	1.6	

*p<0.01

CA = census agglomeration; CMA = census metropolitan area; HS = high school; POPCTR = population centre

Appendix G. Supplementary Results for Objective 1

Table A- 6. Distribution (number and percent) of sociodemographic and health status variables within groups of participants at high/not at high nutritional risk.

	High nutritional risk		Not high nutritional risk		
	Unweighted n	Weighted % (column)	Unweighted n	Weighted % (column)	p-value[1]
Total	6,791	100	12,586	100	
Rural-urban continuum					
Urban core	5,266	67.3	9,363	61.7	<0.0001*
Secondary core	104	1.7	213	2.2	
Urban fringe	108	1.5	211	1.9	
Urban POPCTR outside CA or CMA	264	6.5	480	6	
Rural	760	17.8	1,699	22.8	
Rural/urban classification not available	289	5.1	620	5.5	
Age					
65-69 years	2,204	34.1	4,344	38.6	0.0028*
70-74 years	1,545	25.7	2,965	24.6	
75-79 years	1,804	24.1	3,250	22.8	
80-84 years	1,116	14.4	1,812	12.6	
85-89 years	122	1.7	215	1.5	
Sex					
Male	3,090	41.1	6,575	49.0	<0.0001*
Female	3,701	58.9	6,011	51.0	
Ethnicity					
White	6,526	3.5	12,186	2.7	0.0861
Non-white	265	96.5	400	97.3	
Total Household income					
<$20,000	698	9.8	581	4.6	<0.0001*
$20,000 to <$50,000	2,623	40.6	3,933	33.3	
$50,000 to <$100,000	2,065	30.6	4,769	38.7	
$100,000 to <$150,000	491	6.8	1,533	10.8	
≥$150,000	262	3.3	753	5.1	
Don't know/no answer/refused	652	8.9	1,017	7.4	
Household Size					
One	3,024	39.3	3,078	20.7	<0.0001*
Two	3,145	51.3	8,417	70.3	
Three	421	6.4	747	6.2	
Four	131	2.0	204	1.6	
Five or more	70	1.0	140	1.2	
Highest level of education					
<HS graduation	1,028	17.4	1,374	12.7	<0.0001*
HS graduation	1,353	21.6	2,213	18.1	
Some post-2ndary/trade certificate	879	12.8	1,432	12.3	
College/university certificate	1,354	20.2	2,481	19.3	
Bachelor's degree	1,153	16.1	2,421	19.6	
>Bachelor's degree	1,024	11.9	2,665	18.1	
Access to food outlets					
No	1,502	26.8	2,812	27.1	0.7729
Yes	5,289	73.2	9,774	72.9	
Years in current community					
Less than 5	324	5.2	534	4.1	0.0038*
More than 5 but less than 10	512	7.8	833	7.6	

	High nutritional risk		Not high nutritional risk		
	Unweighted n	Weighted % **(column)**	Unweighted n	Weighted % **(column)**	p-value[1]
10 or more but less than 20	1,058	16.6	1,854	15.8	
20 or more but less than 30	886	12.3	1,692	13.4	
30 or more but less than 40	958	13.7	1,903	14.8	
40 or more but less than 50	1,211	17.8	2,538	19.0	
50 or more but less than 60	735	9.5	1,388	11.2	
60 or more but less than 70	523	7.8	872	6.8	
70 or more	584	9.3	972	7.5	
Structural social capital					
Low	1,614	26.5	2,236	20.8	<0.0001*
Moderate	4,280	61.8	8,203	63.9	
High	864	11.5	2,075	14.6	
Inconclusive due to missing responses	33	0.3	72	0.6	
Cognitive social capital					
Low	832	13.2	808	6.8	<0.0001*
Moderate	4,250	61.5	8,172	64.6	
High	1,012	14.9	2,718	22.0	
Inconclusive due to missing responses	697	10.4	888	6.6	
Province					
Nova Scotia	617	3.0	1,207	3.2	0.1416
New Brunswick	165	2.3	332	2.5	
Prince Edward Island	150	0.4	310	0.5	
Newfoundland and Labrador	360	1.3	894	1.7	
Quebec	1,321	25.9	2,253	24.7	
Ontario	1,432	38.1	2,827	38.9	
Manitoba	686	4.0	1,053	3.1	
Saskatchewan	170	3.0	329	3.0	
Alberta	712	8.2	1,175	8.2	
British Columbia	1,178	13.8	2,206	14.1	
Number of chronic conditions					
0	278	3.9	928	8.4	<0.0001*
1	744	11.5	2,128	17.4	
2	1,205	17.8	2,807	22.3	
3	1,307	18.8	2,539	20.0	
4	1,157	16.8	1,913	14.9	
5	865	13.0	1,172	9.0	
6	575	8.7	605	4.4	
7 or more	660	9.4	494	3.7	
Functional impairment					
None	5,381	78.4	11,182	89.3	<0.0001*
Mild	1,274	19.5	1,329	10.3	
Moderate	94	1.2	49	0.3	
Severe or total	42	1.0	26	0.2	
Perceived oral health					
Excellent	1,521	21.2	4,187	33.1	<0.0001*
Very good	2,494	36.0	5,119	40.1	
Good	2,015	31.0	2,687	21.6	
Fair	577	9.0	479	4.3	
Poor	184	2.9	114	1.0	

*p<0.01

CA = census agglomeration; CMA = census metropolitan area; HS = high school; POPCTR = population centre

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