Investigating socioeconomic inequities in diet quality among adults in Canada using an intersectional approach

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Author’s Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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Abstract

It is well-acknowledged that diet quality differs across socioeconomic position (SEP). However, it is unclear how SEP dimensions intersect to shape diet quality. My dissertation uses an intersectional approach to identify differences in diet quality across SEP dimensions and contexts. The primary objectives of my dissertation research were: (1) to identify individual/household SEP intersections that best predicted lower and higher diet quality among a population-based sample of adults in Canada; (2) to assess whether four dimensions of neighbourhood deprivation were independently and/or jointly associated with diet quality among a nationally representative sample of adults in Canada; and (3) to compare associations between three SEP indicators (educational attainment, perceived income adequacy, household food insecurity) and diet quality between adults in Canada and the United States. In a conditional random forest analysis, I identify educational attainment and Indigenous identity and race/ethnicity as the most important intersectional predictor of diet quality among adults in Canada. By examining four dimensions of neighbourhood deprivation, I find significant interactions that suggest associations between living in a neighbourhood with less material resources and lower HEI-2015 scores was stronger in areas with a smaller proportion of recent immigrants/visible minorities and non-working individuals. In a cross-country comparison, I find that associations between SEP (educational attainment, perceived income adequacy, and household food insecurity) and diet quality did not differ between Canada and

the United States. Overall, this dissertation demonstrates how an intersectional approach to quantitative health research can be used to draw attention to the complex and context-dependent nature of inequities in diet quality.

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Table of Contents

List of Figures

List of Tables

List of Abbreviations

ASA24: Automated Self-Administered 24-hour Dietary Assessment Tool

CAN-Marg: Canadian Marginalization Index

CCHS-N: Canadian Community Health Survey – Nutrition

CEGEP: Collège d'enseignement général et professionnel

CART: Classification and Regression Tree

CHAID: Chi-square automatic interaction detection

CI: Confidence interval

CIT: Conditional inference tree

CRF: Conditional random forests

HEI: Healthy Eating Index

IFPS: International Food Policy Study

MAIHDA: multilevel analysis of individual heterogeneity and discriminatory accuracy

MLR: Multivariable linear regression

SE: Standard error

SEP: Socioeconomic position

Chapter 1: Introduction

1.1 Overview and scope

Poor diet quality increases the risk of adverse health outcomes, including cardiovascular diseases, hypertension, type 2 diabetes mellitus, some cancers, and poor mental health (1,2). Despite considerable efforts to improve dietary patterns among the general population, inequities in diet quality (i.e., differences in diet quality that are unfair and unjust) persist in North America (3–5). These inequities in diet quality vary across socioeconomic position (SEP), which can be assessed using multiple indicators including income, educational attainment, and food insecurity, among others (4,6–9). Although it is well-acknowledged that diet quality differs by SEP (6,10,11), it is unclear how individual SEP dimensions, such as race/ethnicity and educational attainment, intersect to mutually shape diet quality (8).

To examine how diet quality may differ across SEP intersections, researchers can adopt an intersectional approach to nutrition research. Intersectionality is a framework that posits social location, based on multiple social identities and positions individuals occupy, is influenced by multiple dimensions of power that jointly shape human experiences (12–14). Since SEP is a component of an individual's social location, and SEP has multiple dimensions (15–17), using an intersectionality framework can support researchers in identifying how inequities in diet quality differ across SEP intersections. Moreover, considering place as an

element of intersectional inequities (18–20) can help identify how dimensions of power and privilege are conditional on social and economic contexts (14,18).

In this dissertation, *intersect* refers to SEP dimensions meeting and *intersection* refers to the point where SEP dimensions intersect. For example, a non-exhaustive list of socioeconomic intersections defined by gender and race include, Black men, Black women, Black gender-diverse individuals, White men, White women, White gender-diverse individuals, etc. Conversely, *interact* is used to refer to SEP dimensions jointly influencing one another, and *interaction* refers to the interdependent relationships that arise from SEP dimensions interacting. An interaction between gender and race could describe how associations between gender and diet quality differ depending on race—for instance, if associations between gender and diet quality are stronger among individuals who are White compared to Black.

Precisely identifying inequities in diet quality relies on considering how multiple social locations and positions jointly shape diet-related advantages and disadvantages. Therefore, this dissertation seeks to identify (1) individual/household SEP intersections that best predict diet quality (2) dimensions of neighbourhood deprivation that are independently and jointly associated with diet quality, and (3) cross-country differences in associations between three key SEP indicators (educational attainment, perceived income adequacy, household food insecurity) and diet quality. The overall goal of this dissertation is to broaden understanding of

how diet quality could be improved at the population level by attending to differences in diet quality across the individual, household, neighbourhood, and national levels using an intersectional approach.

1.2 Dissertation organization

Chapter 2 begins with an overview of the literature with respect to key concepts: social inequities, social determinants of health, SEP, diet quality, and intersectionality. A significant portion of this chapter is dedicated to describing indicators of SEP that are associated with diet quality, including those at the individual/household, neighbourhood, and country levels. In this section, I also detail methodologic approaches and analytic techniques relevant to research that investigates dietary inequities using an intersectional approach. This chapter concludes with a summary and rationale for my dissertation. **Chapter 3** outlines the objectives of the three studies included in this dissertation.

Chapters 4 to **6** present the manuscripts of the three studies that have been submitted for publication. **Chapter 4** presents an analysis of SEP intersections that best predict diet quality among a population-based sample of adults in Canada. **Chapter 5** presents an analysis of individual and joint associations between dimensions of neighbourhood deprivation and diet quality among a nationally representative sample of adults in Canada. **Chapter 6** presents a cross-country analysis of associations between three key SEP indicators (educational attainment,

perceived income adequacy, household food insecurity) and diet quality among a population-based sample of adults in Canada and the United States. I conclude my dissertation with **Chapter 7**, where I synthesize my overall findings, contributions of my dissertation to the literature, strengths and limitations, and implications for public health research and policy.

Chapter 2: Literature Review

Social inequities contribute to a wide range of health-related inequities, including meaningful differences in diet quality. Inequities in diet quality across dimensions of socioeconomic position (SEP) are shaped by social processes rooted in the unequal distribution of power, money, and resources (4,21,22). Despite the knowledge that multiple dimensions of SEP are associated with diet quality (4,6,11,22), much remains unknown about how multiple socioeconomic processes might jointly influence diet quality (8). To better understand the role and contributions of various socioeconomic processes in shaping diet quality, researchers can use an intersectional approach to assess differences in diet quality across multiple SEP dimensions. By highlighting differences in diet quality across SEP subgroups and contexts, an intersectional approach to health research can enrich our understanding of how to equitably improve population-level diet quality.

In this literature review, I describe the potential value of an intersectional approach to investigating inequities in diet quality and describe quantitative approaches to conducting intersectionality-informed analyses of diet quality across multiple SEP dimensions. While agency and sociocultural factors undoubtedly influence diet quality, dietary choices are structured by the conditions in which individuals live (23,24). Therefore, my dissertation focuses on the broader social and economic determinants of diet quality. To this end, it is critical to first establish a

fundamental understanding of social inequities and diet quality, and how social and dietary inequities are connected.

2.1 An overview of social and health-related inequities

Social inequities—the unequal distribution of power, money, and resources across social and economic groups such as those based on education and income—shape several health-related outcomes (25–27). One framework commonly used to explain the link between social inequities and health is the Commission on the Social Determinants of Health (CSDH) framework (28). The CSHD framework illustrates how socioeconomic and political factors generate and maintain health inequities by shaping differential exposure to health-compromising and health-promoting conditions across SEP (28). In the following sections, I expand on the CSDH framework and its relevance to explaining the connection between social and health-related inequities.

2.1.1 Structural determinants of health-related inequities

The CSDH framework posits that health inequities are produced and reinforced by structural determinants—socioeconomic and political factors that generate and maintain the unequal distribution of power, privilege, and resources across societies (28). Since structural determinants can only be altered through social, economic, and political processes, individuals have little or no direct control

over them (29). Structural determinants of health inequities, such as social policies, societal norms, labour market conditions, and educational systems reflect the broader *socioeconomic and political* contexts and influence patterns of social stratification (28).

Within societies, *social stratification*—the unequal distributions of valued resources across social classes (30)—drive unequal health opportunities across SEP (23). While there are many articulations of social class (31–35), the term typically refers to the structural location of individuals, defined in the context of social, economic, and political relationships (36). Since the mechanisms contributing to health differentials across social strata are often difficult to observe directly, researchers can use indicators of SEP to study and identify social and economic mechanisms underlying health inequities (28).

SEP is a multi-dimensional concept, meaning that it can be assessed based on a wide range of resource- and prestige-based indicators (28,36). Resource-based indicators refer to material and social resources and assets, including indicators of income, wealth, and educational credentials (36). Other resource-based indicators describe inadequate resources, such as poverty and deprivation (36). Prestige-based indicators reflect the rank or status of individuals in a social hierarchy based on access to and consumption of goods, services, and knowledge (36).

There are several SEP indicators which capture underlying socioeconomic dimensions that can contribute to health-related inequities (17,21). Three SEP indicators frequently studied in the health literature relate to educational attainment, occupation, and income (28). Briefly, educational attainment, often measured by an individual's or household's highest level of education, can reflect differential knowledge and skills, but it can also reflect power, prestige, social networks, and material resources (4,21,28,37–40). Indicators of occupational level or employment status can indicate status and power related to individuals' paid work (17,28). Income reflects access to financial resources, including gross income, and influences the ability to afford basic necessities, including food and housing, as well as opportunities to pursue socioeconomic and health-related activities such as education and recreation (17,36). These three indicators of SEP can capture other socioeconomic conditions that shape health at the individual, household, and neighbourhood levels. These three SEP indicators will be described in greater detail in subsequent sections.

2.1.2 *Social (intermediary) determinants of health*

Operating through unfair and unjust processes, structural determinants shape access to the intermediary determinants of health, also known as the social determinants of health (25,41). *Social determinants of health* are defined as the conditions in which individuals live, grow, work, play, and age (28). Unlike structural

determinants of health inequities which are focused on upstream factors, social determinants of health include intermediary factors that influence individual behaviour (29,41). Key social determinants of health include (1) material circumstances, such as household income and educational attainment; (2) psychosocial circumstances, for example, the psychosocial stress experienced by individuals based on their perceived position in society; (3) behavioural and/or biological factors, like dietary patterns and physical activity; and (4) aspects of the health system itself including health service delivery and health promotion efforts (28).

2.1.3 Individual and sociocultural contributions to health

Before concluding this section, it is important to highlight that structural and agentic explanations of health are not mutually exclusive (23,42), as they can simultaneously shape health practices and outcomes (23,42). For example, structural racism can disproportionately expose some Indigenous and racialized communities to poor food environments which may shape their dietary patterns (43). At the same time, traditional and cultural food customs can shape an individual's food preferences and choices (44). Given that my dissertation focuses on *inequities*, I focus on structural factors that contribute to unjust differences; however, I also acknowledge the role of factors at the individual level, such as food preferences, health conditions, emotional states, among others, in shaping dietary patterns.

2.2 An overview of approaches to studying dietary patterns

In recent decades, there has been increasing interest in examining overall *dietary patterns*, rather than exclusively studying single nutrients, foods, or food groups. Studying overall dietary patterns has emerged as an important field of research for three primary reasons (45). The first reason to study overall dietary patterns is related to the recognition that relationships between dietary intake and health are influenced by complex interactions between dietary components, some of which are synergistic, while others are antagonistic (46,47). The second reason is related to the reality that people typically consume meals and snacks consisting of a variety of foods and nutrients, rather than isolated nutrients or foods (48). The third reason is the recognition that changes in the intake of one dietary component are usually accompanied by compensatory changes in other dietary components (47). For these three reasons, it is valuable to assess overall dietary patterns. There are various approaches to characterizing overall dietary patterns. The two most common approaches to studying dietary patterns can be broadly categorized as: (1) data-driven (or *a posteriori*) and (2) hypothesis-driven (or *a priori*) approaches (49).

Studying dietary patterns using a *data-driven approach* often involves identifying dietary patterns within a particular population (45). Studies using a data-driven approach to assessing dietary patterns often use techniques such as principal component and factor analyses to identify underlying interrelationships between

dietary components. Researchers using a data-driven approach to assess dietary patterns have also employed cluster analyses to identify dietary clusters, which distinguish people with similar and dissimilar dietary intakes (50). While dietary patterns identified using data-driven methods will never be identical across studies because of unique variability within any study sample, there are certain commonalities frequently found in derived dietary patterns, including those that are more “prudent” or healthy and others that are more “Western” or less healthy (45).

Contrasting data-driven approaches are *hypothesis-driven approaches* to assessing dietary patterns. Researchers using a hypothesis-driven approach to assess dietary patterns often use numeric indicators, such as scores and indices to assess overall diet quality. These numeric indicators are usually based on healthy eating principles, guidelines, and recommendations known to be associated with positive or negative health outcomes (49,51). Since most diet quality indices focus on select healthy eating principles, they do not capture all dietary components that could be important to health (52). Therefore, it is important for researchers to select the most suitable diet quality index for their specific study. In North America, the Healthy Eating Index (HEI), which is regularly updated based on the Dietary Guidelines for Americans, is the most widely used diet quality index in population-based studies (53). Additionally, the Healthy Eating Food Index 2019 (HEFI-2019) (54), which was developed to measure dietary alignment to the recommendations in

the 2019 Canada's Food Guide, is increasingly used to assess diet quality in Canada.

2.3 An overview of inequities in diet quality across SEP and contexts

Public health and epidemiological research demonstrate that variations in diet quality are observable across multiple SEP indicators at the individual, household, and area levels (22). In this section, I provide an overview of SEP indicators associated with diet quality across these three levels of influence. Although I summarize the literature as if a consensus exists, broader socioeconomic and political contexts contribute to variability in associations between SEP indicators and dietary patterns. Since associations between SEP indicators and diet quality differ considerably across countries with varying contexts, I will focus on the SEP indicators most relevant to the Canadian context based on evidence from Canada and other comparable high-income countries. It is also important to note that diet quality is shaped by a complex interplay of factors—some driven by power dynamics and structural conditions, while others are more agentic in nature, such as physiological needs, psychological states, and food preferences (24).

2.3.1 Inequities in diet quality across individuals and households

Diet quality differs across several SEP indicators at the individual level in ways that are neither coincidental nor inevitable (55). At the individual level, diet

quality differs across age, sex/gender, race/ethnicity, and immigration status (6,56,57). In Australia, Europe, and North America, older adults and females/women generally have higher diet quality than younger adults and males/men (6,11). These differences in diet quality are shaped by the socioeconomic conditions to which individuals are exposed to depending on their age and gender, such as age-related norms and gender roles (55). Additionally, diet quality differs meaningfully between racial/ethnic groups, with evidence from Canada indicating that overall diet quality is typically higher among individuals who identify as Asian (including East Asian, Middle Eastern, and South Asian) compared to individuals who identify as Black, Indigenous, or White (56). Furthermore, evidence suggests that immigration and time since immigration are associated with diet quality because the longer immigrants stay in a host country, the more likely they are to adopt the dietary patterns of people in their host country (57–59). These SEP indicators (i.e., age, gender, race/ethnicity, immigration status) are sometimes overlooked as sources of inequities, as differences in diet quality across these dimensions can be viewed as biologically or culturally determined. However, these dietary patterns can also relate to unequal or unfair treatment, such as differential resource distribution and discrimination.

Among high-income countries in North America and Europe, studies frequently report a gradient in dietary outcomes, where higher educational attainment at the individual and household levels has been associated with higher

diet quality among adults (4,6,8,11,60–62). Most studies assessing educational gradients in dietary patterns have largely focused on vegetable and fruit intake (61). However, more recent studies have also found evidence of an educational gradient in the consumption of several food groups and nutrients (11,62), as well as overall diet quality (4,6,8,60). Since higher educational attainment is associated with differential knowledge, skills, power, prestige, and material resources (4,21,37–40), educational attainment can *directly* influence dietary practices by imparting knowledge about health-promoting practices and *indirectly* by influencing social networks, cultural assets, employment prospects, and income trajectories, among many other socioeconomic opportunities (21,38,40). In a study by Monsivais et al. (2011), food cost did not significantly mediate associations between educational attainment and diet quality (63), suggesting that the influence of educational attainment on diet quality extends beyond affordability to encompass factors such as nutrition knowledge, socialization, and learned effectiveness (10,21,37,40,64–66).

Independent of educational attainment, higher occupational levels have been associated with more favourable dietary intake compared to lower occupational levels (21), particularly in the United Kingdom where SEP is often assessed based on an individual's occupation (17). For historical and cultural reasons, occupation is less commonly studied in North America where occupation-based data are less consistently collected and ranked (21). In North America, employment status is more typically assessed than occupation but associations between employment status

and diet quality are far less conclusive. Nevertheless, the nature of employment and work itself, including shift work and job strain, have been shown to shape individuals' dietary practices (21,67,68).

Among adults, studies generally report higher diet quality at higher income levels (4,6,8,11). For example, studies from the United States and Canada have found that diet quality (based on the Healthy Eating Index) was generally higher at higher income levels, and at higher perceived income adequacy levels among adults (4,6,8). While objective indicators of income offer valuable insight into material mechanisms that shape health-related opportunities (69–73), there are other more subjective indicators of income that capture overlapping yet distinct socioeconomic mechanisms that can contribute to differences in diet quality across income groups. Income can be measured at multiple levels, including the individual, household, and area levels. At the individual and household levels, objective income can be obtained by using self-report questionnaire items or extracted from income tax files, and can be assessed as absolute, weighted, or adjusted values (74). Unlike objective income measures which often reflect annual household income, more subjective measures such as perceived income adequacy reflect objective income to some extent but allow individuals to take into account personal needs, accumulated wealth or debt, desires, priorities, and standards of comparison when indicating subjective feelings about their financial well-being (75). Despite capturing multiple aspects of material deprivation that may contribute to inequities in diet quality,

associations between income and diet quality are often hypothesized to be mediated by factors related to food affordability. For example, a mediation analysis has demonstrated that higher food cost (one metric of affordability) mediates associations between annual household income and diet quality (63).

Food insecurity refers to inadequate or insecure access to food due to financial constraints (76–78) and ranges in severity from worrying about running out of food (marginal), to compromising the quality and/or quantity of food (moderate), to not eating for an entire day (severe) (79). In Canada, food insecurity is generally monitored at the household level (77), although food insecurity status can also be assessed at the individual level. Unlike income measures that often seek to capture income sufficiency, broadly defined, measures of food insecurity are usually based on tangible challenges in procuring adequate and quality foods. For example, household food insecurity status is often assessed based on affirmative responses to statements related to worrying about not having enough food, being unable to afford to eat balanced meals, relying on low-cost foods, and cutting or skipping meals due to not having enough money (78,80). Given the focus on tangible indicators of uncertain or inadequate food access due to limited financial resources, household food insecurity status is a powerful indicator of material deprivation. Several studies have found clear gradients in diet quality across severities of household food insecurity (7,81–83). While poor diet quality among food-insecure households can be understood as a manifestation of pervasive material deprivation

(7), to date, interventions providing cash transfers and food subsidies to address household food insecurity have demonstrated limited effectiveness in alleviating food insecurity and improving diet quality (84,85).

Inequities in diet quality across neighbourhood environments

While most diet quality research has focused on indicators of SEP at the individual and household levels, there is mounting evidence to indicate that determinants of diet quality exist at the neighbourhood level that are not fully explained by the socioeconomic characteristics of individuals who live there. Many studies have found that neighbourhood food and socioeconomic environments are associated with dietary intake (86–94). Over the past decade, research on food environments—particularly geographic access to food retailers—has gained significant attention (94), showing that features of consumer and neighbourhood food environments are associated with dietary intake (95). In the Canadian context, evidence supporting associations between geographic food access, dietary intake, and inequities in diet quality is much more limited than in the United States (88,89). While studies from the United States have highlighted the importance of food deserts–neighbourhoods that are simultaneously materially deprived and have low geographic access to nutritious food sources–the existence of food deserts is less widespread in Canada (86). From a policy perspective, adopting a multi-dimensional approach to studying associations between neighbourhood environments and

dietary intake is essential, as it can further understanding of how different aspects of the neighbourhood environment may interact to shape diet quality (88).

Neighbourhood deprivation, a concept referring to area-level social and economic marginalization, has also been associated with diet quality (87–91,96). Key dimensions of neighbourhood deprivation include residential instability, material deprivation, economic dependency, and the ethnocultural composition of an area (97,98). For example, in a study among adults in seven countries, neighbourhood deprivation was associated with fruit consumption in Canada, New Zealand, and Scotland, with higher odds of greater fruit intake in less deprived neighbourhoods (99). In Canada, Murphy et al. (2022) found that individuals living in neighbourhoods with greater material and social deprivation were less likely to meet recommendations for fruit and vegetable intake (92). Furthermore, Gilham et al. (2020) found that diet quality was lower in the most, compared to the least, socially deprived neighbourhoods in Canada (93). Given that measures of neighbourhood deprivation are often based on the socioeconomic characteristics of residents, associations between neighbourhood deprivation and diet quality may partly reflect compositional differences across neighbourhoods (100). However, associations between neighbourhood deprivation and diet quality persist even when studies adjust for individual-level SEP indicators (87,92,93), suggesting that neighbourhood environments themselves also contribute to inequities in diet quality.

While it is unclear how neighbourhood environments can contribute to inequities in diet quality, factors related to food access, such as availability and proximity to food retailers, may play a role. For example, Menko (2021) found that neighbourhoods in Canada with more visible minorities and socioeconomic disadvantages were located closer to ethnic grocers and further from conventional supermarkets (101). Since researchers have yet to isolate specific mechanisms explaining inequities in diet quality across neighbourhoods, especially in Canada, examining associations between multiple, disaggregated measures of neighbourhood deprivation and diet quality is a critical step towards informing municipal initiatives to improve diet quality, such as revising land use policies and improving public infrastructure.

2.3.2 Inequities in diet quality across countries and regions

Dietary patterns vary greatly between countries, including neighbouring countries. For example, in a comparison of dietary patterns across 187 countries, Imamura et al. (2015) found heterogeneity between neighbouring countries in the Caribbean (Barbados, Dominica), South America (Argentina, Brazil), and Southeast Asia (Laos, Thailand) (102). In the same study, dietary patterns varied according to country-level income, with individuals in higher-income countries consuming both a larger quantity of healthy (e.g., fruits, vegetables, beans and legumes, nuts and seeds, whole grains) and unhealthy (e.g., red meats, processed meats, sugar-

sweetened beverages) items than lower-income countries (102). In a study among 12 European countries, higher country-level gross domestic product (GDP) was positively associated with total sugar intake. Furthermore, vitamin D intake was highest among Scandinavian countries (Denmark, Finland, Sweden), and total folate intake was lowest among Eastern European countries (Estonia, Hungary, Kazakhstan) (103). The authors attributed these cross-country differences to differences in country-level programs, such as agricultural production and food customs.

Beyond cross-country differences in dietary intake, the extent to which diet quality varies by SEP also differs by country and region. In a study of 185 countries, Miller et al. (2022) found that mean Alternative Healthy Eating Index (AHEI) scores were generally higher among women compared to men, with the greatest differences in high-income countries (104). In the same study, higher educational attainment was associated with higher diet quality in most, but not all, world regions, with the largest educational inequities among countries in Central/Eastern Europe and Central Asia. In contrast, they found no clear educational inequities in diet quality in the Middle East, North Africa, and Sub-Saharan Africa (104). Lastly, AHEI scores were higher among urban compared to rural residents in Central/Eastern Europe and Central Asia but lower among urban than among rural residents in the Middle East and North Africa (104). Collectively, these findings highlight regional heterogeneity in inequities in diet quality by SEP.

2.4 An intersectional approach to examining inequities in diet quality

Having established a relationship between SEP and diet quality, I will now introduce and discuss the concept of intersectionality. In this discussion, I will describe how an intersectional approach to assessing differences in diet quality according to multiple SEP dimensions can reveal opportunities to reduce inequities in diet quality through policy interventions.

Originally introduced by Kimberlé Crenshaw, *intersectionality* refers to the ways in which an individual's social location (12,105), defined by intersecting social identities and positions, shapes their life experiences (12,105). Although intersectionality is often referred to as a "theory", intersectionality can be better understood as a framework to critically assess interconnected systems of power (13). While intersectionality has roots in sociolegal scholarship, an intersectionality framework can be applied to a wide range of disciplines, including health research (14). In the context of diet quality, an intersectional approach to examining differences in diet quality can enrich our understanding of inequities in diet quality by highlighting how health varies across SEP intersections (14).

As an analytical framework, an intersectional approach to studying dietary inequities can be used by researchers to highlight opportunities for interventions through uncovering complexities and contradictions in health-related experiences across social intersections (106–108). By investigating the subgroups and contexts

in which inequities are amplified or attenuated, intersectional investigations can highlight underlying socioeconomic mechanisms explaining dietary inequities that could be targeted through social and health policies to reduce them (14,109).

Social locations, particularly those defined by different SEP dimensions, may shape a variety of health-related experiences, including individuals' dietary patterns (8). Given that there are multiple SEP indicators that are associated with diet quality, an intersectionality framework can be usefully applied to conceptualize how dimensions of SEP may mutually influence diet quality. An intersectionality framework assumes that social processes related to power, privilege, and prestige do not operate in isolation and can interact in non-additive ways to influence experiences across a variety of social locations (12–14,110). To highlight the non-additive ways in which SEP can shape experiences, it is helpful to recognize that individuals cannot always isolate a single social identity or position (e.g., race, gender, sexual orientation) as having the greatest impact on their day-to-day experiences since people experience their various social identities and positions simultaneously, not independently (111). Since SEP is a component of an individual's social location, and SEP has multiple dimensions (15,16), using an intersectionality framework can support researchers in identifying how inequities in diet quality differ across SEP intersections.

2.5 Methodological approaches to intersectional inquiry

Applying an intersectional approach to examining diet quality across SEP intersections requires an understanding of the methodological approaches used to study multiple intersecting and complex social relations. This is known as *intersectional complexity* (112). McCall (2005) delineates three methodological approaches to studying intersectional complexity (112).

The first of the three approaches is the *anti*-categorical approach, which critiques the use of rigid analytic categories because the act of categorizing people into social groups can create and perpetuate differences between groups of people (112,113). Researchers adopting this approach emphasize the overlapping and fluid nature of social categories by highlighting aspects of social life that are constructed by social categories themselves, thereby emphasizing the importance of "deconstructing" social categories (112,113). By rejecting rigid social categories, anti-categorical studies seek to locate differences *outside* and *between* conventional social locations (112,114). An example of anti-categorical research is scholarship that challenges the very existence and usefulness of social categories in fully capturing multiple forms of discrimination in anti-discrimination laws (115). Anti-categorical intersectional research is primarily represented in feminist post-structuralist scholarship (112,115–118), but seldom in quantitative health research which requires analytic categories to quantify between-group differences (108).

Intra-categorical approaches to studying intersectional complexity focus on heterogeneity *within* social intersections (112). Scholars who use intra-categorical approaches tend to focus on experiences at social locations that cross the boundaries of traditionally constructed groups, particularly those at neglected social intersections (112). An example of intra-categorical research is a qualitative study that provides rich descriptive accounts of lived experiences of individuals at particular social intersections (119). Compared to anti-categorical research, there are many more examples of intra-categorical research in social science and health fields (106,108,118). Case studies and phenomenological research that delve into the complexity of social life are examples of intra-categorical intersectional research because they can reveal diversity, variation, and heterogeneity within social categories in ways that are challenging for quantitative researchers who rely on much more rigid social categories (112,120). Analytically, quantitative health research that uses multilevel analysis of individual heterogeneity and discriminatory accuracy (MAIHDA) and latent class/profile analyses are classified as intra-categorical research because they can be used to highlight heterogeneity within social groups.

Inter-categorical intersectional research provisionally adopts existing analytic categories to facilitate comparisons of inequities *between* social intersections (112). Unlike intra-categorical approaches to intersectionality that focus on complexity within particular social intersections, inter-categorical approaches treat

categorization pragmatically to explore differences across social locations (106). Such studies frequently employ regression-based models to test interaction terms to assess whether the joint effects of two or more social locations are greater than their individual components or produce stratified estimates to identify differences across social strata, such as age group and gender (121).

The popularity of each methodological approach to assessing intersectional complexity varies depending on the methods adopted by researchers. While intersectionality has been used as a theoretical and methodological tool for qualitative researchers for several decades (111), it has more recently emerged as an analytic framework for quantitative researchers, including those in public health and epidemiology (14,108). Quantitative intersectional methods are particularly useful for furthering knowledge of health-related experiences at the population level (14) such as diet quality among adults in Canada, because they have the potential to increase the precision with which inequities are identified (14). Due to a reliance on discrete social categories in quantitative research, quantitative intersectional researchers often adopt intra-categorical or inter-categorical approaches to intersectionality research.

2.6 Quantitative intersectional health research

Within intersectionality health research, studies can be classified as descriptive or analytic. While *descriptive intersectionality* analyses focus on

identifying differences in experiences/outcomes across social intersections, *analytic intersectionality* analyses focus on testing social processes that shape experiences/outcomes across social intersections (14). In the context of diet quality, examining/identifying differences in diet quality across SEP intersections is descriptive intersectionality research, whereas testing/identifying processes that mediate differences in diet quality across SEP intersections is analytic intersectionality research. While analytic intersectionality analyses explicitly focus on testing whether and how specific social processes may contribute to health inequities, both descriptive and analytic intersectionality studies often consider the role and contributions of social processes in producing and perpetuating health inequities.

To emphasize social processes underlying health inequities, quantitative health researchers often draw attention to social processes that generate, amplify, or temper differences in health outcomes across social intersections (14). In the context of intersectional scholarship, the term “social processes” can have multiple meanings, but usually refers to systems and mechanisms related to oppression and privilege that shape individuals’ experiences/outcomes (119). These social processes can include systems of ideology that ascribe meaning to individual characteristics based on perceived differences in social identities and positions; however, they can also include laws, policies, and programs that reinforce inequities by restricting access to resources, opportunities, and privileges (119). Examples of

systems of ideologies that can generate dietary inequities are ageism, sexism, racism, and classism. Examples of laws, policies, and programs that can reinforce or temper inequities include providing economic incentives for healthy eating and food reformulation (122). In the literature, interventions that use a combination of targeted food taxes and subsidies have demonstrated mixed results in improving dietary intake across SEP groups, with some having a more positive impact on individuals with lower SEP (123,124), while others on individuals with higher SEP (125,126). Food reformulation , such as salt reduction strategies, also have the potential to equitably reduce sodium intake because they influence all individuals in the population, however, findings are mixed (122,127–129).

Comparative methodological approaches that examine associations between SEP indicators and diet quality across different settings can help identify social conditions that shape or modify diet-related inequities (130). These comparisons align with a *situated intersectionality* lens (18–20,131,132), which views intersectionality as a context-informed analytic tool, where context includes dimensions of time and place (18–20,131,132). Adopting this lens allows researchers to investigate how power relations and health inequities may manifest across different settings, where distinct social processes may explain inequities in diet quality. Therefore, using intersectionality as a context-informed tool to support process-oriented interpretations of health inequities (14,133) is important to highlight

the modifiable nature of inequities in diet quality that can potentially be addressed through institutional policies, programs, and practices (14).

2.7 Machine learning techniques to advance intersectional research

Analytic techniques that enable researchers to generate intersection-specific estimates for numerous social locations are valuable for identifying heterogeneity in diet quality across and within various SEP intersections. *Machine learning* techniques which use algorithms to learn and optimize their performance as they are fed new data (134), can be used to generate predictions of diet quality across numerous social intersections. These machine learning techniques, especially tree-based methods, can capture complex and non-linear relationships, even with a relatively modest sample size (n) amidst a large number of predictors (p) (i.e., *small n, large p* problems), which can sometimes be the case with population-based research (135).

2.7.1 Decision-tree based methods

In recent decades, the application of decision tree techniques to answer public health questions has been popularized because they demonstrate the potential to aid in complex decision-making in public health settings (136). Decision tree techniques are data-driven and non-parametric approaches to applying decision rules to partition data into a single decision tree (137). Decision tree techniques,

such as classification and regression trees (CART), conditional inference trees (CIT), and chi-square automatic interaction detectors (CHAID) are appealing from an intersectional perspective because they can identify subgroups of individuals with a health-related profile that could potentially benefit from targeted intervention (138,139).

While single decision tree methods that are based on one tree-like model can generate readily interpretable results, their tree structures can be sensitive to small changes in the data, increasing the risk of overfitting (136). Overfitting happens when models learn to fit to training datasets too well, including the noise in the sample, leading to poor predictive capabilities on other datasets (140). Overfitting is a fundamental issue with data-driven techniques because it reduces the generalizability of the results to other samples (140,141).

2.7.2 Random forests algorithms

Aggregating results from many diverse decision trees can mitigate overfitting and improve prediction accuracy (136). Recognizing the limitations associated with single decision tree techniques for predictive modelling, Breiman (2001) developed a *random forests* framework that uses **b**ootstrap **agg**regat**ing** (referred to as “bagging” for short) (142,143). Briefly, bagging is the process of building an ensemble of decisions from multiple bootstrapped samples of the data and then aggregating the predictions from all the trees to generate a final model (142,143). Since random

forests use multiple bootstrapped samples to train decision trees and aggregate the results from these diverse decision trees to generate predictions, these techniques can mitigate issues like high collinearity among variables and instability in predictions, leading to better predictive accuracy than single decision tree techniques (143).

Aside from enhanced predictive capabilities, random forests can also provide insight into the extent to which variables improve prediction accuracy with measures of *variable importance,* which are generated based on the extent to which each variable reduces prediction errors (135,144,145). Since variable importance measures highlight the most influential variables for predicting an outcome, random forests are not only valuable for generating predictions but also for identifying the variables most relevant to a specific outcome (135). The ability to identify the most important predictors among variables of varying scales of measurement (e.g., continuous, categorical) makes random forests procedures a valuable class of machine learning techniques for researchers interested in identifying predictors of diet quality that could be targeted through interventions (135).

Researchers have developed random forests algorithms that expand on Breiman's original random forests framework, including Strobl's *conditional random forests* (CRF) (146). Strobl introduced the CRF framework out of recognition that traditional random forests that use CART tend to favour variables with more categories when selecting variables for tree splits (145). To correct this bias, CRF

uses conditional inference trees (CIT), which incorporate statistical tests at each split to ensure a variable is significantly associated with an outcome before considering a variable for splitting (145,147,148). This approach ensures that splits are not biased by the number of unique values or categories, resulting in splits that are considered "fairer" or "unbiased" in this manner (145). Since indicators of SEP can vary greatly in the number of categories, CRF can be valuable for assessing differences in diet quality across diverse SEP indicators and deriving intersection-specific estimates of health-related outcomes, such as diet quality.

2.8 Statistical approaches to quantitative intersectionality research

2.8.1 Causal inference and statistical modelling

While it is important to identify how diet quality differs in intersection-specific ways, it is equally important to identify modifiable factors that drive dietary inequities through analytic techniques that enable causal inference. Statistical techniques are ideal for addressing causal inference questions, particularly those related to the context-dependent nature of SEP-diet associations, though there have recently been advancements in machine learning techniques to facilitate causal inference (149). *Statistical techniques*, methods grounded in probability theory and mathematical models, are frequently employed when applying an intersectional framework using quantitative methodologies. Statistical techniques are helpful for understanding "cause-effect" (explanatory) relationships between variables (150,151), including

whether the effect of one exposure on an outcome is conditional (or dependent) on another exposure (152) because they can be used to test potentially important interactions between SEP indicators in their associations with diet quality while adjusting for confounders in a relationship.

From an intersectional perspective, quantitative health researchers aiming to test whether the combined effects of privilege/marginalization are beyond their individual effects on a health-related outcome often test interaction terms (14,153,154). Since interaction terms can be tested with a variety of statistical models (e.g., linear, log-linear, logistic), scales (e.g., additive, multiplicative), and types of variables (e.g., binary, categorical, continuous) (152), researchers frequently test statistical interaction terms to assess whether two (or more) indicators of privilege/marginalization interact to shape health-related inequities (155). There are, however, important considerations related to using statistical techniques for intersectional inquiry (121).

Many traditional statistical techniques are parametric techniques because they rely on statistical assumptions about data parameters for modelling. Regression models, which quantitative health researchers often employ for intersectional inquiry, make a number of statistical assumptions, particularly those related to linearity (156). Linearity is the underlying assumption that the mean value (in linear regression) or log odds/logit (in logistic regression) of the dependent variable is linearly, additively, or proportionally related to the dependent variable (156).

Applying analytical methods to data that do not meet underlying assumptions can produce misleading results, such as incorrectly rejecting or accepting the null hypothesis (157). There are non-parametric techniques that require very few assumptions about underlying data distributions and instead rely on ordered statistics, such as ranges, quantiles, and medians, to compute parametric estimates (158). Due to the absence of statistical assumptions, it is challenging to employ non-parametric statistical techniques to assess complex associations between variables, such as prespecified interaction terms.

Beyond statistical assumptions, there are important statistical considerations related to assessing interaction terms for intersectional inquiry (121). First, testing interaction terms can lead to unstable estimates when too many variables (including interaction terms) are tested simultaneously due to insufficient power (159). Therefore, researchers will often decide *a priori* to focus on select SEP indicators and test a limited number of interaction terms for inter-categorical intersectionality research (139). Second, while researchers can develop many statistical models to test many interaction terms, when testing categorical exposures, researchers must select a reference group for comparisons, which can lead to overlooking potentially meaningful differences at SEP intersections not involving the reference category (14,153,154). This limitation is not relevant to testing interaction terms when the exposure variables are on a continuous scale, as there are no categories. Nevertheless, causal inference statistical techniques that assume specific data

parameters and functional relationships between variables are necessary for generating hypothesis-driven insights into the context-dependent nature of health inequities (157).

2.8.2 Cross-country comparisons

Notwithstanding these limitations, statistical techniques are ideal for causal inference. In addition to the ability to test interaction terms, regression-based models have long been used to facilitate cross-country comparisons that assess whether associations between indicators of privilege/marginalization and health-related outcomes differ across settings (130). For example, while educational attainment, income adequacy, and food insecurity have been consistently associated with diet quality, the strength of associations between these SEP indicators and diet quality may be moderated by contextual differences in the countries in which people live (160,161). To test whether associations between SEP indicators and diet quality are contingent on country-specific contexts, researchers can test interaction terms (e.g., income × country) in relation to an outcome (e.g., diet quality). Testing interaction terms to compare associations between SEP indicators and diet quality across different settings can help generate hypotheses about social processes that shape inequities in diet quality which could be targeted through policy interventions.

Before concluding this section, it is important to note that both machine learning and statistical techniques can be used to generate intersection-specific

estimates. For example, researchers can report (un)adjusted means/percentages across population subgroups to generate intersection-specific estimates of diet quality that can be used to identify similarities and differences in diet quality across SEP intersections (108,138,162). As previously mentioned, machine learning techniques can also generate intersection-specific estimates for a larger number of predictors with fewer data assumptions but often cannot compute variance estimates as they are not usually designed for causal inference (138). Therefore, both machine learning and statistical techniques play a crucial role in enhancing our understanding of whether and how certain social processes may contribute to differences in diet quality across various SEP indicators.

2.9 Research summary and rationale

To date, there has not been a substantive examination of diet quality across SEP intersections. Few studies have examined how interactions between dimensions of SEP shape diet quality (8,163). In a study by Doan et al., the researchers found that racial/ethnic identity (including Indigeneity) was not independently associated with diet quality, however, the interaction between racial/ethnic identity and perceived income adequacy was significantly associated with Healthy Eating Index-2015 (HEI-2015) scores among adults in Canada (8), demonstrating how inequities in diet quality according to race/ethnicity and Indigenous identity may have been missed had their intersections with perceived

income adequacy not been explicitly investigated. In a study by Vadiveloo et al, household food security status, the presence of obesity in households, household poverty-to-income ratio, and participation in the Supplemental Nutrition Assistance Program (SNAP) were all independently associated with HEI-2015 scores, however, HEI-2015 scores were lower among food-secure households that were participating in SNAP compared to food-insecure households that were not participating in SNAP (163). These two studies highlight the importance of examining how individual and household-level SEP indicators intersect to influence diet quality. Since these two studies relied on testing statistical interactions, where power and overfitting are critical limitations, they could only assess a limited number of interaction terms in tandem, and interactions with few categories/levels (121). Researchers can use CRF, which relies on averaging predictions across random samples of the data, to generate relatively stable intersection-specific estimates of diet quality across a wider variety of SEP intersections (138,139,164). However, researchers have not yet used CRF to investigate how diet quality differs across SEP intersections.

While intersectional frameworks have often been used to describe intersecting social identities and positions at the individual level, scholars have highlighted that the places where individuals live also have multiple dimensions that could interact to shape an individual's dietary patterns (18–20). In a study by Menko (2021), the authors characterized mean distances to three types of food retailers (conventional supermarket, discount supermarket, ethnic grocer) across

neighbourhood profiles defined by racial/ethnic composition and social equity (based on area-level household income, unemployment, education, lone-parent families, recent immigrants) (101). Menko found that while neighbourhoods with a higher percentage of visible minorities and lower social equity had longer mean distances to conventional supermarkets, they had shorter mean distances to ethnic grocers (101). While these findings suggest that neighbourhood deprivation dimensions may jointly shape food access, it is unclear to what extent neighbourhood deprivation dimensions may jointly shape diet quality. Therefore, research examining whether dimensions of neighbourhood deprivation are independently and/or jointly associated with diet quality is needed.

Country-level socioeconomic and political contexts can also shape inequities in diet quality according to SEP in important ways. Comparing SEP-diet associations between countries with substantial similarities and differences, such as Canada and the United States, can help generate hypotheses about contextual differences that contribute to inequities in diet quality in a particular setting (130). Despite both being high-income North American countries, contextual differences at the country level may affect inequities in diet quality related to educational attainment, perceived income adequacy, and household food insecurity (166-168(Frenette, 2005; McGrail et al., 2009; Ross et al., 2000). For instance, structural differences in education infrastructure, economic policies, and the presence (or lack) of federal nutrition assistance programs may influence inequities in diet quality in important ways

(103,168–171). Due to these and other differences between Canada and the United States, comparing the associations of educational attainment, perceived income adequacy, and household food insecurity with diet quality can help generate hypotheses about modifiable contextual factors contributing to inequities in diet quality (130,170).

While intersectionality was not originally intended to guide empirical research (172), intersectionality as an analytic framework has significant potential for investigating potentially amenable aspects of dietary inequities (108,109,121,173,174). Therefore, my dissertation examines differences in diet quality across SEP dimensions and contexts. In line with an intersectional approach to health research, I adopted a context-informed and process-oriented approach to interpreting differences in diet quality to generate insights and hypotheses about the socioeconomic mechanisms underlying inequities in diet quality in Canada. Collectively, this research documents heterogeneity in diet quality that highlights modifiable aspects of dietary inequities which may be amenable to policy interventions.

Chapter 3: Research Objectives

This dissertation comprises three studies that examined diet quality across dimensions of SEP using population-based data. The overall goal of my research was to broaden our understanding and provide insights into how diet quality could be improved at the population-level by attending to differences in diet quality across the individual, household, neighbourhood, and national levels. This research highlights the value of adopting an intersectional approach to better understand how diet quality differs across dimensions of SEP. The goal of **Chapter 4** was to identify individual/household SEP intersections that best predicted lower and higher diet quality among adults in Canada. **Chapter 5** sought to examine independent and joint associations between dimensions of neighbourhood deprivation in relation to diet quality among a nationally representative sample of adults in Canada. **Chapter 6** aimed to explore whether associations between key SEP indicators (educational attainment, perceived income adequacy, household food insecurity) and diet quality differed among adults in Canada and the United States.

3.1 Specific Objectives

Chapter 4: Identifying socioeconomic intersections that best predict diet quality in Canada

To identify individual/household SEP intersections that best predicted lower and higher diet quality among a population-based sample of adults in Canada.

Chapter 5: Assessing associations between neighbourhood deprivation and diet quality in Canada

To assess whether four dimensions of neighbourhood deprivation were independently and/or jointly associated with diet quality among a nationally representative sample of adults in Canada.

Chapter 6: Comparing socioeconomic inequities in diet quality in Canada and the United States

To compare the associations between three SEP indicators (educational attainment, perceived income adequacy, household food insecurity) and diet quality between adults in Canada and the United States.

Chapter 4: Intersections of educational attainment, Indigenous identity and race/ethnicity best predicted diet quality among adults in Canada: A conditional random forests analysis

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4.1 Introduction

In Canada and worldwide, individuals with a lower socioeconomic position (SEP) tend to have poorer diet quality than those with a higher SEP (4,11,175). These inequities in diet quality are particularly salient across SEP indicators defined by sex/gender, race/ethnicity, educational attainment, and household income (6,176). However, diet quality has also been shown to differ according to other SEP indicators, including employment status (21,67,68), immigration status (57,177), language competency (178), and household composition (179). There are two primary hypotheses as to how SEP shapes diet quality: (1) differential access to material and social resources (e.g., finances, time) (28); and (2) the psychosocial stress experienced by individuals based on their perceived position in society (180). Although it is well-known that diet quality differs according to SEP (6,10,11), it is unclear whether and how multiple SEP dimensions may intersect to shape diet quality (8).

Intersectionality may provide a useful framework to understand how dimensions of SEP intersect to shape diet quality. Intersectionality refers to the ways in which an individual's social location (12,105), defined by the intersecting social identities and positions they occupy, shapes their life experiences, both positively and negatively (12,105). As highlighted by Olstad's and McIntyre's precision public health framework, it is helpful to interrogate how different dimensions of SEP intersect to shape the diet quality of more precisely defined subgroups to identify

groups in need of dietary intervention and to thereby reduce dietary inequities (174). By enriching understanding of how diet quality differs across SEP intersections, an intersectionality framework can inform precision public health interventions to reduce dietary inequities.

A small number of prior studies have examined how SEP indicators jointly shape diet quality (8,163). In one study, Doan et al. (8) found that racial/ethnic identity (including Indigeneity) was not independently associated with diet quality, however, the interaction between racial/ethnic identity and perceived income adequacy was significantly associated with Healthy Eating Index-2015 (HEI-2015) scores among adults in Canada. These findings demonstrate how inequities in diet quality according to race/ethnicity and Indigenous identity may have been missed had their intersections with income adequacy not been explicitly investigated. In a study from the United States that examined how variables at the household level, including participation in the Supplemental Nutrition Assistance Program (SNAP), food security status, the presence of obesity in households, and poverty-to-income ratio, were all independently associated with HEI-2015 scores (163); HEI-2015 scores were lower among food-secure households that were participating in SNAP compared to food-insecure households that were not participating in SNAP (163). Together, these findings underscore the importance of examining diet quality across SEP intersections at the individual and household levels.

A limitation of these two studies, however, is the use of methods that rely on statistical assumptions, which may hinder the ability to detect intersection-specific differences in diet quality across multiple SEP intersections (121). First, quantitative intersectional researchers often test statistical interactions (14,153,154), which can lead to unstable estimates when too many parameters are tested simultaneously due to insufficient power and overfitting (159). In contrast to testing statistical interactions, random forests—a data-driven machine learning technique—can be used to derive numerous *intersection-specific estimates* simultaneously because predictions are generated by averaging estimates across hundreds of random samples of the dataset (138,142), which improves the stability of estimates (135,141,181). Second, while researchers can run many statistical tests to assess a large number of interactions (138,142,143), testing statistical interactions with categorical variables requires researchers to specify a reference category (a category to which all other categories will be compared) for each SEP variable. This can lead researchers to overlook meaningful differences across SEP intersections that do not include the reference category, particularly those defined by a combination of privilege and marginalization (14,153,154). Third, since random forests do not require statistical assumptions (e.g., linearity) to be met (148), they can capture complex relationships between variables that might be missed when researchers assume specific forms of relationships, such as linear, quadratic, or exponential. For these reasons, the objective of the present study was to use

random forests analysis to identify SEP intersections that best predicted lower and higher diet quality among a large, population-based sample of adults in Canada.

4.2 Methods

4.2.1 Sampling and data collection

This study used cross-sectional data from the 2015 Canadian Community Health Survey - Nutrition (CCHS-N), which provides the largest and most recent data on the dietary intake of individuals living in Canada (182). The CCHS-N used a multistage stratified-cluster design to provide a sample that was nationally representative with respect to age, sex, and geography (182). Individuals excluded from the study were those living on reserves (or other Indigenous settlements), in Canada's three northern Territories, in some remote regions, in collective dwellings, in institutions, and those who were full-time members of the Canadian Forces (182). Prior to data collection, Statistics Canada informed adult participants about the study's purpose and that participation is voluntary (implicit consent). This study was deemed to be exempt from ethical review by University of Waterloo's Office of Research Ethics institutional review board in accordance with the policies set out by Canada's federal research funding agencies (183).

Interviewers visited selected dwellings between January and December 2015 to collect basic household information, and to administer a general health

questionnaire and a 24-hour dietary recall (182,184). Interviewers used the Automated Multiple-Pass Method, a computer-assisted five-step method (182), to assist respondents in recalling all food and beverages consumed in the 24 hours preceding the interview (182). Among the 33,258 households selected to participate in the 2015 CCHS-N, 23,584 households responded (70.9%). Among the responding households, 20,485 individuals who were selected to participate in the survey for their household responded (86.9%), resulting in an overall national-level response rate of 61.6% (182). This sampling procedure was designed by Statistics Canada to ensure a minimum sample size for each Dietary Reference Intake age group (182). This study focused on adults ≥18 years of age (n=14,275). Similar to previous research (127,185,186), individuals who were pregnant, breastfeeding, or who reported no energy intake (2.2%) were excluded. Prior to analyzing the data, individuals with missing data for any of the analytic variables were removed from the adult sample (2.4%), resulting in an analytic sample of 13,617 adults (**Figure 1**).

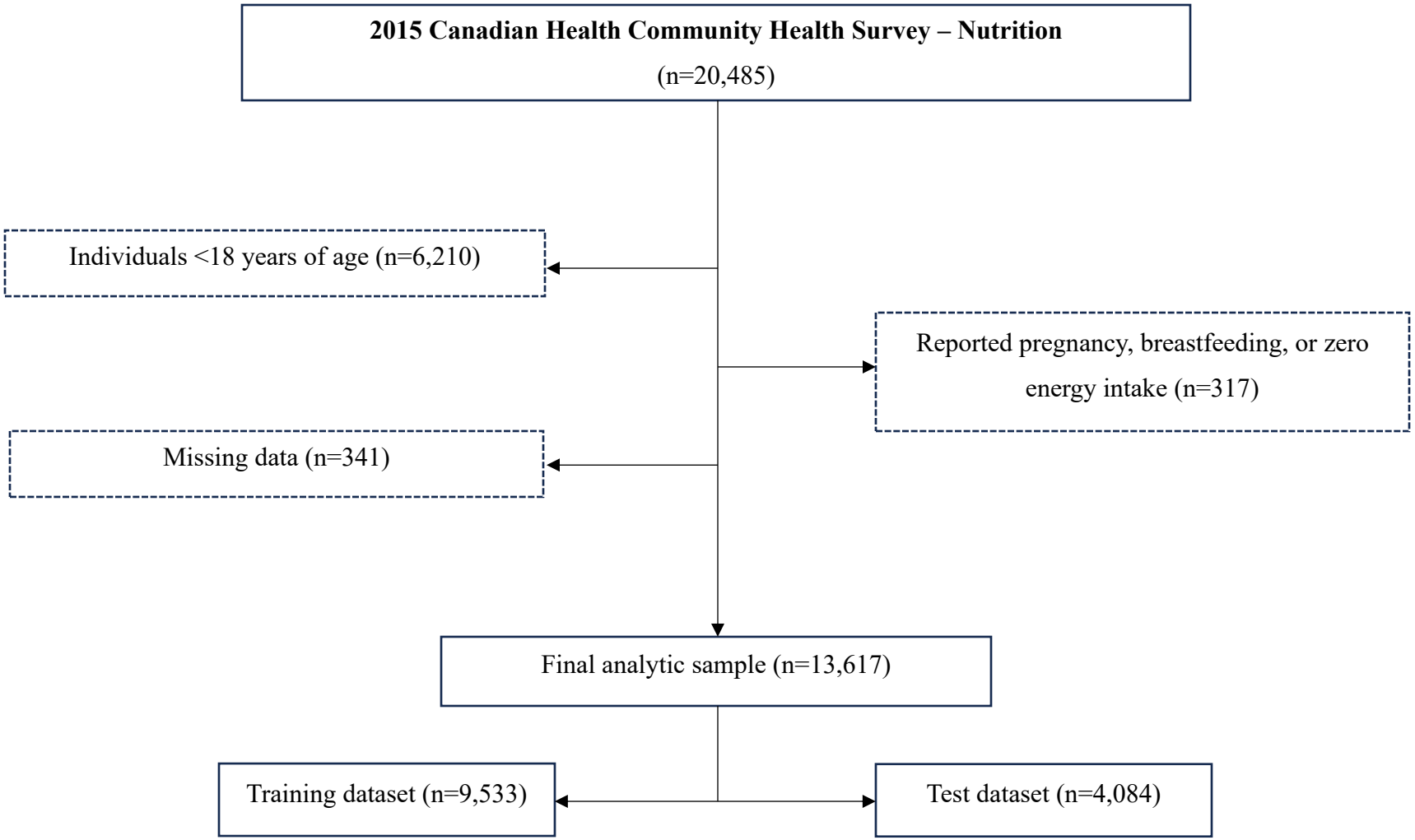

Figure 1. Participant flow chart for the 2015 Canadian Community Health Survey – Nutrition (unweighted data)

4.3 Measures

4.3.1 Healthy Eating Index-2015

The HEI-2015,(187) a well-validated diet quality index (188), was used to characterize diet quality from 24-hour dietary recall data. The index includes 13 components: nine that assess dietary adequacy (Total Fruits, Whole Fruits, Total Vegetables, Greens and Beans, Whole Grains, Dairy, Total Protein Foods, Seafood and Plant Proteins, Fatty Acids), and four that assess dietary moderation (Refined Grains, Sodium, Added Sugars, Saturated Fats) (187). HEI-2015 scores were calculated from the 24-hour recall data by using food code linkages across three datasets: the 2015 Canadian Nutrient File (182,184), the 2015-2016 US Food and Nutrient Database for Dietary Studies (189), and the 2015-2016 US Department of Agriculture's Food Patterns Equivalents Database (190). Person-level scores were calculated using the simple scoring algorithm from the National Cancer Institute (191). Total scores can range from zero to 100, with higher scores indicating better alignment with dietary guidance and, consequently, higher dietary quality (187).

4.3.2 Indicators of socioeconomic position

A theory-driven approach was used to select candidate SEP indicators based on the existing literature on associations between SEP and diet quality.

To account for differences in social, political, and economic opportunities across the life course that may shape diet quality (192), three age groups (young adults 18-29 years, working-aged adults 30-64 years, older adults ≥ 65+ years) were created based

on self-reported age. These age groups were created because they align with the age groups frequently used in public health research and surveillance. Furthermore, since an individual's sex/gender is associated with diet quality (6), a binary sex/gender variable was included in the analysis. Although the questionnaire asked individuals for their sex, this variable served as a proxy for both sex and gender because it was not clear whether respondents provided their sex or gender identity when asked if they were male or female, and because there are < 1% of adults in Canada for whom sex and gender do not align (193).

As Indigeneity and race/ethnicity have been shown to be related to diet quality (56), individuals who identified as First Nations, Métis, and/or Inuk (Inuit) were categorized as Indigenous and all non-Indigenous respondents were grouped based on the racial and/or cultural group(s) they self-reported. Because the CCHS-N did not distinguish between race and ethnicity when asking respondents about the racial and cultural group(s) they belonged to, this variable is referred to as race/ethnicity throughout this paper. We collapsed the responses for these items into seven categories: Black, East Asian (including Chinese, Japanese, Korean), Latin American, Middle Eastern (including Arab, West Asian), South Asian, Southeast Asian (including Filipino), White, and another racial/ethnic group (individuals who selected Other or multiple response options that did not fall exclusively within the analytic race/ethnicity categories) (194).

Educational attainment is strongly associated with diet quality (4). The CCHS asked individuals to indicate their highest level of educational attainment, which was categorized into four categories (less than a high school diploma or equivalent, a high

school diploma or equivalent, some post-secondary education, bachelor's degree or above). The category of some post-secondary education includes collège d'enseignement général et professionnel (CGEP; a post-secondary level of education that follows high school in the province of Québec), trade school, college, non-university certificates/diplomas, and university certificates/diplomas below the bachelor's level. The bachelor's degree or above category included bachelor's degrees and university certificates/diplomas/degrees above the bachelor's level.

Employment status, and the nature of employment and work itself, have been shown to shape individuals' dietary practices (21,67,68). The CCHS-N asked respondents to indicate their working status in the last week, which was categorized into three categories: employed, unemployed, or not in the workforce. Additionally, since students differ from non-students with regard to their income, employment, and housing (195,196), individuals who were currently attending high school, college, CEGEP, or university were identified (student, non-student).

Research demonstrates that diet quality differs between immigrants and individuals born in Canada (57,177). In addition, evidence suggests that time since immigration is important to consider because the longer immigrants stay in a host country, the more likely they are to adopt the dietary patterns of their host countries (59). Using two items that asked respondents whether they were immigrants to Canada and the time since immigration, a variable with four categories was created to specify whether the participant was Canadian born, a temporary resident, a recent immigrant (<10 years), or a longer-term immigrant (≥10 years) (197,198).

The ability to speak an official national language has far-reaching ramifications for social, economic, educational, and employment opportunities, which may in turn shape diet quality (199–201). To account for official language competency, a binary variable was created to identify individuals who could not converse in English or French and those who could speak English and/or French.

In addition to individual-level SEP, SEP at the household level also shapes diet quality (7,163,202,203). One such household-level variable is household composition. Adults leading single-parent households, especially mothers, have lower diet quality than adults who live with a partner or who are married (199). A variable with six categories was created to capture household composition (unattached individuals living alone or with others, attached individuals living with a partner, individuals living with a partner and children, single parents living with children, individuals living with parents, and another living arrangement).

Household food insecurity is associated with diet quality (7). Household food security status and severity in the previous 12 months were assessed using Health Canada's validated Household Food Security Survey Module (80). Based on respondents' answers to 18 items, respondents were assigned to one of four household food insecurity categories (food secure, marginally food insecure, moderately food insecure, or severely food insecure) (80).

Annual household income is also an important indicator of SEP that is associated with diet quality (15,204). Since the low income cut-offs (LICOs) by community and family size are income thresholds below which households likely devote a larger share of income to basic necessities (205), the adjusted ratio of total annual household

income to the low income cut-offs were used as a proxy for economic marginalization (182). This study used the version of the adjusted ratio that was converted into deciles to derive annual household income quintiles for analysis: 1-2 (very low), 3-4 (low), 5-6 (medium), 7-8 (high), and 9-10 (very high).

Receipt of income support has been associated with diet quality (206). To identify whether a household received social assistance/welfare as a source of income, a binary variable was created from a survey item that asked respondents to confirm whether their household had received any provincial or municipal social assistance or welfare in the past 12 months (receiving social assistance, not receiving social assistance).

4.3.3 Statistical and machine learning analyses

Descriptive analyses were performed in SAS Enterprise Version 7.1 and machine learning analyses were conducted in RStudio Version 4.0.4 (207,208). We produced weighted descriptive estimates to characterize the sample. In accordance with Statistics Canada's standards for data release (209), sampling weights provided by Statistics Canada were applied.

The *party* package was used to employ conditional random forests (CRF) (210), an ensemble machine learning technique that averages the predictions from conditional inference trees grown with bootstrapped subsamples drawn from the data (146). A conditional inference tree is a decision tree that identifies the predictor that best discriminates between values of the outcome of interest (137,210). By using a random sample of predictors for each bootstrapped sample, CRF can be used to identify SEP indicators and intersections that best predict lower and higher diet quality, without being

prone to overfitting to the data (146). Sampling weights were not applied to the CRF because Statistics Canada's sampling weights are not compatible with the *cforest* function.

Using a simple random sampling procedure, the dataset was partitioned into two segments used for training (70%) and validation (30%). The 70:30 split was chosen over other split options because it demonstrates high accuracy for random forests tasks (211). The CRF were trained with default/common practice values for the hyperparameters: 500 trees and a minimum of five variables tried at each split. Similar to previous research (138), and as depicted in **Figure 2**, after training a CRF with individual SEP indicators (individual indicator model), the four most important indicators of HEI-2015 scores were used to form all possible two-way intersections and passed through the CRF a second time to train a model with the SEP intersections (intersectional indicator model). For both the individual and intersectional indicator models, the four most important predictors were identified based on their variable importance measures (VIM) which indicates the extent to which a predictor improves prediction accuracy (145). Although the four most important indicators were selected based on previous research (138), focusing on this number of indicators also ensured the analyses remained computationally manageable while still being able to assess a range of SEP intersections. To understand the functional relationship between SEP and diet quality, this study assessed predicted HEI-2015 scores from partial dependence tests of the four most important individual predictors and the four most important intersections using the training dataset. The Root Mean Squared Error (RMSE) and Mean Absolute Error (MAE) were used to assess prediction error and R-squared (R^2) to

assess model fit. Comparing these metrics between the training and test data allowed us to assess whether the models were overfitting to the training data or were generalizing effectively when introduced to new data. A threshold of <0.05 for the VIM was used to determine significant individual indicators and intersections.

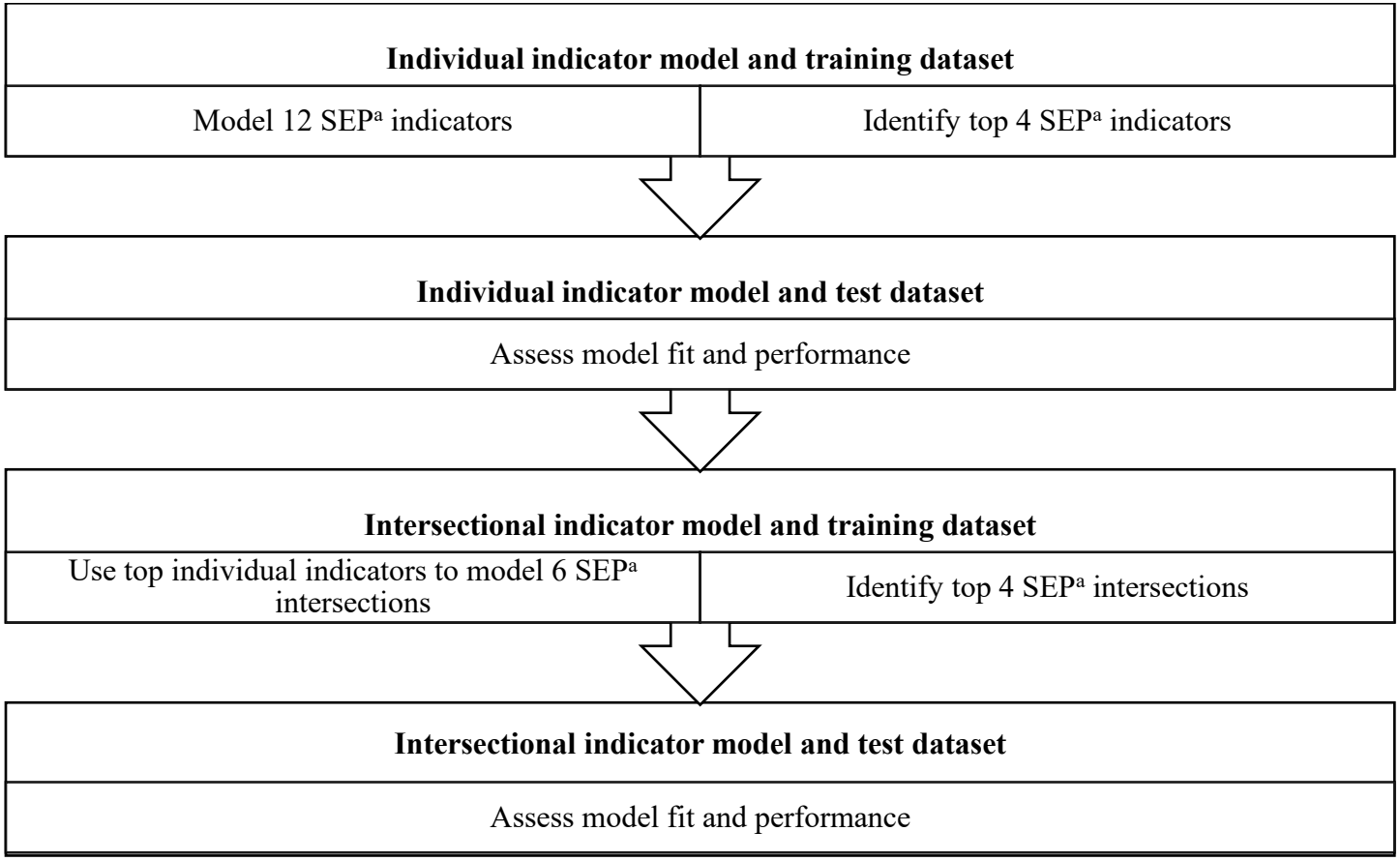

Figure 2. Flow chart depicting the process used to identify the individual and intersectional indicators of socioeconomic position that best predicted lower and higher Healthy Eating Index-2015 scores

[a] SEP = Socioeconomic position

4.4 Results

4.4.1 Weighted descriptive characteristics

The analytic sample of 13,617 adults included relatively equal proportions of male and female respondents (**Table 1**). The majority of participants were 30-64 years of age (62.8%), identified as White (73.8%), Canadian born (70.9%), and could speak English and/or French (98.9%). The largest educational attainment group were individuals who had some post-secondary education (33.8%), and the most common household composition was living with a partner and children (28.6%). Most were employed (64.5%), not students (91.5%), food secure (88.6%) and not receiving social assistance (95.7%). Using a graded approach that categorizes HEI-2015 scores from A to F, the mean HEI-2015 score of 57.9 (SE=0.3) out of 100 corresponds with an “F” (187,212).

Table 1. Weighted characteristics of adults who participated in the 2015 Canadian Community Health Survey – Nutrition (n=13,617, weighted n=26,886,768)

Variable	%/Mean (SE)[a,b]
Age group	
18-29 years	16.2 (0.7)
30-64 years	62.8 (0.8)
≥ 65 years	21.1 (0.4)
Sex/gender	
Male	50.4 (0.2)
Female	49.6 (0.2)
Indigenous identity and race/ethnicity[c]	
Black	3.3 (0.4)
East Asian	5.1 (0.4)
Indigenous	2.8 (0.2)
Latin American	1.3 (1.3)
Middle Eastern	2.5 (0.3)
South Asian	4.5 (0.4)
Southeast Asian	3.4 (0.4)
White	73.8 (1.0)
Another racial/ethnic group	3.3 (0.4)
Immigration status	
Canadian born	70.9 (0.9)
Longer-term immigrant	20.2 (0.8)
Recent immigrant	6.8 (0.5)
Temporary resident	2.1 (0.3)
Official language competency	
English and/or French	98.9 (0.1)
Neither English nor French	1.1 (0.1)
Educational attainment[d]	
Less than a high school diploma or equivalent	11.8 (0.5)
High school diploma or equivalent	26.7(0.8)
Some post-secondary school education	33.8 (0.8)
Bachelor's degree or above	27.6 (0.9)
Employment status	
Employed	64.5 (0.7)
Unemployed	28.3 (0.7)
Not in the workforce	7.3 (0.2)
Student status	
Student	8.5 (0.5)
Not a student	91.5 (0.5)
Household composition	
Unattached living alone or with others	24.8 (0.8)

Table 1, *continued*.

Attached living with a partner	27.8 (0.7)
Living with a partner and children	28.6 (0.8)
Single parent living with children	4.5 (0.4)
Living with parents	8.4 (0.6)
Other	5.9 (0.4)
Annual household income	
Very low	19.4 (0.7)
Low	20.2 (0.7)
Middle	19.5 (0.6)
High	19.6 (0.7)
Very high	21.3 (0.8)
Household food insecurity status	
Food secure	88.6 (0.6)
Marginally food insecure	3.7 (0.3)
Moderately food insecure	5.3 (0.3)
Severely food insecure	2.4 (0.3)
Social assistance	
Receiving social assistance	4.3 (0.4)
Not receiving social assistance	95.7 (0.4)
HEI-2015 score[e] (Mean, SE[b])	57.9 (0.3)

[a] In accordance with Statistics Canada's confidentiality policies, all estimates incorporate sampling weights and replicate bootstrap weights provided by Statistics Canada
[b] SE = Standard error of the weighted mean or percentage
[c] Another racial/ethnic group includes individuals who selected Other or multiple response options
[d] Some post-secondary education includes collège d'enseignement général et professionnel, trade school, college, non-university certificates/diplomas, university certificates/diplomas below the bachelor level. Bachelor's degree or above includes bachelor's degree and university certificates/diplomas/degrees above the bachelor's level
[e] HEI-2015 = Healthy Eating Index-2015

4.4.2 Random forests models

Model performance. R^2 statistics indicated that the individual and intersectional models explained 16% and 8% of variability in predicted HEI-2015 scores, respectively, while MAE values of 10.5 and 11.0 suggest large discrepancies between predicted and actual HEI-2015 scores (**Table 2**). The moderate discrepancy in model fit and the small discrepancy in prediction error metrics between the training and test datasets suggests that the models were generalizing effectively to new data. The similar performance of the individual and intersectional indicator models suggests that the four individual SEP dimensions, which make up the SEP intersectional indicators, capture similar variation in predicted HEI-2015 scores.

Table 2. Conditional random forests model performance (500 trees) among adults who participated in the 2015 Canadian Community Health Survey – Nutrition (training n=9,533, test n=4,084)

Model	RMSE[a]	R^{2b}	MAE[c]
Individual indicator model			
Training data	13.04	0.16	10.54
Test data	13.47	0.08	10.91
Intersectional indicator model			
Training data	13.62	0.08	11.02
Test data	13.59	0.06	11.00

[a] RMSE = Root Mean Squared Error, larger values indicate larger discrepancies between predicted and actual Healthy Eating Index-2015 scores
[b] R2 = R-Squared, larger values indicate the model explains a larger proportion of variance in Healthy Eating Index scores-2015
[c] MAE = Mean Absolute Error, larger values indicate larger absolute differences between predicted and actual Healthy Eating Index-2015 scores

Individual indicator model. The indicators with the highest VIM, and therefore the variables that improved model predictions to the greatest extent, were educational attainment (VIM=14.1), followed by Indigenous identity and race/ethnicity (VIM=4.0),

household food insecurity (VIM=2.4), and sex/gender (VIM=1.7; **Figure 3**). While this study focused on the four indicators with the highest VIM, selected based on previous research, (138) it is important to note the fourth and fifth highest VIM were similar.

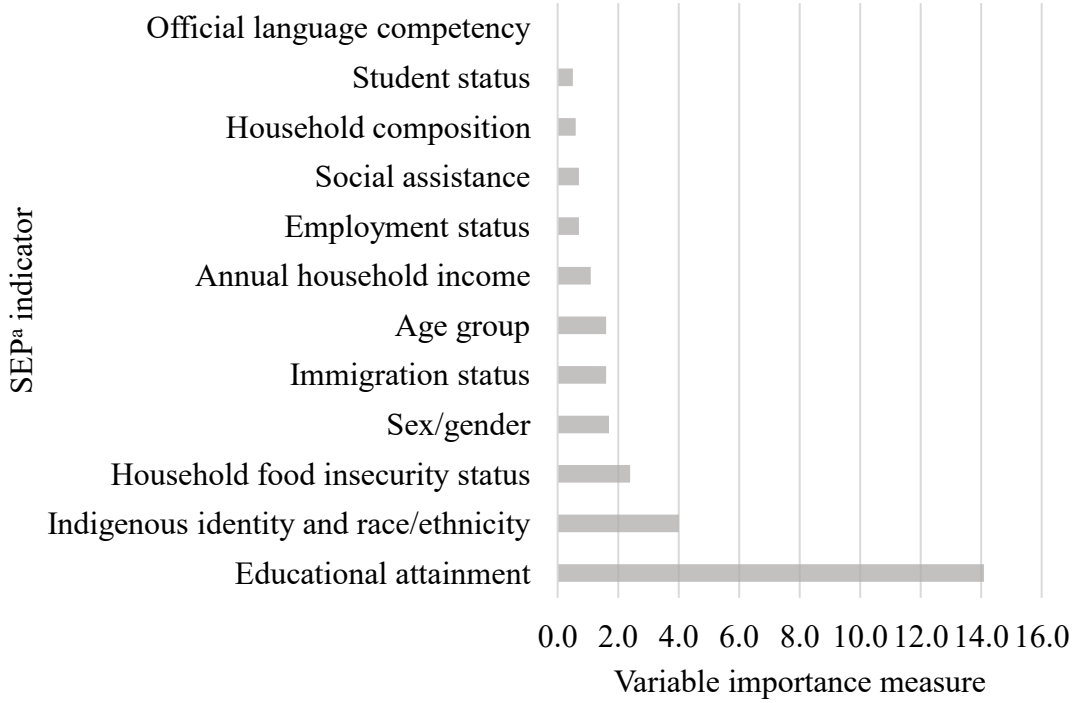

Figure 3. Variable importance measures derived from the conditional random forests individual indicator model among adults who participated in the 2015 Canadian Community Health Survey – Nutrition (training n=9,533)

[a] SEP = Socioeconomic position

Partial dependence measures for educational attainment indicated that individuals with less than a high school diploma had the lowest (53.5) and individuals with a bachelor's degree or above had the highest (61.5) predicted HEI-2015 scores (**Figure 4**). For the second-most important individual indicator, Indigenous identity and race/ethnicity, individuals identifying as Indigenous had the lowest (55.4) and individuals identifying as South Asian had the highest (59.8) predicted HEI-2015 scores. For the

third-most important individual indicator, household food insecurity, individuals living in a severely food insecure household had the lowest (53.6) and those living in a food secure household had the highest (57.3) predicted scores. For the fourth-ranked individual indicator, sex/gender, males had lower (56.2), and females had higher (57.8) predicted HEI-2015 scores.

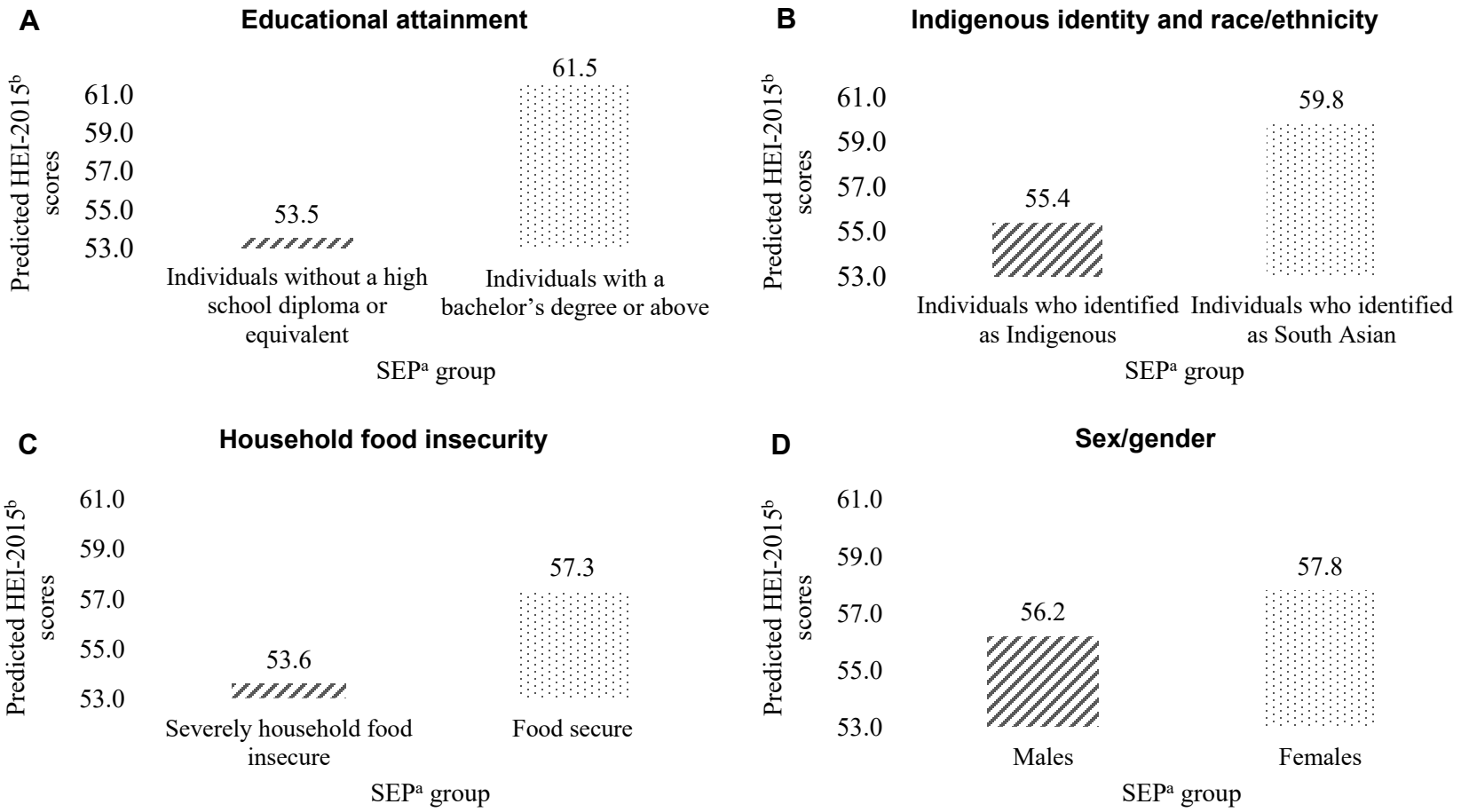

Figure 4. The top four indicators and the lowest and highest predicted Healthy Eating Index-2015 scores for each individual indicator of socioeconomic position among adults who participated in the 2015 Canadian Community Health Survey – Nutrition (training n=9,533)

[a] SEP = Socioeconomic position
[b] HEI-2015 = Healthy Eating Index-2015

Intersectional indicator model. All possible two-way intersections created from the four most important variables from the individual indicator model were passed through a second CRF to train an intersectional indicator model. The four intersections identified by the intersectional model as most important were educational attainment and Indigenous identity and race/ethnicity (VIM=15.2), educational attainment and household food insecurity (VIM=7.6), educational attainment and sex/gender (VIM=3.3), and household food insecurity and sex/gender (VIM=2.8; **Figure 5**).

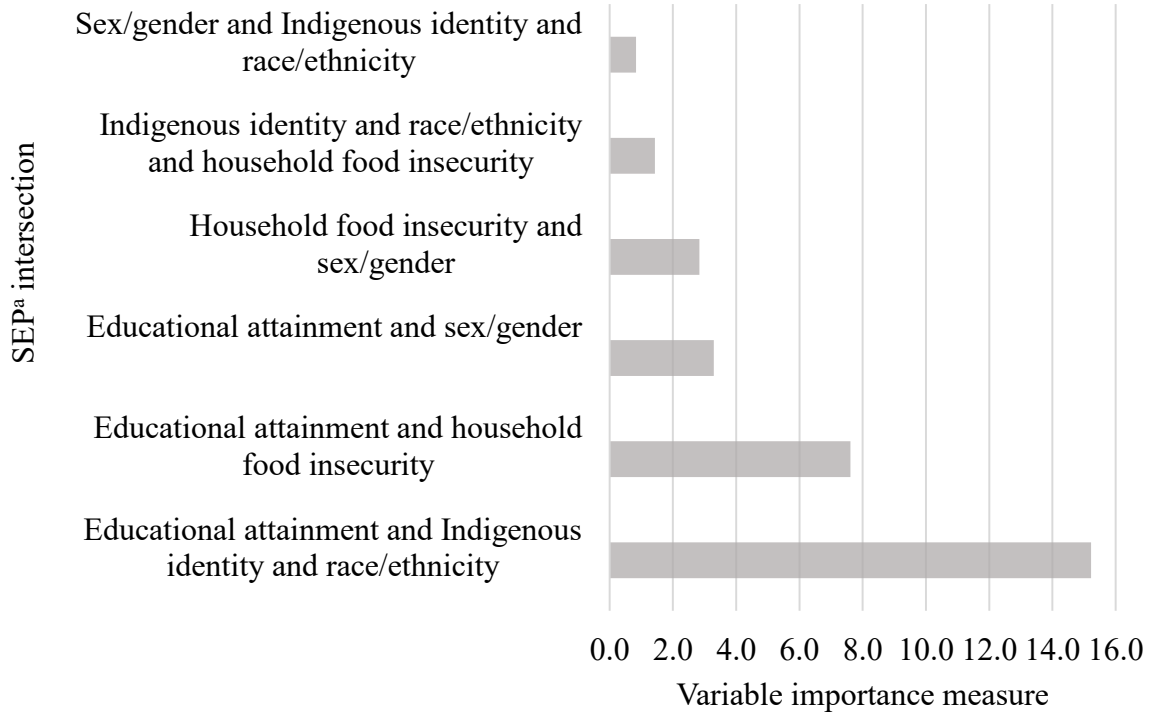

Figure 5. Variable importance measures derived from the condition random forests intersectional indicator model among adults who participated in the 2015 Canadian Community Health Survey – Nutrition (training n=9,533)

[a] SEP = Socioeconomic position

At the intersections defined by educational attainment and Indigenous identity and race/ethnicity, partial dependence measures indicated that individuals with some

post-secondary education and who identified as Indigenous had the lowest (56.0) and individuals without a high school diploma and who identified as Middle Eastern had the highest (64.5) predicted HEI-2015 scores (**Figure 6**). It is worth noting that predicted HEI-2015 scores were similar across the three educational attainment groups where individuals identifying as Indigenous did not have a bachelor's degree (56.0-56.4), and were distinctly higher among Indigenous individuals with a bachelor's degree or above (60.2).

At the intersection defined by educational attainment and household food insecurity, individuals without a high school diploma who lived in a severely food insecure household had the lowest (55.7) and individuals with some post-secondary education who lived in a marginally food insecure household had the highest (59.4) predicted HEI-2015 scores. At the intersection defined by educational attainment and sex/gender, individuals with a high school diploma who identified as male had the lowest (56.9) and individuals with some post-secondary education who identified as female had the highest (58.3) predicted HEI-2015 scores. At the intersection defined by household food insecurity and sex/gender, individuals who lived in a severely food insecure household and identified as male had the lowest (56.3) and individuals who lived in a food secure household and identified as female had the highest (57.9) predicted HEI-2015 scores.

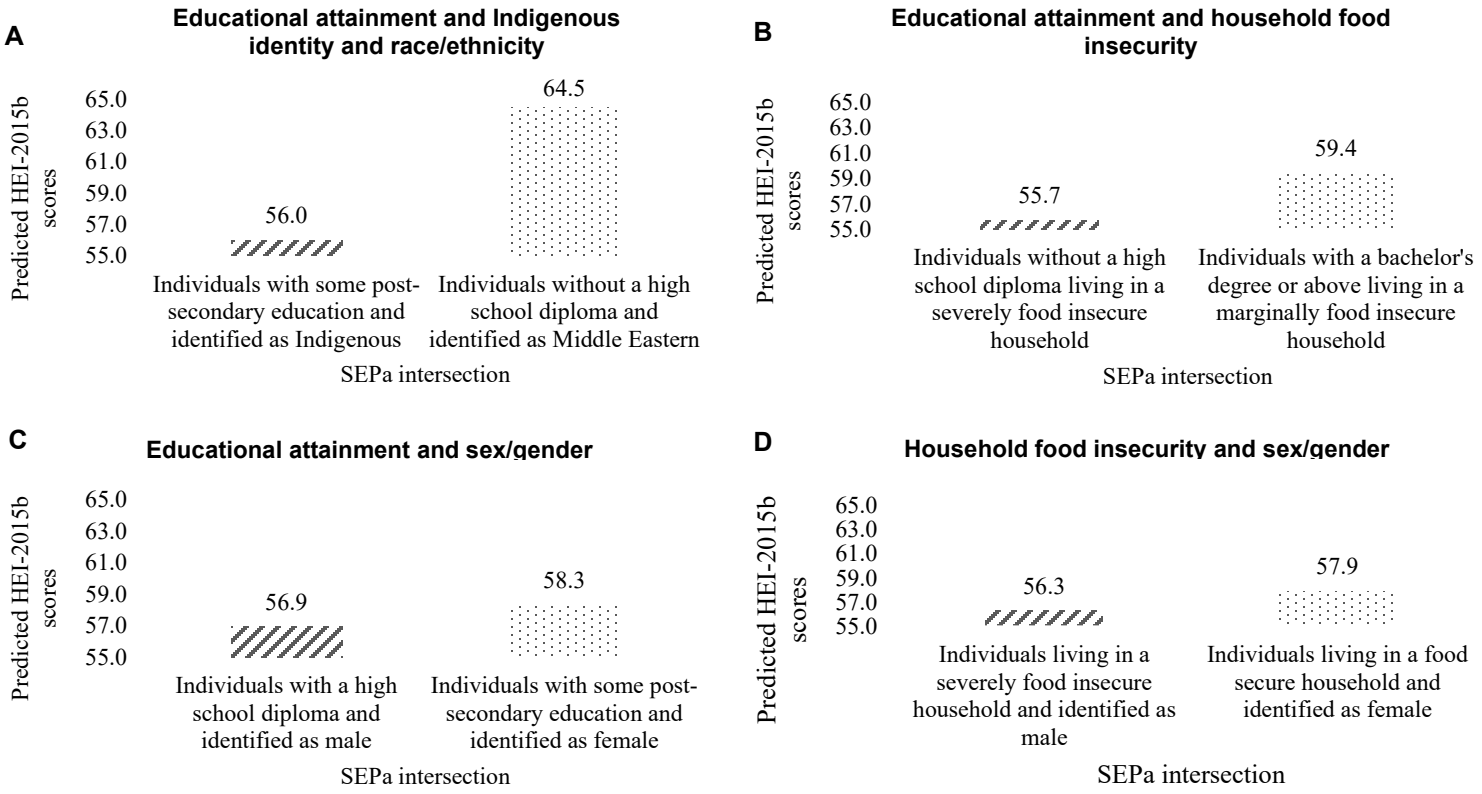

Figure 6. The top four intersections and the lowest and highest predicted Healthy Eating Index-2015 scores for each intersectional indicator of socioeconomic position among adults who participated in the 2015 Canadian Community Health Survey – Nutrition (training n=9,533)

[a] SEP = Socioeconomic position
[b] HEI-2015 = Healthy Eating Index-2015

4.5 Discussion

Although it is well-acknowledged that dimensions of SEP are individually associated with diet quality (6,10,11), it is unclear which SEP intersections are the most important predictors of diet quality among adults. Therefore, this study used CRF to identify dimensions of SEP that best predicted diet quality among a large, population-based sample of adults in Canada. After modeling individual SEP indicators, the four most important individual SEP predictors of diet quality based on VIM were: (1) educational attainment, (2) Indigenous identity and race/ethnicity, (3) household food insecurity, and (4) sex/gender. From these four SEP indicators, we tested all possible two-way intersections and found that the most important predictor of diet quality was the intersection defined by educational attainment and Indigenous identity and race/ethnicity. The four most important intersectional predictors of diet quality were: (1) educational attainment and Indigenous identity and race/ethnicity, (2) educational attainment and household food insecurity, (3) educational attainment and sex/gender, and (4) household food insecurity and sex/gender. Notably, individuals without a high school diploma who lived in a severely food insecure household were predicted to have the lowest, while individuals without a high school diploma and who identified as Middle Eastern were predicted to have the highest diet quality across all intersections.

Of the four most important individual SEP indicators, only educational attainment exhibited at least a 5-point difference between groups with the lowest and

highest predicted HEI-2015 scores—a value that is widely considered to indicate clinically meaningful differences (212). There was also a clear difference in diet quality according to educational attainment, with individuals without a high school diploma having the lowest predicted HEI-2015 scores and those with a bachelor's degree or above having the highest predicted scores. This finding is consistent with previous research by Olstad et al. (4) who found more pronounced gradients in educational inequities in diet quality than inequities according to household income or neighbourhood disadvantage among adults in Canada. According to several social theories, including health lifestyle theory, human capital theory, and health commodity theory (23,213,214), individuals with higher educational attainment may consume diets higher in quality due to greater knowledge, skills, power, prestige, and material resources to support healthy dietary patterns (4,21,37–40). Considering the numerous advantages associated with higher educational attainment, removing barriers to achieving higher education may, directly and indirectly, enhance diet quality among adults in Canada.

While educational attainment is an important individual predictor of diet quality among adults in Canada, this study also found that the intersections defined by an individual's educational attainment, Indigenous identity, and race/ethnicity most strongly predicted diet quality. Unlike statistical interactions, diet quality predictions using CRF do not reflect conditional effects (215,216). Instead, the CRF models identify groups of individuals with the poorest and highest predicted diet quality

across intersections defined by two SEP indicators. In other words, findings based on intersectional predictors do not indicate that the importance of one predictor (e.g., educational attainment) in relation to diet quality is dependent on another predictor (e.g., Indigenous identity and race/ethnicity). Rather, they identify smaller, more specific subgroups of individuals with poorer or higher diet quality. Moreover, the more than 5-point difference between the lowest and highest predicted HEI-2015 scores across the SEP intersections defined by an individual's educational attainment, Indigenous identity and race/ethnicity, is indicative of a potentially clinically meaningful dietary gap.

While there was a clear difference in diet quality based on educational attainment alone, individuals who had some post-secondary education and who identified as Indigenous had the lowest predicted HEI-2015 scores. Just as educational gradients in health are not always uniform across population subgroups (217,218), study findings suggest that educational gradients in diet quality can also vary by Indigenous identity and race/ethnicity. Furthermore, having a bachelor's degree may have a greater impact on the diet quality of individuals identifying as Indigenous than other types of formal education, as the predicted HEI-2015 scores for the three levels of educational attainment where individuals did not have a bachelor's degree were similarly low, especially compared to the individuals identifying as Indigenous with a bachelor's degree or above. Despite clear differences in diet quality by educational attainment, it is important to attend to the

unique ways educational attainment may structure diet quality among Indigenous populations, especially given that the socioeconomic returns to formal education are not universal (217,218). Further research will be important for better understanding differences in diet quality by educational attainment among Indigenous people in Canada.

Acculturation, or the extent to which individuals adopt elements of a new cultural environment (219), might help explain how an individual's educational attainment and race/ethnicity intersect to shape diet quality. As education can serve as a catalyst for acculturation (220,221), individuals with lower levels of educational attainment may experience less acculturation than their more educated counterparts (220,221). For this reason, individuals identifying as Middle Eastern without a high school diploma may be more likely to retain elements of their traditional cultural dietary practices that support higher diet quality (222,223). These intersectional findings underscore the complex, but sometimes contradictory, ways in which structural and sociocultural factors may intersect to shape individuals diet quality.

4.5.1 Strengths and limitations

The present study assessed a wide range of SEP dimensions in relation to diet quality, which is an advantage afforded by using CRF. This analytical approach allowed us to identify potential inequities in diet quality across multiple SEP intersections. By focusing on SEP intersections where the groups with the lowest

and highest predicted HEI-2015 scores differed by more than 5 points, this study was able to highlight potentially meaningful differences in HEI-2015 scores (212). Moreover, while multiple studies have demonstrated clear gradients in diet quality across several SEP dimensions (4,6,7), this study was the first to assess the relative importance of several individual- and household-level SEP dimensions in predicting diet quality (224). Lastly, leveraging population-based data from the 2015 CCHS-N allowed us to generate evidence from individuals living in Canada's ten provinces, making the findings well-suited to inform understandings of socioeconomic inequities in diet quality at the national level.

Several limitations must also be considered. First, model performance statistics indicated large prediction errors. The large prediction errors are unsurprising given this study's sole focus on modeling SEP indicators rather than all factors that contribute to diet quality. Researchers aiming to use CRF to predict diet quality in a population, rather than for understanding differences in diet quality across SEP intersections, should consider developing CRF models that incorporate a broader range of factors that may influence diet quality. Additionally, the omission of sampling weights could also contribute to prediction error. Since the CRF approach did not permit the inclusion of Statistics Canada's sampling weights, the results are not nationally representative. Omitting sampling weights can distort the representativeness of the training data, leading to biased model estimates and higher prediction error for under-represented subgroups. Future research should

employ analytic approaches that can appropriately accommodate sampling weights and use multiple random data partitions to evaluate the generalizability of these findings and model prediction error.

Second, dietary misreporting, including errors in recall, are always a concern with self-reported dietary intake data (46,225,226). Unlike food frequency questionnaires which are commonly used to collect dietary data, the 2015 CCHS-N used the Automated Multiple-Pass Method which has been shown to improve the accuracy of food recall. Moreover, because this study relied on one day of dietary recall data, the results do not account for within-person variability (e.g., day-to-day differences) in dietary intake (227,228); however, one day of intake can provide appropriate estimates of mean population intake (229). In addition, as the HEI-2015 was developed to reflect adherence to the Dietary Guidelines for Americans, it may not reflect the cultural food practices of ethnic and Indigenous groups in Canada (187).

Lastly, there are ethical considerations related to the use of Indigenous identifiers on the CCHS-N data. The Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans – TCPS (2) (2022) indicates that the use of publicly available secondary data, such as the CCHS, are not normally subject to institutional ethics review (183). In the case of research involving Indigenous peoples, however, it is increasingly argued that even data that are not specifically collected from Indigenous peoples, but which contain information about them, should be

considered from the perspective of “Indigenous Data Sovereignty” (230). For some, this perspective suggests that the analysis and interpretation of any data leading to conclusions relevant to Indigenous populations, should be controlled by Indigenous people themselves (231). The research presented here has not involved Indigenous people or communities in the analysis or interpretation, and we acknowledge that some would see this as a limitation.

In conclusion, this study found that educational attainment was the strongest Lastly, there are important considerations that must be made when interpreting the results by the sex/gender and Indigenous identity and race/ethnicity dimensions. Since it was not clear whether respondents provided their sex or gender identity when asked if they were male or female, there may be a discordance between sex and gender for some individuals. Additionally, as the 2015 CCHS-N did not collect data from individuals living in Canda’s three northern territories, in some remote regions, or on Indigenous settlements (including reserves) (182), these findings primarily represent Indigenous peoples living in urban settlements and do not reflect the experiences of those who reside in the areas excluded from the sampling frame.

4.6 Conclusion

In conclusion, this study found that educational attainment was the strongest individual SEP predictor of diet quality, and the SEP intersection defined by educational attainment and Indigenous identity and race/ethnicity was the strongest

intersectional predictor of diet quality among a large, population-based sample of adults in Canada. These intersectional findings underscore the complex, but sometimes contradictory, ways in which structural and sociocultural factors may intersect to shape individuals diet quality (232–234). To account for the complex ways in which different SEP dimensions may intersect to shape inequities in diet quality, future research should explore the potential of precision public health interventions (174) to improve diet quality across and within levels of educational attainment.

Chapter 5: Neighbourhood deprivation and diet quality among a nationally representative sample of adults in Canada: An intersectional investigation

Status: Prepared for Public Health Nutrition.

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5.1 Introduction

Poor diet quality, based on conformity with dietary recommendations (46), increases the risk of morbidity and mortality (235,236). The quality of individuals' dietary patterns is often defined in relation to conformity with dietary recommendations (237), including guidance on adequacy, moderation, variety, and balance of nutrient and food intake (51). Researchers have developed and validated summary indices of overall diet quality that combine two or more components of healthy dietary patterns on the same scale (46), such as the Healthy Eating Index (HEI-2015), which assesses dietary adequacy and moderation (187,188).

Determinants of diet quality are multilevel and can include individual, household, and neighbourhood factors (24). At the individual and household levels, differences in diet quality have been observed by dimensions of socioeconomic position, including sex/gender, race/ethnicity, education, income, household composition, and food insecurity status (4,6,56,203). At the neighbourhood level, many studies have found that neighbourhood food and socioeconomic environments are associated with dietary intake (86–93). In particular, neighbourhood deprivation appears to be associated with diet quality (92,93,96).

Internationally, studies have found that neighbourhood deprivation is associated with dietary intake (93,99). For example, in a study among adults in seven countries, higher neighbourhood deprivation was associated with lower fruit intake in Canada, New Zealand, and Scottland (99). In Canada, Murphy et al. (2022) found that individuals living in neighbourhoods with greater material and social deprivation were less likely to

meet recommendations for fruit and vegetable intake (92). Furthermore, Gilham et al. (2020) found that diet quality was lower in the most, compared to the least, socially deprived neighbourhoods in Canada (93). However, there are two key gaps in the literature pertaining to associations between neighbourhood deprivation and diet quality.

First, most studies that have examined neighbourhood deprivation in relation to dietary outcomes have assessed associations between neighbourhood deprivation and intake of specific food groups, such as fruits, vegetables, or fast food (99), which do not capture the quality of overall dietary intake (46). Diet quality indices, such as the Healthy Eating Index (HEI-2015) (187), provide insight into overall diet quality because it assesses multiple aspects of healthy eating on the same scale (46). Second, researchers have not taken an intersectional approach (12) that considers how aspects of neighbourhood deprivation might interact to shape individuals' diet quality. While intersectional frameworks have often been used to describe intersecting social identities/positions at the individual level, the places where individuals live also have multiple dimensions that might interact to shape individual's dietary patterns (12).

Given the limited knowledge about how dimensions of neighbourhood deprivation may interact to affect diet quality, we examined whether four dimensions of neighbourhood deprivation were independently and/or jointly associated with diet quality among a nationally representative sample of adults in Canada using intersectionality as a context-informed tool (18) to guide our analyses of various socioeconomic-geographic dimensions.

5.2 Methods

5.2.1 Data source

The present study used cross-sectional data from the 2015 Canadian Community Health Survey – Nutrition (CCHS-N) (182). The 2015 CCHS-N dataset was selected because it contains the most recent, detailed, and representative population data on the dietary intake of Canadians. The 2015 CCHS-N was a nationally representative survey that collected detailed information on dietary intake, along with other health-related information, for individuals living in Canada who were ≥1 year of age. Excluded from the sampling frame were people living on First Nations reserves, in Canada's three northern Territories, in collective dwellings, in institutions, and who were full-time members of the Canadian Forces (<3% of the population).

5.2.2 Data collection

Between January and December 2015, interviewers visited selected dwellings (based on a multi-stage sampling design) to collect basic household information and administered a general health questionnaire and a 24-hour dietary recall (238). Interviewers used the Automated Multiple-Pass Method, a computer-assisted five-step method, to guide respondents through recalling all foods and beverages consumed during the 24 hours before the interview (238). Using a set of standardized prompts and response options, interviewers obtained detailed information about the foods (including beverages) consumed by respondents (182).

From the adults ≥ 18 years of age in the dataset (n=14,275), we excluded individuals who were pregnant, breastfeeding, or who reported no energy intake (2.2%), and removed respondents with missing data (1.1%). The final analytical sample for the primary models included data from 13,806 individuals.

5.2.3 Measures

5.2.3.1 Canadian Marginalization Index (CAN-Marg)

We used the Canadian Marginalization Index (CAN-Marg) to assess neighbourhood deprivation in the Canadian context (97). The CAN-Marg is a geography-based index comprising 18 items associated with area-level deprivation and marginalization (97), classified into four dimensions: material resources, immigration and visible minority, age and labour force, and households and dwellings (**Supplemental Table 1**) (97). We used CAN-Marg values computed for 2016 Census Dissemination Areas (DA), which are small and stable geographic units averaging 400-700 people, (239) and the Postal Code Conversion File + version 6D (240) to assign CCHS-N participants into DAs based on their residential postal codes. For each of the four dimension of neighbourhood deprivation, we assessed standardized factor scores, with lower scores indicating less neighbourhood deprivation and higher scores indicating more neighbourhood deprivation (97).

	Households and dwellings	Material resources	Age and labour force	Immigration and visible minority
Indicators	Proportion of the population living alone	Proportion of the population aged 15+ without a high-school diploma	Proportion of the population who are aged 65+	Proportion of the population who are recent immigrants (past 5 years)
	Proportion of the population who are not youth (age 5-15)	Proportion of families who are lone parent families	Dependency ratio (total population 0-14 and 65+/total population 15 to 64)	Proportion of the population who self-identify as a visible minority
	Average number of persons per dwelling	Proportion of total income from government transfer payments for population aged 15+	Proportion of the population not participating in labour force (aged 15+)	
	Proportion of dwellings that are apartments in a building with 5+ stories	Proportion of the population aged 15+ who are unemployed		
	Proportion of the population who are single/divorced/widowed	Average after-tax income for population aged 15+		
	Proportion of dwellings that are not owned	Proportion of households living in dwellings that are in need of major repair		
	Proportion of the population who moved during the past 5 years			

Supplemental Table 1. 2016 CAN-Marg dimensions and their respective census indicators

Notes: Adapted from the Can-Marg 2016 User guide (97).
Abbreviations: CAN-Marg = Canadian Marginalization Index.
Image description: Presented are the four CAN-Marg dimensions along with the 2016 census indicators that comprise each dimension.

5.2.3.2 Healthy Eating Index (HEI-2015)

The Healthy Eating Index-2015 (HEI-2015) (187) was used to characterize diet quality. The HEI-2015 has been extensively evaluated and applied to describe diet quality (53). This index is made up of 13 components, nine of which assess dietary *adequacy* (Total Fruits, Whole Fruits, Total Vegetables, Greens and Beans, Whole Grains, Dairy, Total Protein Foods, Seafood and Plant Proteins, Fatty Acids), and four that assess dietary *moderation* (Refined Grains, Sodium, Added Sugars, Saturated Fats) (187). To convert food and nutrient intakes into the components necessary to calculate HEI-2015 scores, we used datasets which researchers had linked to food codes in the 2015 Canadian Nutrient File (182,184), the 2015-2016 US Food and Nutrient Database for Dietary Studies (189), and the 2015-2016 US Department of Agriculture's Food Patterns Equivalents Database (190). Person-level scores were calculated using the simple algorithm available from the National Cancer Institute (241). Total HEI-2015 scores can range from zero to 100, with higher scores indicating better alignment with dietary guidance and therefore higher diet quality (187).

5.2.3.3 Potential confounders

Individual level characteristics, including age (continuous), sex/gender (male, female), Indigenous identity and race/ethnicity (Black, East Asian [Chinese, Japanese, Korean], Indigenous [First Nations, Métis, and/or Inuk], Latin American, Middle Eastern [Arab, West Asian], South Asian, Southeast Asian [Southeast Asian, Filipino], White, and another racial or ethnic group [individuals who selected "Other" or multiple responses]), immigration status (Canadian born, <10 years since immigration, ≥10

years since immigration, temporary resident), marital status (married or common-law, not married or common law), employment status (employed, unemployed, not in the workforce), and smoking (not at all, occasionally, daily) were included in all models because of their established relationships with neighbourhood deprivation and diet quality. All models were also adjusted for household and area-level factors associated with neighbourhood deprivation and diet quality, including household composition (unattached individuals living alone or with others, attached individuals living with a partner, living with a partner and children, single parents living with children, living with parents, another household composition), urbanicity (rural, urban) (242), and province.

5.2.4 Statistical analyses

5.2.4.1 Primary models

All analyses were conducted using SAS Enterprise (207). Sampling weights and replicate bootstrap weights provided by Statistics Canada were applied to all analyses to account for the complex sampling design. Descriptive analyses were conducted to characterize the sample. Weighted linear regression was used to examine associations between neighbourhood deprivation and diet quality, adjusting for potentially confounding individual, household, and area characteristics. We used fixed-effects rather than mixed-effects models since the number of individuals in each DA was fewer than the recommended 30 units at each level of a multi-level analysis (243). Since CAN-Marg dimensions were not all correlated with HEI-2015 scores in the same direction (97), we did not use CAN-Marg summary scores in our models.

For the primary analyses, we first assessed the main effects of each of the four CAN-Marg dimensions in relation to HEI-2015 scores. In this paper, “effects” refer to statistical associations, not causal relationships. Second, given that different dimensions of neighbourhood deprivation may jointly influence diet quality, all possible two-way interactions among CAN-Marg dimensions were assessed in relation to HEI-2015 scores.

5.2.4.2 Secondary models

We developed models that adjusted for respondent highest educational attainment (less than a high school diploma, high school diploma, some post-secondary education, a bachelor's degree or above), annual household income (very low, low, medium, high, very high), and household food insecurity status (food secure, marginally food insecure, moderately food insecure, severely food insecure) to examine the impact of including variables that could potentially mediate associations between neighbourhood deprivation and diet quality. Our annual household income measure was computed relative to the national distribution, based on deciles reflecting the ratio of total annual household income adjusted for the low income cut-off by community and family size. Severity of household food insecurity was assessed using Health Canada’s validated Household Food Security Survey Module and scoring method (80).

5.2.4.3 Sensitivity models

To examine the potential effects of dietary misreporting on associations between neighbourhood deprivation and diet quality, we developed models that adjusted for an

indicator of dietary intake misreporting – the ratio of total energy intake to total energy expenditure, assuming a low physical activity level (244).

5.3 Results

5.3.1 Sample characteristics

Among the weighted analytic sample, the mean age was 48.9 years and approximately equal proportions of individuals identified as male and female (**Table 4**). The highest proportions of individuals identified as White (73.6%), were Canadian born (70.5%), married or common-law (63.3%), had some post-secondary school education (33.5%), and did not smoke (81.4%). The most common household composition was living with a partner and children (28.5%). A majority of individuals lived in food-secure households (88.3%), most lived in urban areas (82.7%), and the highest proportion lived in the province of Ontario (38.8%). The standardized factor scores for each CAN-Marg dimension had a mean close to zero, while the HEI-2015 scores averaged 57.9/100.0.

Table 3. Weighted characteristics of adults who participated in the 2015 Canadian Community Health Survey - Nutrition (n=13,806)

Variable	% (SE)[a]
Mean age, years	48.9 (0.1)
Sex/gender	
Male	49.9 (0.1)
Female	50.1 (0.1)
Indigenous identity and race/ethnicity[b]	
Black	3.4 (0.4)
East Asian	5.3 (0.4)
Indigenous (First Nation, Inuk/Inuit, Métis)	2.7 (0.2)
Latin American	1.3 (0.2)
Middle Eastern	2.4 (0.3)
South Asian	4.5 (0.4)
Southeast Asian	3.5 (0.4)
White	73.6 (0.9)
Another racial/ethnic group	3.4 (0.4)
Immigration status	
Temporary resident	2.1 (0.3)
Recent immigrant	6.9 (0.5)
Longer-term immigrant	20.6 (0.8)
Canadian born	70.5 (0.9)
Marital status	
Married or common law	63.3 (0.8)
Not married or common law	36.7 (0.8)
Employment status	
Employed	63.9 (0.7)
Unemployed	28.6 (0.7)
Not in the labour force	7.5 (0.2)
Smoking	
Daily smoker	14.0 (0.6)
Occasional or former smoker	4.6 (0.3)
Not at all	81.4 (0.7)
Household composition	
Unattached living alone with others	25.0 (0.8)
Living with a partner	27.8 (0.7)
Living with a partner and children	28.5 (0.8)
Single parent living with children	4.5 (0.4)
Living with parents	8.3 (0.6)
Another household composition	5.9 (0.4)
Urbanicity	
Urban	82.7 (0.8)

Table 3, *continued.*

Rural	17.3 (0.8)
Province	
Newfoundland and Labrador	1.5 (0.0)
Prince Edward Island	0.4 (0.0)
Nova Scotia	2.7 (0.0)
New Brunswick	2.1 (0.0)
Quebec	23.7 (0.1)
Ontario	38.8 (0.1)
Manitoba	3.3 (0.0)
Saskatchewan	2.9 (0.0)
Alberta	11.3 (0.1)
British Colombia	13.2 (0.1)
Respondent educational attainment[c]	
Less than a high school diploma or equivalent	11.8 (0.5)
High school diploma or equivalent	26.7 (0.8)
Some post-secondary school education	33.5 (0.8)
Bachelor's degree or above	27.4 (0.9)
Not stated/don't know/refusal	0.6 (0.1)
Annual household income	
Very low	19.8 (0.7)
Low	20.1 (0.7)
Middle	19.4 (0.6)
High	19.5 (0.7)
Very high	21.2 (0.8)
Household food insecurity status	
Severely food insecure	2.4 (0.3)
Moderately food insecure	5.4 (0.3)
Mildly food insecure	3.6 (0.3)
Food secure	88.3 (0.6)
Not stated/don't know/refusal	0.2 (0.1)
Mean households and dwellings factor scores	0.0 (0.0)
Mean material resources factor scores	-0.1 (0.0)
Mean age and labour force factor scores	-0.1 (0.0)
Mean immigration and visible minority factor score	0.2 (0.0)
Total	57.9 (0.2)

Abbreviations: HEI-2015 = Healthy Eating Index-2015; SE = Standard Error; % = Percentage.
[a] In accordance with Statistics Canada's confidentiality policies, all estimates incorporate sampling weights and replicate bootstrap weights provided by Statistics Canada. Standard errors represent the variability in the percentage across bootstrapped samples.
[b] Another racial/ethnic group includes individuals who selected "Other" or multiple response options that did not fall exclusively within our race/ethnicity categories.
[c] Some post-secondary education includes collège d'enseignement général et professionnel, trade school, college, non-university certificates/diplomas, university certificates/diplomas below the bachelor level. Bachelor's degree or above includes bachelor's degree and university certificates/diplomas/degrees above the bachelor's level.

5.3.2 Primary models

5.3.2.1 Main effects models

After adjusting for confounding variables, individuals living in neighbourhoods with lower access to material resources (β=-0.955, 95% CI=-1.438, -0.471; **Table 5**) and with a lower proportion of recent immigrants and visible minorities (β =0.768, 95% CI=0.268, 1.268) had lower average HEI-2015 scores. The households and dwellings (β=-0.140, 95% CI=-0.614, 0.333) and age and labour force dimensions were not significantly associated with HEI-2015 scores (β=-0.116, 95% CI=-0.615, 0.383).

Table 4. Primary models testing the main effects and two-way interactions between each CAN-Marg dimension in relation to HEI-2015 scores (n=13,806)

Dimensions	β (95% CI)[a]	p[a]
Main effects		
Households and dwellings	-0.140 (-0.614, 0.333)	0.561
Material resources	**-0.955 (-1.438, -0.471)**	**<0.001**
Age and labour force	-0.116 (-0.615, 0.383)	0.649
Immigration and visible minority	**0.768 (0.268, 1.268)**	**0.003**
Two-way interactions		
Households and dwellings × material resources	0.231 (-0.166, 0.628)	0.254
Material resources × age and labour force	**-0.643 (-1.052, -0.234)**	**0.002**
Age and labour force × immigration and visible minority	0.501 (-0.032, 1.034)	0.065
Immigration and visible minority × households and dwellings	0.128 (-0.293, 0.549)	0.550
Households and dwellings × age and labour force	-0.087 (-0.447, 0.273)	0.635
Material resources × immigration and visible minority	**0.521 (0.174, 0.868)**	**0.003**

Abbreviations: CAN-Marg = Canadian Marginalization Index; HEI-2015 = Healthy Eating Index-2015; β = Beta estimate; CI = Confidence interval.

[a] In accordance with Statistics Canada's confidentiality policies, all estimates incorporate sampling weights and replicate bootstrap weights provided by Statistics Canada. Bolded estimates are significant at α=0.05. Estimates adjusted for age, sex/gender, Indigenous identity and race/ethnicity, immigration status, marital status, smoking, household composition, urbanicity, and province.

5.3.2.2 Interaction models

After adjusting for confounding variables, the interaction between the material resources dimension and the age and labour force dimension was significant (β=-0.643 , 95% CI=-1.052, -0.234), indicating that the association between living in a neighbourhood with limited material resources and lower HEI-2015 scores was stronger for those living in neighbourhoods with a lower proportion of people in the labour force. The interaction between the material resources and immigration and visible minority dimensions was significant (β=0.521, 95% CI=0.174, 0.868), indicating that association between living in a neighbourhood with less material resources and lower HEI-2015 scores was stronger for those living in neighbourhoods with a smaller proportion of recent immigrants and visible minorities. No other interactions were significantly associated with HEI-2015 scores.

5.3.3 Secondary models

After adjusting for respondent educational attainment, annual household income, and household food insecurity status, the immigration and visible minority dimension (β=0.774, 95% CI=0.270, 1.277) remained significantly associated with HEI-2015 scores; however, the material resources dimension (β=-0.431, 95% CI=-0.935, 0.072) was no longer significant. (**Table 6**). The interaction between the material resources and age and labour force dimensions (β=-0.562, 95% CI=-0.962, -0.162) and the interaction between the material resources and immigration and visible minority dimensions (β=0376, 95% CI= 0.012, 0.741) remained significant.

Table 5. Secondary models testing the main effects and two-way interactions between each CAN-Marg dimension in relation to HEI-2015 scores (n=13,698)

Dimensions	β (95% CI)[a]	p[a]
Main effects		
Households and dwellings	-0.084 (-0.568, 0.400)	0.734
Material resources	-0.431 (-0.935, 0.072)	0.093
Age and labour force	-0.081 (-0.557, 0.394)	0.737
Immigration and visible minority	**0.774 (0.270, 1.277)**	**0.003**
Two-way interactions		
Households and dwellings × material resources	0.124 (-0.287, 0.535)	0.552
Material resources × age and labour force	**-0.562 (-0.962, -0.162)**	**0.006**
Age and labour force × immigration and visible minority	0.392 (-0.153, 0.937)	0.277
Immigration and visible minority × households and dwellings	0.073 (-0.368, 0.514)	0.746
Households and dwellings × age and labour force	-0.061 (-0.416, 0.294)	0.736
Material resources × immigration and visible minority	**0.376 (0.012, 0.741)**	**0.043**

Abbreviations: CAN-Marg = Canadian Marginalization Index; HEI-2015 = Healthy Eating Index-2015; β = Beta estimate; CI = Confidence interval.

[a] In accordance with Statistics Canada's confidentiality policies, all estimates incorporate sampling weights and replicate bootstrap weights provided by Statistics Canada. Bolded estimates are significant at α=0.05. Estimates adjusted for age, sex/gender, Indigenous identity and race/ethnicity, immigration status, marital status, smoking, household composition, urbanicity, province, educational attainment, annual household income, and household food insecurity status.

5.3.4 Sensitivity models

The results of the sensitivity analyses which adjusted for total energy intake to energy expenditure ratio were consistent with our primary models (**Table 7**).

Table 6. Sensitivity models testing the main effects and two-way interactions between each CAN-Marg dimension in relation to HEI-2015 scores (n=13,126)

Dimensions	β (95% CI)[a]	p[a]
Main effects		
Households and dwellings	-0.096 (-0.575, 0.382)	0.693
Material resources	**-0.996 (-1.495, -0.496)**	**<0.001**
Age and labour force	-0.185 (-0.692, 0.323)	0.476
Immigration and visible minority	**0.679 (0.163, 1.195)**	**0.010**
Two-way interactions		
Households and dwellings × material resources	0.251 (-0.154, 0.657)	0.224
Material resources × age and labour force	**-0.612 (-1.038, -0.186)**	**0.005**
Age and labour force × immigration and visible minority	0.488 (-0.064, 1.040)	0.083
Immigration and visible minority × households and dwellings	0.136 (-0.296, 0.569)	0.536
Household and dwellings × age and labour force	0.121 (-0.489, 0.248)	0.521
Material resources × immigration and visible minority	**0.499 (0.132, 0.867)**	**0.008**

Abbreviations: CAN-Marg = Canadian Marginalization Index; HEI-2015 = Healthy Eating Index-2015; β = Beta estimate; CI = Confidence interval.

[a] In accordance with Statistics Canada's confidentiality policies, all estimates incorporate sampling weights and replicate bootstrap weights provided by Statistics Canada. Bolded estimates are significant at α=0.05. Estimates adjusted for age, sex/gender, Indigenous identity and race/ethnicity, immigration status, marital status, smoking, household composition, urbanicity, province, and the total energy intake to energy expenditure ratio.

5.4 Discussion

Given limited knowledge about interactions between dimensions of neighbourhood deprivation and diet quality, we examined whether and to what extent four dimensions of neighbourhood deprivation were independently and jointly associated with diet quality among a nationally representative sample of adults in Canada. We found that living in a neighbourhood with less material resources was associated with lower diet quality, while living in a neighbourhood with a higher proportion of recent immigrants and visible minorities was associated with higher diet quality. Two-way interactions between the material resources, immigration and visible minority, and age and labour force dimensions revealed that some dimensions of neighbourhood deprivation were jointly associated with diet quality.

We found that two out of four dimensions of neighbourhood deprivation were independently associated with diet quality. First, individuals living in neighbourhoods with less material resources were more likely to have lower diet quality. This finding is supported by a study by Murphy et al. (2022), which found that individuals living in neighbourhoods with very high material deprivation were less likely to meet fruit and vegetable consumption recommendations compared to those living in areas with very low material deprivation (92). Although neighbourhood factors may impact the accessibility and affordability of healthier foods in more materially deprived neighbourhoods (245,246), residents' educational attainment, annual household income, and food insecurity status may be confounders of the association between the

neighbourhood material resource dimension and diet quality, as this main effect was no longer significant, after adjusting for these variables.

Second, living in a neighbourhood with a higher proportion of recent immigrants and visible minorities was associated with higher diet quality, independent of respondents' race/ethnicity and immigration status, and other individual- and household-level characteristics. It is therefore important to consider features of the social and/or built environments that could explain these associations. For example, it is possible that areas with higher concentrations of recent immigrants and visible minorities have greater demand for, and therefore higher access to, food retailers that sell culturally relevant foods from regions where many immigrants and visible minorities have ancestry (e.g., East Asia, South Asia, Middle East). The diets from these regions often emphasize whole, minimally processed and nutrient-dense foods (e.g., vegetables, fruit, pulses, legumes, fish and seafood), in contrast to dominant Western dietary patterns, which are often higher in energy-dense, nutrient-poor and ultra-processed foods (47).

The significant interaction between the material resources dimension and the immigration and visible minority dimension indicates that there was a stronger association between living in a neighbourhood with less material resources and lower diet quality for individuals who also lived in neighbourhoods with a smaller proportion of recent immigrants and visible minorities. Recent immigrants and visible minorities may be more likely to reside in neighbourhoods with more material deprivation than non-immigrants/visible minorities (247). This suggests that some characteristics of the areas where many recent immigrants and visible minorities live, such as more healthful retail

food environments (as described above), may buffer the negative effects of neighbourhood material deprivation on diet quality. Therefore, inequities in diet quality based on neighbourhood deprivation may be amenable to changes to the built or food environment, for example, by increasing access to diverse food retailers which are more prevalent in areas with higher concentrations of immigrants and visible minorities (248).

Although the age and labour force dimension was not independently associated with diet quality, there was a significant interaction between the material resources dimension and the age and labour force dimension. This significant interaction suggests that living in a neighbourhood with a smaller proportion of non-working individuals is not broadly associated with diet quality, but when combined with higher neighbourhood material deprivation, is associated with poorer diet quality. This finding extends previous research suggesting that area-level unemployment may be most strongly associated with poorer diet quality in neighbourhoods with higher material deprivation (249,250). It is important to note, however, that the age and labour force dimension is based not only on the proportion of non-working individuals, but also the ratio of individuals aged <15 and 65+ to those aged 15-65. Given the paucity of research on how neighbourhood age and employment composition are associated with diet quality, further research is warranted to understand these associations.

5.4.1 Strengths and limitations

To our knowledge, this study was the first to assess joint associations between multiple dimensions of neighbourhood deprivation and diet quality. By leveraging data from the 2015 CCHS-N, we were able to assess these associations among a nationally

representative sample of adults in Canada. We expanded on existing literature, which has primarily examined how neighbourhood deprivation relates to intake of fruits, vegetables, and fast-food by evaluating overall diet quality (99). By using intersectionality as a context-informed analytic tool to investigate differences in diet quality across the intersections of multiple socioeconomic-geographic contexts, we were able to identify joint associations between dimensions of neighbourhood deprivation and diet quality that had not been previously identified.

There are also several limitations to consider. Due to the cross-sectional and observational nature of the data, we cannot make causal inferences about the temporal relationships between variables. Moreover, since we assessed neighbourhood deprivation based on respondents' residential postal codes, our measures of neighbourhood deprivation capture only *residential* neighbourhood deprivation and not other neighbourhoods where people may work, study, and play.

With respect to characterizing diet quality, we relied on self-reported 24-hour dietary recall data, which may contain errors due to misreporting (251). To assess the potential impact of misreporting on our estimates, we conducted sensitivity analyses that adjusted for the total energy intake to energy expenditure ratio as an indicator of dietary misreporting and found consistent results. Lastly, because we relied on a single dietary recall we were not able to account for within-person variations in dietary intake (227); however, a single recall captures mean diet quality at the population-level (229).

5.5 Conclusion

In conclusion, we found that dimensions of neighbourhood deprivation were independently and jointly associated with diet quality among a nationally representative sample of adults in Canada. Since some dimensions of neighbourhood deprivation were jointly associated with diet quality, our research underscores the importance of using intersectionality as a context-informed tool to investigate dietary inequities at the neighbourhood level. Additionally, although individuals living in neighbourhoods with less material resources were more likely to have lower diet quality, significant interactions with the immigration and visible minority dimension, as well as the age and labour force dimension, suggest that inequities in diet quality based on neighbourhood material deprivation are not ubiquitous. Therefore, inequities in diet quality based on neighbourhood deprivation may be amenable to changes to the built or food environment, such as increasing access to nutritious and affordable foods.

Chapter 6: Socioeconomic inequities in diet quality: A cross-country comparison of Canada and the United States

Status: Prepared for Preventive Medicine.

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6.1 Introduction

Socioeconomic position (SEP), the social and economic factors that reflect and influence an individual's position in society, affects access to health-promoting resources and environmental exposures (16,25). Inequities in daily living conditions have substantial dietary implications, as individuals with a lower SEP have poorer diet quality than their more socioeconomically advantaged counterparts (4,6,22). A variety of SEP indicators that capture distinct yet overlapping socioeconomic processes are associated with diet quality, including educational attainment, household income, and household food insecurity (4,17,21).

Educational attainment, an objective SEP indicator, is often measured by an individual's highest level of education. Education can shape diet quality by conferring differential knowledge, skills, power, prestige, and material and social resources (4,17,21,37–39,65). Research suggests that educational attainment can influence dietary practices *directly* by imparting knowledge about health-promoting practices and *indirectly* by influencing social networks, cultural assets, employment prospects, and income trajectories (21,38,40,65).

While perceived income adequacy partially reflects objective income, it is also shaped by subjective factors that influence an individual's sense of financial well-being such as personal needs, accumulated wealth and debt, financial desires and priorities, and standards of comparison (75). These additional considerations which are not captured by objective household income can contribute to psychosocial and financial strain and thereby influence diet quality (8,252).

Household food insecurity, like perceived income adequacy, is a subjective SEP indicator. Defined as inadequate or insecure access to food due to financial constraints (77,78,253), food insecurity ranges in severity from worrying about running out of food (marginal) to compromising the quality and/or quantity of food (moderate) to not eating for an entire day (severe) (77,78). Unlike perceived income adequacy which reflects general income insufficiency, food insecurity captures extreme resource constraints where food is sacrificed to make ends meet (77,78). Household food insecurity is a powerful indicator of material deprivation associated with poorer diet quality(7,81,82).

Although educational attainment, perceived income adequacy, and household food insecurity are associated with diet quality, these associations may be moderated by the socioeconomic and political contexts of the countries in which people live (28,130). While the health literature documents numerous similarities and differences between countries in terms of SEP-health associations (130,254,255), cross-country comparisons of SEP-diet associations are much more limited. However, three prior studies suggest that the strength of associations between SEP and dietary intake differs between countries (103,104,171).

Canada and the United States (US) are both high-income North American countries with similar histories and cultures that also differ in ways that could influence inequities in diet quality. For instance, the US has a higher gross domestic product (GDP) than Canada (165,166,170). Higher GDP is a marker of a higher standard of living that could influence perceptions of income adequacy and its associations with diet quality (103,169,170). Another difference is that the US has federal nutrition assistance

programs which Canada lacks that could reduce associations between household food insecurity and diet quality (171). Due to these similarities and key differences in socioeconomic and political contexts, comparing associations between educational attainment, perceived income adequacy and household food insecurity and diet quality between Canada and the US can help to generate hypotheses regarding potentially modifiable contextual drivers of inequities in diet quality (130). However, studies comparing the strength of associations between SEP and diet quality among adults in Canada and the US have not been conducted. Therefore, the purpose of this study was to compare associations between three indicators of SEP (educational attainment, perceived income adequacy, household food insecurity) and diet quality among adults in Canada and the US in 2020–2022.

6.2 Methods

6.2.1 Sampling and data collection

This study used data from the International Food Policy Study (IFPS), an annual cross-sectional online survey aimed at evaluating dietary patterns and practices in relation to national and subnational contexts (256–258). For the present analyses, we analyzed data from the Canada and US surveys completed by adults in 2020, 2021, or 2022. Participants were recruited through the Nielsen Consumer Insight Global Panel and their partners' panels (256–258). Participants who were 18–100 years of age and who resided in Canada, or the US were randomly selected and received an invitation with a unique link to complete an online eligibility screener. A quota sampling strategy was used to meet quotas for age and sex in each country. The survey was delivered in

English and French in Canada and in English and Spanish in the US. In accordance with the panel's incentive structure, participants were remunerated with loyalty points or monetary rewards (256–258). This study received institutional ethical approval (REB #30829, REB #46345; REB21-1307). Additional details regarding the IFPS can be found elsewhere (https://foodpolicystudy.com/).

Participants who were eligible and provided consent to participate were directed to complete a main survey which collected socioeconomic and health-related information. Participants subsequently completed a 24-hour dietary recall via the Automated Self-Administered 24-Hour Recall Dietary Assessment Tool (ASA24) (259). The Canadian survey used the Canadian adaptation of the ASA24 (256–258).

In total, 32,708 adults (Canada: n=13,318, US: n=19,390) completed the main survey in 2020, 2021 or 2022. Among the individuals who completed the main survey, 16,322 (49.9%) completed the ASA24 (Canada: n=8,893, US: n=7,429). To address dietary underreporting, we removed 4,696 (28.8%) participants who were deemed to have potentially implausible dietary data because they had any of the following characteristics: (1) ASA24 completion time <5 minutes, (2) zero energy intake, or (3) very low estimated energy intake (<600 kcal/day for females, <650 kcal/day for males) and did not indicate that they ate 'less than usual' on that day (256–258). After excluding a further 227 participants (2.0%) with missing data for the exposures, outcome or covariates (including not stated, don't know, and refuse to answer), the analytic sample included 11,399 participants.

6.2.2 Measures

6.2.2.1 Healthy Eating Index-2020

We used the Healthy Eating Index-2020 (HEI-2020) (260) to characterize diet quality. The HEI-2020 fully aligns with the HEI-2015, which is among the most robust diet quality indices (187). The HEI-2020 has 13 components, nine of which assess *adequacy* (Total Fruits, Whole Fruits, Vegetables, Greens and Beans, Whole Grains, Dairy, Total Protein Foods, Seafood and Plant Proteins, Fatty Acids), and four that assess *moderation* (Refined Grains, Sodium, Added Sugars, Saturated Fat). Since the HEI-2020 components and scoring standards are the same as the HEI-2015, the National Cancer Institute's simple algorithm for the HEI-2015 was used to calculate person-level HEI-2020 scores.(191) HEI-2020 scores were calculated for all participants based on data collected through ASA24 dietary recalls which automatically coded foods and beverages to allow us to calculate HEI-2020 scores (259). Total HEI-2020 scores can range from zero to 100, with higher scores reflecting greater alignment with dietary guidance and, therefore, higher diet quality.

6.2.2.2 Socioeconomic position

6.2.2.2.1 Educational attainment

To assess educational attainment, participants were asked: “What is the highest level of formal education that you have completed?” with country-specific response options. Responses were collapsed into three levels of educational attainment: low (high school diploma and below), medium (certificates or diplomas from a

technical/vocational school, community college, associate's degree, a university program below a bachelor's degree, apprenticeship training, or *collège d'enseignement general et professionnel [CEGEP]*), and high (bachelor's and advanced university degrees).

6.2.2.2.2 Perceived income adequacy

Participants in both countries were asked: Thinking about your total monthly income, how difficult or easy is it for you to make ends meet? Possible response options were very difficult, difficult, neither easy nor difficult, easy, or very easy. Similar to previous research (8), responses to this item were collapsed into three perceived income adequacy levels: very difficult/difficult, neither easy nor difficult, and easy/very easy.

6.2.2.2.3 Household food insecurity

The severity of household food insecurity in the previous 12 months was assessed using the Household Food Security Survey Module (HFSSM). The 18-item HFSSM has 10 items that assess food insecurity among adults and eight items about the experiences of children (77). Missing responses were imputed in accordance with guidance in the US Department of Agriculture Guide to Measuring Food Security (78). Using Health Canada's scoring standards (77), participants were assigned to one of four food insecurity status categories: food secure, marginally food insecure, moderately food insecure, or severely food insecure (77).

6.2.2.3 Potential confounders

All models were adjusted for age (continuous) and gender identity (man, woman, another gender identity [including trans male/trans man, trans female/trans woman, gender queer/gender non-conforming, different identity]). Additionally, we adjusted for birthplace (host country, abroad) and whether participants selected a racial/cultural background that corresponded with the majority (White and open-ended text responses such as American, Canadian, European, Québécois, Jewish) or minority (e.g., Asian, Black, Hispanic or Latino, Indigenous, Middle Eastern, Native American Indian, Pacific Islander, other, multiple origins) group for their country. Lastly, we adjusted for whether participants were currently living with a partner/spouse (yes, no), the presence of children in the household (yes, no), usual intake (less than usual, usual, more than usual), and the year of data collection (2020, 2021, 2022).

6.2.3 Statistical analyses

All analyses were conducted using SAS Enterprise Guide 8.4 (207). To enhance statistical power, we pooled data from the 2020, 2021, and 2022 surveys. Data were weighted with post-stratification sample weights constructed using a raking algorithm with population estimates for each country based on age group, sex, region, ethnicity (US only) and education. Sample weights for each country were rescaled to the analytic sample size for analysis (256–258).

6.2.3.1 Descriptive analyses

Weighted descriptive statistics (percentages, means) were used to characterize the analytic sample. We used weighted regression and chi-square tests to compare the characteristics of the analytical sample to those who were excluded from the analyses (i.e., individuals who did not complete a dietary recall, had dietary data that we deemed potentially implausible, or had missing data).

6.2.3.2 Primary models

Weighted multivariable linear regression models were developed to examine whether associations between the three indicators of SEP (educational attainment, perceived income adequacy, household food insecurity) and diet quality differed between Canada and the US. When modelling each SEP indicator, main effects and interaction models were tested to assess statistical significance (p-value), beta coefficients (β), and variance estimates (95% confidence intervals [CI]). In this paper, we use the term “effects” to refer to statistical associations and not causal relationships. In each main effects model, SEP and country were included as individual main effects along with potential confounders. For each interaction model, we added a two-way interaction term for SEP × country.

All models were adjusted for variables that may confound the associations of interest, including age, gender identity, racial/cultural background, living with a partner, presence of children in the home, usual food intake, and the year of data collection. Variables that could potentially mediate associations between each SEP indicator and

diet quality were not included in the first set of models (Model I); however, they were included in subsequent models that assessed the impact of including these variables (Model II). Thus, in Model II where educational attainment was the SEP exposure, we also adjusted for perceived income adequacy and household food insecurity. In Model II, where perceived income adequacy was the SEP exposure, we additionally adjusted for household food insecurity. For all analyses, the reference category for the country variable was set to Canada, and the reference category for SEP was the most socioeconomically advantaged group.

6.2.3.3 Sensitivity models

To test the robustness of findings from the primary models, we conducted two sets of sensitivity analyses. For the first set of sensitivity analyses, we did not exclude individuals who may have underreported their intake and instead examined whether our findings changed when we adjusted for an indicator of misreporting (based on the three criteria described above). For the second set of sensitivity analyses, we added two-way (SEP × year) and three-way (SEP × country × year) interactions to our primary main effect and interaction models, respectively, to explore whether the findings from our primary models were potentially affected by temporal events/changes that may have occurred between 2020 and 2022 (e.g., the coronavirus-19 pandemic, increases in food price inflation). A p-value <0.05 was considered to indicate statistically significant differences.

6.3 Results

6.3.1 Weighted sample characteristics

The age and gender identity composition of our analytic sample (**Table 8**) paralleled each country's population-specific distribution. Among participants in Canada, approximately one-third of the weighted sample was in each educational attainment category (low, 36.9%; medium, 35.5%; high, 27.6%). Among participants in the US, a majority had a low level of educational attainment (53.1%). Among participants in Canada and the US, approximately one-third of participants were categorized into each perceived income adequacy category (percentages ranged from 27.6% to 37.2%). The proportion of participants living in households with any level of food insecurity was 37.1% in Canada and 46.2% in the US.

Table 7. Characteristics of adults in the 2020-2022 International Food Policy Study in Canada and the United States (n=11,399)

Characteristics	**Canada** n = 6,297		**United States** n = 5,102	
	n	**%**	**n**	**%**
Age (mean, SE)	49.1	0.3	48.9	0.3
Gender identity				
Man	2856	45.3	2245	44.3
Woman	3383	53.5	2831	55.1
Another gender identity	58	1.2	26	0.5
Racial/cultural background				
Majority	5070	79.6	3958	70.0
Minority	1227	20.4	1144	30.0
Birthplace				
Host country	5225	83.4	4641	89.5
Abroad	1072	16.6	461	10.5
Living with a partner				
No	2687	45.5	2140	44.5
Yes	3610	54.5	2962	55.5
Children in household				
No	5064	80.8	3689	72.7
Yes	1233	19.2	1413	27.3
Usual intake				
Much more than usual	238	4.2	258	5.3
Usual	5241	81.9	4123	80.1
Much less than usual	818	14.0	721	14.6
Year				
2020	2176	34.6	1635	32.0
2021	2194	34.8	2017	39.5
2022	1927	30.6	1450	28.4
Educational attainment				
Low	1429	36.9	1837	53.1
Medium	2588	35.5	1127	10.9
High	2280	27.6	2138	36.0
Perceived income adequacy				
Very difficult/difficult	1525	27.6	1515	31.6
Neither easy nor difficult	2200	35.2	1545	32.0
Very easy/easy	2572	37.2	2042	36.4
Household food insecurity				
Severely food insecure	684	13.0	813	17.2
Moderately food insecure	868	15.2	889	19.0
Marginally food insecure	534	8.8	464	10.0
Food secure (ref)	4211	62.9	2936	53.8
HEI-2020 (Mean, SE)	50.3	0.2	45.6	0.2

Abbreviations: HEI = Healthy Eating Index; SE = Standard Error of the Mean.

Values represent unweighted n and weighted %, unless otherwise specified.

The distribution of participant characteristics differed significantly between individuals included and excluded from the primary analytic sample (**Supplemental Table 2**). Notably, compared to excluded participants, included participants reported higher SEP (i.e., higher levels of education, perceived income adequacy, and household food security), potentially indicating the presence of selection bias.

Supplemental Table 2. Comparisons of the weighted sociodemographic characteristics of adults who were included and excluded from the analyses in the 2020-2022 International Food Policy Study (n=26,018)

Characteristics	Adults included n=11,399 % (95% CI)	Adults excluded[1] n=14,300 % (95% CI)	p value
Age (mean, SE)	49.0 (0.2)	46.5 (0.2)	<0.0001
Gender identity			<0.0001
Man	44.9 (43.8, 45.9)	51.5 (50.6, 52.5)	<0.0001
Woman	54.3 (53.2, 55.3)	47.5 (46.5, 48.5)	
Another gender identity	0.9 (0.7, 1.1)	0.9 (0.7, 1.2)	
Racial/cultural background			<0.0001
Majority	75.3 (74.3, 76.3)	66.9 (65.9, 67.8)	
Minority	24.7 (23.7, 25.7)	33.1 (32.2, 34.1)	
Birthplace			0.0003
Host country	86.2 (85.4, 86.9)	84.3 (83.6, 85.0)	
Abroad	13.8 (13.1, 14.6)	15.7 (15.0, 16.4)	
Living with a partner			<0.0001
No	45.0 (44.0, 46.1)	49.5 (48.5, 50.5)	
Yes	55.0 (53.9, 56.0)	50.5 (49.5, 51.5)	
Children in household			<0.0001
No	77.1 (76.2, 78.0)	72.9 (72.0, 73.7)	
Yes	22.9 (22.0, 23.8)	27.1 (26.3, 28.0)	
Usual intake			<0.0001
Much more than usual	4.7 (4.2, 5.1)	10.4 (9.4, 11.5)	
Usual	81.1 (80.2, 82.0)	78.2 (76.8, 79.6)	
Much less than usual	14.3 (13.5, 15.0)	11.4 (10.3, 12.5)	
Education attainment			<0.0001
Low	44.3 (43.2, 45.4)	51.3 (50.3, 52.3)	
Medium	24.4 (23.6, 25.2)	19.6 (19.0, 20.3)	
High	31.4 (30.5, 32.3)	29.1 (28.3, 29.8)	
Perceived income adequacy			<0.0001
Very difficult/difficult	29.4 (28.4, 30.4)	28.3 (27.4, 29.2)	
Neither easy nor difficult	33.8 (32.7, 34.8)	37.0 (36.1, 38.0)	
Very easy/easy	36.8 (35.8, 37.8)	34.6 (33.7, 35.6)	
Household food insecurity			<0.0001
Severely food insecure	14.9 (14.1, 15.7)	22.4 (21.6, 23.2)	
Moderately food insecure	16.9 (16.1, 17.8)	23.0 (22.2, 23.9)	
Marginally food insecure	9.4 (8.7, 10.0)	8.3 (7.8, 8.8)	
Food secure	58.8 (57.7, 59.9)	46.3 (45.3, 47.2)	

Abbreviations: SE = standard error.

Values represent weighted proportions (95% confident intervals), unless otherwise specified.
[1] Excluded case are participants who did not complete a dietary recall, have potentially implausible dietary data, and/or have missing data.

6.3.2 Primary models

Tables 9-11 present the β and 95% CI estimates for the primary models testing for associations between the SEP indicators and diet quality. Since the estimates were slightly attenuated in Model II (included potential mediators) but were not statistically different from Model I (excluded potential mediators), we report the estimates from Model I in the text.

Table 8. Primary multivariable linear regression models testing main effects and interactions between educational attainment and country in relation to Healthy Eating Index-2020 scores among adults in the 2020-2022 International Food Policy Study (n=11,399)

	Model I		**Model II**	
	β (95% CI)	p	β (95% CI)	p
Educational attainment		<0.0001		<0.0001
Low	-5.59 (-6.27, -4.91)		-4.76 (-5.44, -4.07)	
Medium	-3.05 (-3.70, -2.40)		-2.59 (-3.24, -1.93)	
High (ref)	-		-	
Country				<0.0001
US	-4.32 (-4.94, -3.71)	<0.0001	-4.13 (-4.74, -3.52)	
Canada (ref)	-		-	
Educational attainment × country	-	0.33	-	0.34

Abbreviations: β = beta coefficient, CI = confidence interval.

Model I: Adjusted for age, gender identity, racial/cultural background, birthplace, living with a partner, children in the household, usual intake, and year of data collection.
Model II: Additionally adjusted for perceived income adequacy and household food insecurity.

Table 9. Primary multivariable linear regression models testing main effects and interactions between perceived income adequacy and country in relation to Healthy Eating Index-2020 scores among participants in the 2020-2022 International Food Policy Study (n=11,399)

	Model I		**Model II**	
	β (95% CI)	p	β (95% CI)	p
Perceived income adequacy		<0.0001		0.0009
Very difficult/difficult	-2.55 (-3.29, -1.82)		-0.96 (-1.84, -0.08)	
Neither easy nor difficult	-1.81 (-2.49, -1.13)		-1.33 (-2.03, -0.63)	
Very easy/easy (ref)	-		-	
Country		<0.0001		<0.0001
US	-4.28 (-4.89, -3.67)		-4.13 (-4.74, -3.52)	
Canada (ref)	-		-	
Perceived income adequacy × country	-	0.94	-	0.94

Abbreviations: β = beta coefficient, CI = confidence interval.

Model I: Adjusted for age, gender identity, racial/cultural background, birthplace, living with a partner, children in the household, usual food intake, educational attainment, and year of data collection.
Model II: Additionally adjusted for household food insecurity.

Table 10. Primary multivariable linear regression model testing main effects and interactions between household food insecurity and country in relation to Healthy Eating Index-2020 scores among participants in the 2020-2022 International Food Policy Study (n=11,399)

	β (95% CI)	p
Household food insecurity		<0.0001
Severely food insecure	-3.13 (-4.16, -2.10)	
Moderately food insecure	-2.28 (-3.18, -1.37)	
Marginally food insecure	-1.87 (-2.87, -0.87)	
Food secure (ref)	-	
Country		<0.0001
US	-4.13 (-4.74, -3.52)	
Canada (ref)	-	
Household food insecurity × country	-	0.34

Abbreviations: β = beta coefficient, CI = confidence interval.

Estimates are adjusted for age, gender identity, racial/cultural background, birthplace, living with a partner, children in the household, usual intake, educational attainment, perceived income adequacy, and year of data collection.

6.3.2.1 Main effect models

The main effect models revealed that educational attainment, perceived income adequacy, and household food insecurity were each independently associated with HEI-2020 scores (p<0.0001). Compared to individuals with high educational attainment, individuals with medium (β=-3.05, 95% CI=-3.70, -2.40) or low (β =-5.59, 95% CI=-6.27, -4.91) educational attainment had lower HEI-2020 scores. Similarly, compared to individuals who reported that making ends meet was very easy/easy, individuals who stated it was neither easy nor difficult (β =-1.81, 95% CI=-2.49, -1.13) or very difficult/difficult (β=-2.55, 95% CI=-3.29, -1.82) had lower HEI-2020 scores. Individuals living in marginally (β=-1.87, 95% CI=--2.87, -0.87), moderately (β=-2.28, 95% CI=-3.18, -1.37) or severely (β=-3.13, 95% CI=-4.16, -2.10) food insecure households had lower

HEI-2020 scores than their food secure counterparts. The main effect of country was also significant. Across the educational attainment (β=-4.32, 95% CI=-4.94, -3.71), perceived income adequacy (β=-4.28, 95% CI=-4.89, -3.67), and household food insecurity (β=-4.13, 95% CI=-4.74, -3.52) models, adults living in the US had lower HEI-2020 scores than adults living in Canada (p<0.0001).

6.3.2.2 Interaction models

Interactions between educational attainment (p=0.33), perceived income adequacy (p=0.94), and household food insecurity (p=0.34) with country were not significantly associated with HEI-2020 scores.

6.3.3 Sensitivity models

Retaining participants with dietary data that we deemed potentially implausible yielded results that were statistically consistent with our primary models, with the exception that the interaction between household food insecurity and country became significant (p=0.0006) (**Supplemental Table 3**). In addition, none of the interactions with year (SEP × year, SEP × country × year) were statistically significant, indicating that associations did not differ based on the year of data collection (**Supplemental Table 4**). However, the household food insecurity × year (p=0.058) and household food insecurity × country × year (p=0.055) interaction terms were close to 0.05.

Supplemental Table 3. Sensitivity models testing main effects and interactions between socioeconomic position (educational attainment, perceived income adequacy, household food insecurity) and country among adults in the 2020-2022 International Food Policy Study, including individuals with dietary data deemed potentially implausible* (n=15,939)

	β (95% CI)	p
Educational attainment		<0.0001
Low	-4.7 (-5.2, -4.1)	
Medium	-2.4 (-3.0, -1.9)	
High (ref)	-	
Country		<0.0001
US	-3.3 (-3.8, -2.7)	
Canada (ref)	-	
Educational attainment × country	-	0.34
Perceived income adequacy[1]		<0.0001
Very difficult/difficult	-2.30 (-2.93, -1.67)	
Neither easy nor difficult	-1.56 (-2.14, -0.98)	
Very easy/easy (ref)	-	
Country[1]		<0.0001
US	-3.27 (-3.79, -2.76)	
Canada (ref)	-	
Perceived income adequacy × country[1]	-	0.23
Household food insecurity[1,2]		<0.0001
Severely food insecure	-2.19 (-3.04, -1.35)	
Moderately food insecure	-1.75 (-2.47, -1.02)	
Marginally food insecure	-1.31 (-2.16, -0.47)	
Food secure (ref)	-	
Country[1,2]		<0.0001
US	-3.17 (-3.68, -2.65)	
Canada (ref)	-	
Household food insecurity × country[1,2]	-	0.0006

Abbreviations: β = beta coefficient, CI = confidence interval.

Adjusted for age, gender identity, racial/cultural background, birthplace, living with a partner, children in the household, usual intake, potentially implausible intakes, and year of data collection.
*We identified participants with potentially implausible dietary data based on three indicators: (1) Automated Self-Administered 24-Hour Assessment Tool completion time <5 minutes, (2) zero energy intake, and/or (3) very low energy intake (<600 kcal/day for females, <650 kcal/day for males) and did not indicate that they ate 'less than usual' on that day.
[1] Additionally adjusted for educational attainment.
[2] Additionally adjusted for perceived income adequacy.

Supplemental Table 4. Sensitivity models testing interactions between SEP (educational attainment, perceived income adequacy, household food insecurity), country, and year in relation to Healthy Eating Index-2020 scores among adults in the 2020-2022 International Food Policy Study (n=11,399)

	p[1]
Educational attainment	
Educational attainment × year	0.56
Educational attainment × country × year	0.31
Perceived income adequacy	
Perceived income adequacy × year	0.36
Perceived income adequacy × country × year	0.52
Household food insecurity	
Household food insecurity × year	0.058
Household food insecurity × country × year	0.055

[1] Overall significance of the interaction in the model.

6.4 Discussion

Cross-country comparisons provide a unique opportunity to examine how diet quality differs across socioeconomic and political contexts. As high-income, developed countries within close geographical proximity, Canada and the US share many similarities in history and culture. However, these two countries also differ in important ways that might affect inequities in diet quality. Therefore, we compared the strength of associations between three SEP indicators and diet quality among adults in Canada and the US. Across all models, we found that living in Canada was associated with higher HEI-2020 scores than living in the US. Additionally, educational attainment, perceived income adequacy, and household food insecurity were each independently associated with HEI-2020 scores. Associations between educational attainment, perceived income adequacy, and household food insecurity with HEI-2020 scores did not differ between Canada and the US.

Consistent with previous studies (4,6), we found that diet quality was low among adults living in both Canada and the US, with mean scores of just 50.3 and 45.6 out of 100, respectively. Additionally, diet quality was significantly higher among adults in Canada compared to adults in the US, independent of individual and household characteristics. This 5-point difference in diet quality is potentially meaningful at a population level (212), and may, in part, reflect sociocultural and environmental factors that shape country-level consumption patterns. For instance, ultra-processed foods (UPF)—food products manufactured to contain mostly or entirely of substances extracted from foods, with little to no whole foods (e.g., fast food, packaged snacks, sugar-sweetened beverages)—account for a larger proportion of energy intake in the United States than Canada (261,262). Recognizing that the food environments in both countries could be substantially improved (263,264), lower diet quality and higher consumption of UPF in the US may suggest that physical, social, cultural, and digital exposure to unhealthy, energy-dense, nutrient-poor foods is more extensive in the US than in Canada. Since diet quality was on average low in both countries, policies aimed at improving food environments (e.g., food supply quality, food marketing practices, retail food environments) could potentially enhance population-level diet quality in Canada and the US.

We observed a gradient in associations between SEP and diet quality in that higher educational attainment, perceived income adequacy and household food security were each associated with higher diet quality in Canada and the US, aligning with prior studies (4,6–8). Moreover, since educational attainment remained significant after adjusting for perceived income adequacy and household food insecurity (Model II), it is

evident that the affordability of more/less healthy foods can only partly explain differences in diet quality according to educational attainment.(37) Associations between educational attainment and diet quality, therefore, must reflect a broader spectrum of socioeconomic processes that contribute to socioeconomic stratification in societies (265). One process could relate to processes of social distinction which can consciously influence diet quality through external pressures and internal desires for individuals to distinguish themselves from other educational groups, and unconsciously through socialization around similar sociocultural environments, including social networks (21,38,40,64). Other processes contributing to differences in diet quality across educational groups might relate to how formal education fosters a sense of learned effectiveness, control, and agency that supports engaging in health-promoting dietary practices (37,65).

Despite notable differences in the socioeconomic and political contexts between Canada and the US, we did not detect cross-country differences in associations between SEP and diet quality. While contextual differences may contribute to higher diet quality among adults in Canada relative to adults in the US, our findings suggest these factors do not differentially affect overall diet quality by educational attainment, perceived income adequacy, or household food insecurity in these two countries—or at least not at levels that we were able to detect. Since the net impact of the most influential socioeconomic and political factors on inequities in diet quality may be relatively balanced in Canada and the US, researchers may want to compare countries with larger socioeconomic and political differences (e.g., collective values, economic development, systems of government) or assess more specific contextual differences

(e.g., policies, programs) to capture cross-country differences that could meaningfully influence SEP-diet quality associations.

6.4.1 Strengths and limitations

This study was the first to directly compare associations between educational attainment, perceived income adequacy, and household food insecurity in relation to diet quality among adults in Canada and the US. A major strength is the use of comparable data collection procedures in both countries. Nevertheless, there are several limitations to consider when interpreting these findings. First, we relied on data that are not nationally representative. The estimates, however, were weighted with post-stratification sampling weights constructed based on the age, sex, education, regional, and ethnic (US only) distribution of individuals living in both countries (256–258). Second, due to the cross-sectional and observational nature of the data, we cannot make causal inferences about the relationships between SEP and diet quality. Third, we relied on self-reported 24-hour dietary recall data which are subject to misreporting (226). The dietary recall was completed after the main survey, and as such survey fatigue may have resulted in underreporting of consumed foods and beverages. To mitigate the impacts of dietary underreporting we excluded individuals from our primary analysis who had dietary data that we deemed potentially implausible, using methods that improve the comparability of dietary data collected in the IFPS with other nationally representative surveys (266). In sensitivity analyses, we confirmed that results did not significantly differ when these individuals were retained in the analyses except for the interaction household food insecurity and country. Lastly, because we relied on a single

dietary recall, we were not able to account for within-person variations in dietary intake; however, a single recall is appropriate for capturing mean diet quality at the population level (229).

6.5 Conclusion

We observed gradients in SEP-diet associations in that higher SEP (educational attainment, perceived income adequacy, household food insecurity) was associated with higher diet quality in Canada and the US. Additionally, diet quality was consistently higher in Canada than in the US across all SEP groups. While contextual differences may contribute to higher diet quality among adults in Canada than in the US, the evidence does not suggest that associations between educational attainment, perceived income adequacy, or household food insecurity and diet quality differ between the two countries.

Chapter 7: General Discussion

7.1 Overview

Despite the understanding that multiple dimensions of socioeconomic position (SEP) may intersect to mutually shape diet quality, there is limited empirical research on this topic. To address evidence gaps, my dissertation used an intersectional approach to identify differences in diet quality across the intersections of multiple SEP dimensions and contexts. By doing so, I identified heterogeneity in diet quality that could be used to inform targeted interventions to improve diet quality. In this chapter, I summarize the key findings, contributions, strengths, and limitations of my dissertation research presented in **Chapters 4, 5,** and **6**.

7.2 Summary of key findings

To date, few studies have examined whether there is heterogeneity in diet quality across SEP intersections defined by two or more SEP dimensions, such as educational attainment, income adequacy, and household food insecurity. Therefore, in the study presented in **Chapter 4,** I used conditional random forests (CRF) to identify SEP intersections that best predicted lower and higher diet quality among adults in Canada. In this cross-sectional analysis of adults who participated in the 2015 Canadian Community Health Survey – Nutrition (CCHS-N), the four most important individual SEP predictors of diet quality based on the Healthy Eating Index-2015 (HEI-2015) were: (1) educational attainment, (2) Indigenous identity and

race/ethnicity, (3) household food insecurity status, and (4) sex/gender. From these four SEP indicators, I tested all possible two-way intersections, and identified the four most important intersectional predictors of diet quality: (1) educational attainment and Indigenous identity and race/ethnicity, (2) educational attainment and household food insecurity, (3) educational attainment and sex/gender, and (4) household food insecurity and sex/gender. Across all these SEP intersections, individuals without a high school diploma who lived in a severely food insecure household were predicted to have the lowest, while individuals without a high school diploma who identified as Middle Eastern had the highest predicted HEI-2015 scores.

While intersectional frameworks have often been used to describe intersecting social identities and positions at the individual level, scholars are increasingly suggesting that the characteristics of the places where individuals live are also crucial dimensions of intersectionality (18–20). In the study presented in **Chapter 5**, I examined the independent and joint associations of four dimensions of neighbourhood deprivation, based on the Canadian Marginalization Index (CAN-Marg) with diet quality among adults in Canada. Among a nationally representative sample, the neighbourhood material resources and immigration and visible minority dimensions were each independently associated with HEI-2015 scores. Significant interactions suggested that living in a neighbourhood with less material resources

was more strongly associated with lower HEI-2015 scores in neighbourhoods with a smaller proportion of recent immigrants and visible minorities and non-working individuals. These findings suggest that inequities in diet quality based on neighbourhood material deprivation may be amenable to changes to the built or food environment, for example, by increasing access to diverse food retailers which are more prevalent in areas with higher concentrations of immigrants and visible minorities (248).

While structural and sociocultural differences between Canada and the US can potentially modify associations between SEP and diet quality, studies comparing the strength of associations between SEP and diet quality among adults in these two countries have not been conducted. In **Chapter 6**, I compared associations between three SEP indicators (educational attainment, perceived income adequacy, and household food insecurity) with Healthy Eating Index-2020 (HEI-2020) scores among adults in Canada and the US in 2020–2022. My findings demonstrated that living in Canada was associated with higher HEI-2020 scores than in the US. Additionally, educational attainment, perceived income adequacy, and household food insecurity were each independently associated with HEI-2020 scores. There were no detectable cross-country differences in associations between educational attainment, perceived income adequacy, or household food insecurity and HEI-2020 scores in Canada and the US. While contextual differences could contribute to

higher diet quality among adults in Canada relative to adults in the US, my findings suggested these factors did not differentially affect overall diet quality by educational attainment, perceived income adequacy, or household food insecurity in these two countries.

7.3 Contributions of the dissertation

In the following section, I will describe four key contributions of this research to advancing understandings of inequities in diet quality:

1) Diet quality varies across, and within, levels of educational attainment

Multiple studies have demonstrated clear gradients in diet quality across several SEP dimensions (4,6,7,56,176,267), and the studies contained in this dissertation support and extend this body of literature. For example, the study described in **Chapter 4** found differences in diet quality by educational attainment, Indigenous identity and race/ethnicity, household food insecurity, and sex/gender that aligned with existing research in Canada (4,7,51,56). Unlike previous studies, this study was the first to examine the relative importance of several individual and household SEP indicators in predicting diet quality, and found that educational attainment was the most important predictor of diet quality. Based on educational attainment alone, individuals without a high school diploma had the lowest predicted HEI-2015 scores, while individuals with a bachelor's degree or above had the

highest. While CRF does not permit making causal inferences, findings in the literature and those presented in **Chapter 6** support an independent association between educational attainment and diet quality (4,203,252).

The finding that educational attainment was the most important SEP dimension in predicting diet quality has critical research and policy implications. In Canada, food insecurity and dietary inequities are most often framed as being driven by income inadequacy, necessitating income-based responses to address them (79,253). While income-based interventions may help improve food purchases (15–17) and increase fruit and vegetable consumption (268), the results from this dissertation provide a rationale to explore interventions that can address inequities in diet quality by educational attainment that are not explained by income. In addition to influencing an individual's ability to understand nutrition-related information (21,38,40,269,270), educational attainment can reflect differentials in social networks, prestige, power, influence, and other socioeconomic and psychosocial differences that can influence diet quality (4,21,38,40). Given the many ways that educational attainment could influence diet quality (21,37,214,271), there could be multiple opportunities to intervene and reduce inequities in diet quality by investigating the role of educational attainment in shaping diet quality. Depending on the target population (272,273), ensuring culturally appropriate curriculum, reducing financial, geographic, and language barriers in the education system, and fostering a

sense of self-efficacy and control could all potentially play a role in closing gaps in education and reducing inequities in diet quality.

While there are gradients in diet quality across levels of educational attainment, the results from the intersectional SEP model presented in **Chapter 4** also provide evidence of heterogeneity in diet quality within levels of educational attainment. Across the SEP intersections defined by an individual's educational attainment and Indigenous identity and race/ethnicity, for example, individuals identifying as Indigenous with some post-secondary education had the lowest predicted HEI-2015 scores, while individuals identifying as Middle Eastern without a high school diploma had the highest. Since these patterns in diet quality could not be anticipated based on the results of the individual SEP model alone, attending to intersection-specific differences in diet quality could provide insight into the social and environmental exposures that are potentially important to improving diet quality in specific subgroups. Given the multiple pathways through which educational attainment can shape diet quality across, and within, levels of educational attainment, both universal and precision public health initiatives could play an important role in improving diet quality across and within levels of educational attainment.

2) Group membership, whether marginalized or privileged, can influence diet quality in positive and negative ways

While occupying a marginalized position in society can negatively influence individuals, such experiences do not necessarily translate to lower diet quality. The studies presented in **Chapters 4** and **5** demonstrate that individuals can simultaneously occupy a marginalized SEP and have a higher diet quality than their more advantaged counterparts. Findings such as these highlight that an individual's diet quality is influenced by a variety of differences between SEP groups that include, but are not limited to, social marginalization and privilege. Importantly, they highlight that overly simplistic notions of social marginalization/privilege resulting in worse/better outcomes do not accurately capture the complex ways in which power shapes individual experiences. Since power does not *determine* experiences, it is important to acknowledge that group membership, even socially marginalized group memberships, has the potential to positively shape diet quality. In the following sections, I will provide examples of these seemingly counterintuitive findings and propose potential explanations.

The results presented in **Chapter 4** highlight that individual SEP dimensions may interact with other societal and cultural factors to shape an individual's diet quality. Some of the findings presented in this study were intuitive based on existing knowledge about marginalization and privilege, however, marginalization and

privilege do not completely explain the results from either the individual or intersectional SEP models. On the one hand, for example, individuals who identified as Indigenous, did not have a high school diploma, and/or were living in severely food insecure households had some of the lowest predicted HEI-2015 scores, which could be related to marginalization. On the other hand, marginalization does not explain why individuals identifying as South Asian, and individuals identifying as Middle Eastern without a high school diploma had some of the highest predicted HEI-2015 scores. It is necessary to consider how other socioeconomic advantages, such as above average educational attainment and representation in professional occupations (274), may intersect to facilitate higher diet quality for some racialized groups in Canada.

Cross-cultural differences in dietary practices may also help explain patterns in predicted HEI-2015 scores related to race/ethnicity (not including Indigenous identity) observed in **Chapter 4**. For instance, individuals identifying as South Asian and Middle Eastern had higher predicted HEI-2015 scores than the dominant racial group in Canada. This may be partly due to adherence to their traditional cultural eating patterns that can sometimes be healthier than Western ones (45,275). Given that dietary practices differ considerably within and across racial/ethnic groups, it is important to consider how a variety of factors may intersect with SEP to differentially influence individuals' diet quality.

One factor that may explain how an individual's educational attainment and race/ethnicity intersect to explain my intersectional findings in **Chapter 4** is acculturation or the extent to which individuals adopt elements of a new cultural environment. Acculturation is influenced by factors such as age, immigration generation, country of origin, religion, and educational attainment (220,223). Formal education can act as a catalyst for acculturation by placing individuals in environments that facilitate exploring and learning (220,221); however, limited dietary acculturation could also protect against adopting Western dietary patterns, which are associated with declines in diet quality (30). Limited dietary acculturation may therefore explain why individuals identifying as Middle Eastern without a high school diploma had one of the highest predicted HEI-2015 scores.

Similarly, the results in **Chapter 5** indicated that living in an area with a higher proportion of recent immigrants and visible minorities was associated with higher, not lower, diet quality. As the detrimental effects of xenophobia and racism on health would lead us to expect the opposite (276), these forms of marginalization cannot explain these results. One reason specific to the neighbourhood level that could explain these findings is that individuals living in areas with a higher proportion of recent immigrants and visible minorities may have higher access to a diversity of foods, including healthy foods commonly consumed outside of typical Western dietary patterns (26). This may assist them to retain their cultural dietary patterns

and resist acculturating to dominant Western dietary patterns. Therefore, overly simplistic assumptions about the impact of marginalization on diet quality—while helpful to centre oppression and privilege—may not accurately reflect associations between SEP and diet quality in all contexts, including diet quality at the individual and neighbourhood levels.

3) Contextual factors may interact to shape inequities in diet quality

Intersectional scholars are increasingly emphasizing that the places people live are made up of multiple dimensions that can interact to shape individual experiences (18,19). From a public health perspective, these interactions are worth exploring as they challenge the perceived inevitability of inequities by SEP and highlight how, with appropriate action, these inequities could be possibly attenuated or even eliminated. Therefore, in **Chapter 6**, I sought to identify cross-country differences in SEP-diet quality associations that might suggest that inequities in diet quality by SEP are contextually dependent. However, other than diet quality being lower among adults in the US compared to Canada, I was not able to detect any cross-country differences that might suggest that inequities in diet quality are moderated by contextual factors.

From an intersectional perspective, the inability to detect contextual differences in inequities in diet quality may be due to a reliance on an individual's

country of residence as the sole contextual indicator. As evidenced by my findings presented in **Chapter 5**, synergistic and antagonistic interactions at the neighbourhood level could have obscured cross-country differences in diet quality. Beyond neighbourhood contexts, the places in which people live are shaped by numerous factors that could interact to render country of residence an insufficiently specific indicator of differences in diet quality across contexts. To better assess how inequities in diet quality differ across contexts, future studies should examine exposures to specific policies, programs, and social conditions that could mutually shape associations between SEP and diet quality.

The study presented in **Chapter 5** illustrates how using multiple indicators to contextualize the places people live could aid in generating evidence that highlights the context-dependent nature of inequities in diet quality. Since only two out of the four neighbourhood deprivation dimensions were significantly associated with diet quality, and not all in the same direction, using only the CAN-Marg summary score as my measure of neighbourhood deprivation would have led me to incorrectly conclude that neighbourhood deprivation was not associated with diet quality. However, by testing all two-way interactions between the CAN-Marg dimensions, I was able to identify the specific neighbourhood contexts in which dimensions of neighbourhood deprivation were most strongly associated with diet quality. Similarly, rather than concluding that there was no association between the age and labour

force dimension and diet quality after only testing the main effect models, testing interactions between the CAN-Marg dimensions allowed me to identify one, of potentially many, specific contexts in which the age and labour force dimension was significantly associated with diet quality. Together, these findings highlight the need to examine interactions between multiple contextual indicators, as only assessing differences in inequities in diet quality by country of residence could obscure meaningful cross-country differences in diet quality at sub-national levels.

4) SEP can have both additive and multiplicative effects on diet quality

Intersectional scholars often emphasize the need for multiplicative approaches to identify the ways social structures intersect to produce unique experiences across SEP intersections. The value of adopting a multiplicative approach to examining diet quality across SEP intersections is evident in **Chapters 4** and **5**. As already mentioned, in **Chapter 4**, there was heterogeneity across SEP intersections defined by an individual's educational attainment and Indigenous identity and race/ethnicity that could not have been predicted based on the results of the individual SEP model. Additionally, in **Chapter 5**, the significant interaction between the neighbourhood material resources and age and labour force dimensions suggests heterogeneity in diet quality that could have only been identified by considering how these two neighbourhood deprivation dimensions were jointly associated with diet quality.

Intersectionality emphasizes that axes of inequality do not merely add together (additivity) but intersect in complex ways to produce unique experiences (multiplicativity) (121). Based on the results of the individual SEP model, it was not surprising that individuals without a high school diploma living in severely food insecure households had the lowest predicted HEI-2015 scores. In this instance, simply using the insights from the individual SEP model for educational attainment and household food insecurity status yielded additive insights that sufficiently explained HEI-2015 scores. At other times, an additive approach to explaining differences in diet quality was insufficient in predicting HEI-2015 scores across SEP intersections, such as the ones defined by an individual's educational attainment and Indigenous identity and race/ethnicity. These findings highlight the need for multiplicative approaches to examine diet quality across SEP intersections, as they might capture heterogeneity that additive approaches might miss (248).

Despite the evidence of intersectional multiplicativity from this dissertation, it is important to remember that additivity can still be a useful concept to describe how social structures independently shape diet quality. Indeed, the results from this dissertation demonstrate that the individual components that make up a SEP intersection can at times be sufficient to predict an individual's diet quality. In **Chapter 4**, for example, diet quality across the SEP intersections defined by an individual's educational attainment and household food insecurity status were

consistent with the results from the individual SEP model, suggesting that the social structures shaping diet quality across these two dimensions are useful for explaining differences in diet quality across the intersections defined by these two SEP dimensions. Moreover, the findings in **Chapter 6** did not generate evidence to suggest that associations between SEP and diet quality differ between Canada and the US, suggesting that additive explanations may explain differences in diet quality in this study. Since the concept of additivity is not incompatible with intersectionality and can at times sufficiently explain differences in diet quality across SEP intersections, the need for population-wide or universal interventions can still emerge as an evidence-based suggestion from intersectional research.

7.4 Strengths and limitations of included studies

There are several overarching strengths and limitations of the studies presented in **Chapters 4, 5** and **6**. Most importantly, the strength of the studies included in this dissertation is the use of intersectionality as an analytic framework to identify heterogeneity in diet quality across individual, household, neighbourhood, and country contexts. Using intersectionality in this way allowed me to generate evidence that demonstrate how some inequities in diet quality are not universal and instead are contingent on certain socioeconomic and contextual factors. Decisions, however, were made to limit the breadth and depth of the studies included in this dissertation, which meant that not all potentially meaningful SEP dimensions,

intersections, and contexts were assessed (e.g., disability, sexual orientation, policy contexts). These decisions were made with the recognition that there is always the opportunity for future research to expand on the analyses conducted in this dissertation. For example, researchers can use findings from this dissertation to inform future analyses of whether associations between individual-level SEP indicators and diet quality differ across neighbourhood contexts.

An intersectional approach combined with population-based data allowed me to identify potentially important heterogeneity in diet quality that can inform public health policies. The large and diverse analytic samples allowed me to detect heterogeneity in diet quality that could be difficult to detect in smaller or less representative datasets. Conversely, my approach may have missed socioeconomic differences that shape diet quality among certain communities that were not represented in my samples. Therefore, future research should seek to identify other SEP intersections that may be better captured in other data sets as they may be important to address dietary inequities within specific provinces, territories, or municipalities.

All studies in this dissertation relied on data from studies that used 24-hour dietary recall data (259). This method of dietary data collection has been shown to improve recall accuracy, especially compared to food frequency questionnaires, which are also commonly used for population-level dietary assessment (238,277).

However, as with all self-reported dietary data, misreporting is always a concern (46,225,226). Sensitivity analyses in **Chapters 5** and **6** aimed to assess the influence of dietary misreporting and yielded generally consistent results. As under-reporting (and over-reporting) is not random and is more prevalent among certain population groups (278), misreporting can inflate differences between SEP groups, such as those related to sex/gender, age group, and educational attainment (278). It is also important to note that all analyses were based on a single day of recall, which can provide valid estimates of mean population intake (229) but do not capture within-person variability in dietary intake (227,228). Future studies should collect multiple dietary recalls and use the National Cancer Institute method to estimate usual intakes of nutrients and foods to account for within-person variability in diet quality (228,279,280).

While considering the role of context can help generate hypotheses about underlying structural and societal influences on inequities in diet quality (119), the indicators available in population-based health surveys—including the CCHS-N and IFPS—provide very limited insights into the specific conditions that could be targeted to reduce inequities in diet quality. Merging data from the CCHS-N with environmental databases containing country-wide data on the food and built environment can help identify availability and accessibility barriers that shape diet quality (281,282). Still, to inform evidence-based strategies to improve diet quality it

is necessary to explore how participating in specific social programs, such as income assistance and food subsidy programs, are associated with diet quality.

It is worth noting the weighting practices adopted in this dissertation. In **Chapter 4**, neither sampling nor bootstrap weights provided in the 2015 CCHS-N dataset were incorporated into the CRF analyses because they interfere with variable selection and may compromise the validity of the estimates (139). As CRF do not generate effect and variance estimates, it is not clear whether this decision influenced the generalizability of the results. All estimates presented in **Chapter 5** were weighted with sampling and bootstrap weights, making the estimates nationally representative with respect to age, sex, and region of residence. The study presented in **Chapter 6** was not based on nationally representative data, but the use of post-stratification sampling weights resulted in a sample that mirrored the national distribution of the Canadian and US populations with respect to age group, sex, region, ethnicity (US only) and education. Future research should explore how weighting procedures can be used to analytically correct for under-representation in the data that could affect the reliability of estimates for under-represented groups.

Limitations related to the contextual indicators assessed in this dissertation must also be considered. In **Chapter 5**, neighbourhood deprivation was only based on participants' residential postal codes. Therefore, neighbourhood contexts in this study only refer to residential neighbourhood contexts, and not work, school,

recreational, or any other potentially relevant work contexts. Lastly, as previously mentioned, the study in **Chapter 6** only assessed context based on a single indicator reflecting participants' country of residence. Due to exposure to various contextual factors that may interact, such an assessment of context could obscure cross-country differences in diet quality by SEP in smaller geographic areas. From an intersectional perspective, there are likely other contextual factors that interact to shape diet quality that are worth exploring in future research.

7.5 Implications for public health policy and research

This dissertation makes three key contributions to advancing quantitative intersectionality research in public health:

1) *Uncovering the social structures and dynamics shaping diet quality*

At the core of intersectionality is an emphasis on interlocking systems of power that influence everyday experiences, shifting attention away from individual characteristics and towards broader structures of oppression and privilege (12,110). This intentional focus on power, oppression, and privilege is essential to highlight the structural determinants of dietary inequities that are often not directly observable, and therefore, easy to overlook (283). For this reason, my dissertation used SEP indicators to provide insights into the structural determinants of inequities in diet quality. For example, in **Chapter 4,** I highlighted how the structural influence of

educational attainment on diet quality may differ by Indigenous identity and race/ethnicity because of differential socioeconomic returns of formal education based on an individual's Indigenous identity and race/ethnicity. In **Chapter 5**, I drew attention to how the accessibility and affordability of healthy foods can influence the diet quality of individuals living in neighbourhoods that are simultaneously more materially deprived and have a smaller proportion of non-working individuals. Lastly, in **Chapter 6,** I suggested differences in the food environment that may contribute to higher diet quality among adults in Canada than in the US, such as more extensive physical, social, cultural, and digital exposure to unhealthy, energy-dense, nutrient-poor foods in the US. When my findings could not be fully explained by structural factors such as oppression and privilege, I provided suggestions of sociocultural factors that can contribute to differences in diet quality across SEP groups.

2) *Advancing intersectionality as a context-informed tool*

A core tenet of intersectionality is to understand the broader influence of social and structural contexts on individual experiences (108–110,234). Consequently, much of intersectional health research uses individual-level social identities to indirectly capture the broader influence of interpersonal and structural dynamics on health-related experiences (14,106). However, intersectional scholars increasingly advocate for a more direct assessment of structural influences by incorporating area-level variables into intersectional analyses (18–20,153). In line

with this extension of intersectionality, the studies presented in **Chapters 5** and **6** use intersectionality as a context-informed tool to examine and compare SEP-diet associations across neighbourhood and country contexts. This application extends traditional applications of intersectionality, emphasizing that inequities in diet quality are dependent on social and structural contexts.

It is worth noting, that although I did not find evidence that associations between SEP and diet quality differed between Canada and the US in **Chapter 6**, cross-country comparisons may still be useful for revealing the context-dependent nature of inequities in diet quality. For instance, several studies have found that associations between various SEP indicators and health outcomes differed between Canada and the US (284–286). Therefore, it is important to continue to explore how differential access to resources, environments, and experiences may differentially shape an individual's diet quality through cross-country comparisons using other SEP indicators, such as race/ethnicity and immigration status.

3) Interrogating overlooked socioeconomic intersections

Within an intersectional framework, the emphasis on avoiding assumptions of homogeneity can provide a theoretical rationale for conducting non-hypothesis driven research (14,138,153,154). In the study presented in **Chapter 4**, I employed CRF to identify SEP intersections that best predicted HEI-2015 scores. The analytic

approach used in this study allowed me to compare diet quality across a broader range of SEP intersections than would conventionally be assessed using regression modelling. For example, if instead of using CRF, I used multivariable linear regression to test statistical interactions between SEP indicators, I still would have missed differences in diet quality not involving the reference group. Although various analytic techniques can theoretically be used to generate intersectional insights (108), they all have limitations for intersectional inquiry. For example, while useful for assessing the context-dependent nature of SEP-diet associations, regression-based models have parametric limitations that can make it onerous to assess all possible SEP configurations. On the other hand, CRF, despite relying on less parametric assumptions, still requires researchers to make numerous decisions, such as those related to variable selection, which can limit the range of SEP intersections researchers investigate in a single study. Consistent across all three studies, I used a theory-driven approach for variable selection, combined with either a data-driven or statistical modelling approach, to reveal unexpected heterogeneity in diet quality while producing interpretable findings to inform evidence-based strategies to improve diet quality.

Some methodological limitations could potentially be addressed by combining analytic techniques within a single study using a two-step process. For example, researchers can use machine learning techniques, such as CRF, to identify relevant

variables and intersections to further investigate using causal inference techniques, such as regression-based models, to calculate effect and variance estimates for potentially important SEP intersections (138). Additionally, recent and ongoing advances that enable causal inference using machine learning techniques may also help researchers generate explanatory insights with predictive modelling techniques (149).

7.6 Conclusions

Over the past decade, intersectionality has emerged as a powerful analytic framework with the potential to enrich public health research and policy by encouraging researchers to consider the heterogeneous ways in which social structures intersect to shape individual experiences (108,109,121,173,174). Despite increasing calls to use intersectionality to guide empirical research, few studies have used this approach to examine inequities in diet quality. To advance public health research, my dissertation used an intersectional approach to identify and interpret differences in diet quality across SEP intersections and contexts. By situating inequities in diet quality within broader social structures and contexts, the studies presented in this dissertation challenge the ubiquity of inequities by SEP.

This dissertation demonstrates how an intersectionality framework can be used to identify heterogeneity in diet quality. In **Chapter 4**, I demonstrate that

educational attainment was the strongest SEP predictor of diet quality. Yet, substantial heterogeneity within levels of educational attainment indicated that other factors, namely sociocultural factors, may be key to improving diet quality among SEP subgroups. The study presented in **Chapter 5** show that neighbourhood material deprivation was associated with lower diet quality, but it also demonstrates the need to consider how other neighbourhood contexts may modify associations between neighbourhood deprivation and diet quality. Lastly, the study in **Chapter 6** provide evidence that contextual differences related to the countries in which people live may influence their diet quality, but future studies are needed to identify specific contextual factors that may underly inequities in diet quality by SEP.

Taken together, this dissertation demonstrates how an intersectional approach to quantitative health research can be used to draw attention to the complex and context-dependent nature of inequities in diet quality. This dissertation broadens and enriches understandings of inequities in diet quality by generating knowledge that sometimes supports, while other times challenges, additive assumptions about socioeconomic disadvantages/advantages and dietary inequities. As methods themselves are not intersectional, there is a great need to explore how conventional and novel techniques can be leveraged to generate insights into the complex ways in which structural and sociocultural factors may intersect to shape

diet quality. Such insights may highlight opportunities to address the root causes of poor diet quality in the population.

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