Evaluating the associations between social variables and nutritional risk in a population cohort of Canadian adults

Nicole Ingham

School of Human Nutrition

McGill University, Montreal

Date: December 2022

A thesis submitted to McGill University in partial fulfillment of the requirements of the degree of Master of Science

TABLE OF CONTENTS

ABSTRACT (ENGLISH)

Background: Nutritional risk is a public health concern associated with aging. While nutritional risk has been linked to various individual social factors, an assessment of the relationship between nutritional risk and the overall strength of social environment, through the assessment of multiple social factors in combination, has not been considered in previous research.

Objective: To evaluate associations between the strength of social environment and nutritional risk using cross-sectional data from the Canadian Longitudinal Study on Aging (n=20,786). Subgroup analyses were performed among middle-aged (45-64 years, n = 13,060) and older-aged (≥65 years, n = 7,726) subgroups. Consumption of four major food groups (whole grains, proteins, dairy products, and fruits and vegetables) by social environment group was assessed as a secondary outcome.

Methods: Latent class analysis (LCA) was performed to classify participants into social environment groups according to data on network size, social participation, social support, social cohesion, and social isolation. Nutritional risk was assessed with the SCREEN-II-AB questionnaire and consumption of food groups by the Short Dietary Questionnaire. Analysis of covariance was conducted to compare estimated means of the SCREEN-II-AB score by strength of social environment group, adjusted for sociodemographic and lifestyle factors. Three statistical models were performed with increasing adjustment (model 1: adjusted for age, sex, and province; model 2: additionally adjusted for income, education, urban/rural residence, ethnicity and immigration status; model 3: additionally adjusted for smoking status). Models were repeated to compare the mean consumption of food groups (times/day) by social group.

Results: LCA identified three distinct social environment groups classified as low, medium, and high social strength (18%, 40%, and 42% of the sample, respectively). Adjusted mean SCREEN-

II-AB scores differed significantly between all social environment groups in a dose-response manner for all three statistical models, with the low social strength group consistently having an adjusted mean score indicating high nutritional risk. For the fully adjusted model, Model 3, adjusted mean SCREEN-II-AB scores were as follows; Low: 37.1 (99% confidence interval (CI): 36.8, 37.4); Medium: 39.3 (39.2, 39.5); High: 40.3 (40.2, 40.5), ($p<0.0001$). Respondents in the low strength of social environment group also reported significantly lower consumption frequency of the proteins, dairy, and fruits and vegetables food groups (including and excluding juices) compared to the medium and high social strength groups with some variation among age subgroups ($p<0.002$). Responses significantly differed by strength of social environment for all items of the SCREEN-II-AB, with the low social strength group indicating greater frequency of skipping meals, having a poorer appetite, difficulty swallowing food, and cooking their own meals compared to the other social groups. The low strength of social environment group also indicated lower daily servings of fruits and vegetables, cups of fluids, and the consumption of meals with others.

Conclusions: These findings suggest that adults with weak social environments are more vulnerable to nutritional risk. Nutritional risk interventions should consider social factors as targets.

Keywords: Aging; social environment; nutrition; nutritional risk; food groups; CLSA

RESUMÉ (FRENCH)

Contexte : Le risque nutritionnel est un problème de santé publique associé au vieillissement. Bien qu'il ait été associé à divers facteurs sociaux individuels, une évaluation de la relation entre le risque nutritionnel et la force globale de l'environnement social, par le biais de l'évaluation de plusieurs facteurs sociaux combinés, n'a jamais été considérée.

Objectif : Évaluer les associations entre la force de l'environnement social et le risque nutritionnel à l'aide des données de l'Étude longitudinale canadienne sur le vieillissement (n = 20 786). Des analyses par sous-groupe ont été réalisées avec des sous-groupes d'âge moyen (45-64 ans, n = 13 060) et d'âge plus avancé (≥ 65 ans, n = 7 726). La consommation de quatre principaux groupes d'aliments (grains entiers, protéines, produits laitiers, et fruits et légumes) selon le groupe d'environnement social a été évaluée comme résultat secondaire.

Méthode : Une analyse de classes latentes (ACL) a été réalisée pour classer les participants dans des groupes d'environnement social en fonction de données sur la taille du réseau, la participation sociale, le soutien social, la cohésion sociale et l'isolement social. Le risque nutritionnel a été évalué avec le questionnaire SCREEN-II-AB et la consommation des groupes d'aliments avec le Short Dietary Questionnaire. Une analyse de covariance a été réalisée pour comparer les moyennes estimées du score au SCREEN-II-AB entre les groupes d'environnement social, en ajustant pour des facteurs sociodémographiques et liés au mode de vie. Trois modèles statistiques ont été réalisés avec un ajustement croissant (modèle 1 : ajusté pour l'âge, le sexe et la province; modèle 2 : additionnellement ajusté pour le revenu, l'éducation, la résidence urbaine/rurale, l'origine ethnique et le statut d'immigration; modèle 3 : additionnellement ajusté pour le tabagisme). Les modèles ont été répétés pour comparer la consommation moyenne des groupes d'aliments (nombre de fois/jour) selon le groupe social.

Résultats : L'ACL a identifié trois groupes d'environnement social distincts ayant une force sociale faible, moyenne et élevée (18 %, 40 % et 42 % de l'échantillon, respectivement). Les scores ajustés obtenus au SCREEN-II-AB différaient significativement entre ces groupes en suivant une relation dose-réponse pour chaque modèle statistique. Le groupe d'environnement social faible avait un score indiquant systématiquement un haut risque nutritionnel. Pour le modèle complètement ajusté (modèle 3), les scores obtenus au SCREEN-II-AB étaient les suivants; faible : 37,1 (intervalle de confiance (IC) à 99 % : 36,8; 37,4); moyen : 39,3 (39,2; 39,5); élevé : 40,3 (40,2; 40,5), ($p < 0,0001$). Les répondants du groupe d'environnement social faible ont également rapporté une consommation significativement moins fréquente de protéines, de produits laitiers, et de fruits et légumes (en incluant et excluant les jus) comparativement aux groupes d'environnement social moyen et élevé, avec quelques variations entre les sous-groupes d'âge ($p < 0,002$). Les réponses différaient significativement en fonction de la force de l'environnement social pour tous les items du SCREEN-II-AB, le groupe de faible force sociale ayant indiqué sauter des repas plus fréquemment, avoir un appétit plus faible, avoir plus de difficultés à avaler la nourriture, et cuisiner des repas plus fréquemment comparativement aux autres groupes sociaux. Le groupe ayant un faible environnement social a également rapporté un nombre plus faible de portions quotidiennes de fruits et légumes, de tasses de liquide, et de repas consommés en compagnie d'autres personnes.

Conclusion : Ces résultats suggèrent que les adultes ayant un environnement social faible sont plus vulnérables au risque nutritionnel. Les interventions sur le risque nutritionnel devraient considérer les facteurs sociaux comme cibles potentielles.

Mots-clés : Vieillissement; environnement social; nutrition; risque nutritionnel; groupes d'aliments; ÉLCV

ACKNOWLEDGEMENTS

I would firstly like to thank Dr. Nielsen for her continued guidance, support and brilliant insight throughout the duration of my thesis and my time at McGill. I would also like to thank Katherine Labonté for her guidance and endless encouragement, she has helped me to become a better and more well-rounded scientific writer, academic, professional and person. I would also like to thank my lab members for their continued insight and guidance. I would especially like to thank lab member Atheer Attar for her kindness and compassion and her endless advice and insight. I am eternally grateful for my family and friends who supported me daily and especially during my time at McGill and while writing my thesis. I am extremely grateful for the opportunity I had this past summer to intern with Johnson and Johnson as the experience allowed me to grow immensely as a future professional. I know that my time as a master's student at McGill has helped me to grow not only academically and professionally but also as a person. I will always cherish the time I spent attending this marvellous institution surrounded by wonderful and brilliant people.

CONTRIBUTIONS OF AUTHORS

Nicole Ingham (MSc Candidate) was mainly responsible for conducting the analysis. The candidate conducted the formal statistical analysis, wrote the thesis, and prepared all the figures and tables.

Dr. Daiva Nielsen (Supervisor of Candidate, Assistant Professor and William Dawson Scholar, School of Human Nutrition McGill University): provided access to the CLSA database, obtained ethics approval, and provided continuous research guidance and feedback for data analysis. Dr. Nielsen thoroughly contributed to the editing of this thesis.

Dr. Stéphanie Chevalier (Associate Professor, School of Human Nutrition McGill University): provided feedback on Colloquium presentations, statistical analysis and helped edit and format this thesis.

Dr. Katherine Labonté (Post-Doctoral Fellow, School of Human Nutrition McGill University): provided feedback on statistical analysis approaches and helped edit this thesis.

Dr. Catherine Paquet (Professor; Department of Marketing, Faculty of Business Administration, Université Laval): provided feedback on statistical analysis approaches and helped with interpretation of results.

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

CLSA: Canadian Longitudinal Study on Aging, SCREEN-II-AB: Seniors in the Community Risk Evaluation for Eating and Nutrition II- Abbreviated, LCA: Latent class analysis, SDQ: Short Dietary Questionnaire, DR: Dimensionality Reduction, FA: Factor Analysis, PCA: Principal Component Analysis.

CHAPTER 1: INTRODUCTION

Nutritional risk is a condition on the continuum between satisfactory nutritional status and malnutrition (1). The signs and symptoms associated with chronic malnutrition are often erroneously attributed to the normal aging process (1). Older aged individuals are more vulnerable to nutritional risk and health outcomes related to inadequate nutrition due to physiological changes associated with the aging process such as weakened senses and reduced appetite (1, 2). Therefore, adequate nutritional screening and assessment methods are paramount for the prevention of consequences associated with prolonged undernutrition, including malnutrition, falls, hospitalization, frailty, and death (1, 3). Social circumstances such as eating alone and insufficient help with grocery shopping and meal preparation may likewise contribute to nutritional risk in older aged adults (2).

Social factors such as emotional security and social relationships are important determinants of health and disease and largely impact the aging process (4-6) with an increased need for social support as individuals age (7). Evidence from diverse health-related research illustrates the importance of strong social ties, both in quality and in quantity (8). Research on mortality has reported that the risk of death from all causes for men and women with the fewest number of social relationships was more than twice as high compared to those with strong social relationships (9). Furthermore, impaired social support networks are not only associated with increased risk for all-cause mortality but also poor nutritional behaviours (7). Considering demographic factors and mental and physical well-being, low social support and less than weekly social participation have been shown to be significantly associated with an increased likelihood of nutritional risk (1). Living alone and having limited social networks have also been previously identified as risk factors for poor nutritional status (1, 7). Conversely, numerous social factors have been previously associated with good nutritional status, including being married, having a sense of trust and security in the community and participating in religious organisations (7). While the relationship between individual social factors and nutritional risk status has been previously evaluated (7), the simultaneous relationship between multiple social factors and their overall contribution to the strength of the social environment has not been considered. As social factors may act synergistically to affect nutritional outcomes (10), an investigation that assesses multiple social factors in combination is warranted.

Given that the strength of the social environment may be determined by multiple social factors in combination, the primary objective of the present study was to assess the relationship between the distinct strength of social environment groups and nutritional risk status among adults. The strength of social environment groups were composed of individual measures of network size, social support, social cohesion, and objective social isolation. Evaluation of the consumption of major food groups (whole grains, protein foods, dairy products, and fruits and vegetables) by the strength of social environment group and nutritional risk status was a secondary objective. Compared to a strong social environment group, weaker social environment groups were hypothesized to have higher nutritional risk status and lower consumption of health-promoting foods. To explore whether associations varied across life stages, analyses were conducted among the total sample as well as by middle-aged (45-64 years) and older-aged (≥65 years) subgroups.

CHAPTER 2: LITERATURE REVIEW

Malnutrition and Nutritional Risk

Malnutrition is a commonly under-diagnosed and chronically undertreated condition, the result of nutrient deficiency, imbalance or excess (11). Malnutrition can be a consequence of disease, or regrettably, the underlying condition that results in disease (11). The physiological consequences of prolonged malnutrition produce quantifiable adverse health outcomes related to bodily functioning and body composition (11, 12). Malnutrition should be considered a supplementary disease, due to its capacity to worsen clinical outcomes and increase the likelihood of all-cause mortality and morbidity (13). Proper nutritional intervention can prevent and mostly reverse the clinical symptoms and long-term consequences of prolonged malnutrition; however, malnutrition often remains undetected due to a lack of knowledge, awareness and the existence of proper pre-emptive clinical protocols (13).

Malnutrition is a clinical disorder and likewise, malnutrition risk screening identifies individuals in a clinical setting who present at risk for malnutrition, i.e., those presenting with inadequate food intake, functional loss or weight loss (14). Malnutrition screening tools, such as the Malnutrition Screening Tool (MST) (15) and the Malnutrition Universal Screening Tool (MUST) (16), identify malnutrition risk in a clinical setting, however, they do not consider the determinants and risk factors that place an individual at risk for poor nutrition (14). In other words, there are several determinants and risk factors that impact dietary intake that are not taken into consideration with malnutrition risk screening. To address the limitations associated with malnutrition risk screening, nutritional risk screening identifies and acknowledges the influence of these determinants and risk factors on dietary intake and pinpoints where intake does not meet dietary recommendations (14). If insufficient dietary intake persists without proper nutritional intervention, intake will eventually fail to meet dietary requirements, resulting in adverse health events and loss of weight, muscle tissue and function (14). At this point, the upper threshold of identifiable nutritional risk has been surpassed and the clinical indications of malnutrition are present (14).

Nutritional Risk Screening

Nutritional risk screening builds upon the foundation of malnutrition screening by identifying the determinants and risk factors that place an individual at risk for inadequate food intake that, if uninterrupted, can result in malnutrition (14). Nutritional risk screening is essential for the implementation of focused community-level interventional programs and policies due to its identification of vulnerable sub-populations (1). Over the last several decades, a number of screening tools have been developed to identify nutritional risk, including the Mini Nutrition Assessment – Short Form (MNA-SF) (17), the Nutrition Risk Screening 2002 (NRS 2002) (18), the Short Nutritional Assessment Questionnaire (SNAQ) (19), the Canadian Nutrition Screening Tool (CNST) (20), and the complete and abbreviated forms of the *Seniors in the Community Risk Evaluation for Eating and Nutrition*, version I (SCREEN-I and SCREEN-I-AB respectively) and II (SCREEN-II and SCREEN-II-AB, respectively) (21). The SCREEN-II has been demonstrated to be more valid when compared to the SCREEN-I in the identification of nutritional risk in aging adults due to improved sensitivity, specificity and reliability (21-23).

To screen for nutritional risk while limiting the time burden imposed on study participants, many researchers interested in nutritional risk have used the SCREEN-II-AB (21). The SCREEN-II-AB was developed from the SCREEN-II, a 14-item skip pattern questionnaire with queries pertaining to weight changes, dietary intake, appetite and meal preparation (21). Per the recommendations of clinical dietitians with expertise in seniors' nutrition, each item of the

SCREEN-II was ranked based on its importance to the construct of nutritional risk; the items were then regressed to determine which were the most predictive of nutritional risk rating (21). The most predictive elements of the SCREEN-II were identified and used to form the SCREEN-II-AB (21). Seven questions were omitted or consolidated from the SCREEN-II to form the SCREEN-II-AB, including i) Have you been trying to change your weight in the past 6 months; ii) Do you think your weight is?... (perception of overweight, underweight, or appropriate weight); iii) Do you limit or avoid certain foods?; iv) How often do you eat meat, eggs, fish, poultry or meat alternatives?; v) How often do you have milk products?; vi) Do you use commercial meal replacements or supplements; vii) Do you have any problems getting your groceries? (22).

Social and Lifestyle Factors Related to Nutritional Risk

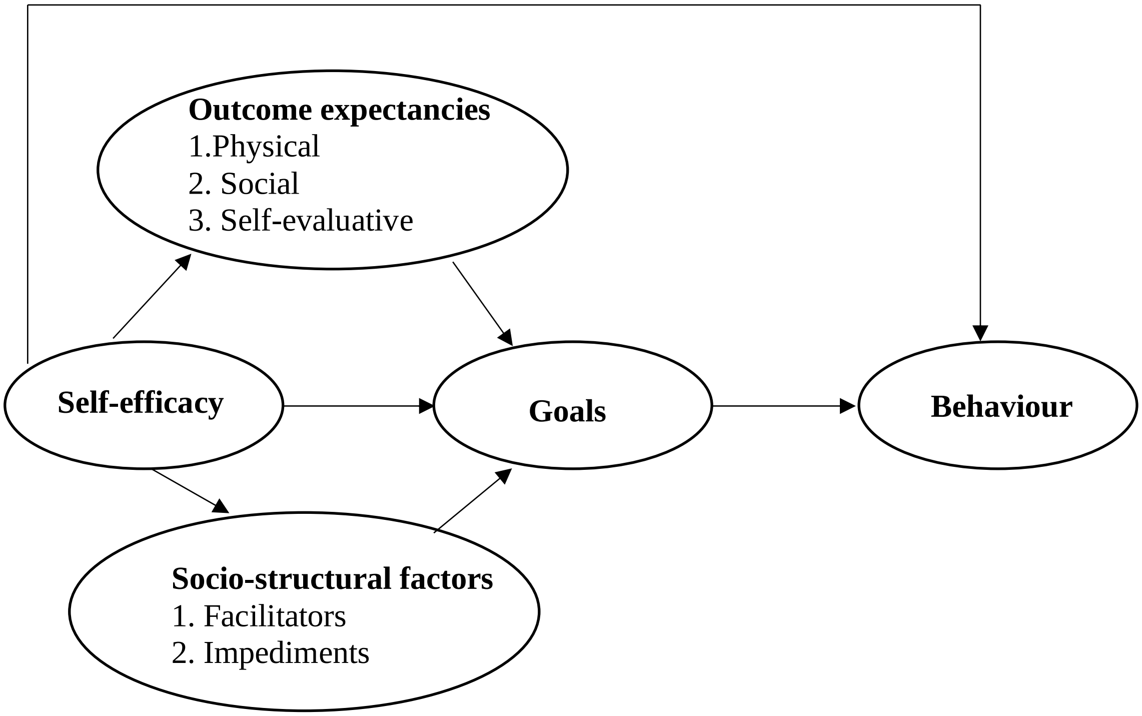
Current prevalence data indicates that nearly one-third of Canadians aged 65 and older are at nutritional risk, with 4.5 kg weight loss or gain in the past six months and frequent meal skipping (almost every day), being the two main contributors (1). Older aged Canadians, especially women, are more vulnerable to nutritional risk due to the physiological changes associated with the aging process, including a weakened sense of taste and smell and reduced appetite (1). Increased medication usage in the aging population can interfere with the consumption, absorption and metabolism of key nutrients and is also associated with increased nutritional risk (1). In addition to these biological and health-related considerations, social factors have also been implicated, although patterns of association differ by various factors such as gender (1). Social determinants of Health (SDOH) refers to the simultaneous relationship that exists between social factors that determine optimal health, and social factors that determine inequalities in health including conditions and situations in which individuals are born, grow, age, live and work (24, 25). A plethora of social factors have been identified as playing a powerful role in health promotion and health inequality including income, education, living environment and nutrition (24).

According to an analysis performed by Ramage-Morin et al., women aged 75 and older were more likely to be at nutritional risk compared to their younger female counterparts, aged 65-74 years old, however, when economic, social and psychological variables were taken into consideration, age served as a protective factor against nutritional risk in women but not men (1). In multivariate analysis, lower household income and education were not significantly statistically associated with nutritional risk in women; however, income was associated with a significantly higher probability of nutritional risk in the lowest income bracket compared to the highest income bracket for men (1), poverty being a major indicator of increased nutritional risk (7). Additionally, education level and income are both inversely associated with poor nutritional health in both men and women; higher education levels correlate with improved nutritional education and enhanced autonomy when making health-related decisions (7).

Social Environment and Nutritional Risk

The Social Cognitive Theory (**Figure 1**) hypothesizes that behaviour is influenced by a multitude of simultaneously influential personal and environmental factors (26, 27). This model indicates that self-efficacy may, directly and indirectly, influence health behaviours through factors that create the social environment (26, 27). In that regard, the factors that form the social environment (social support, social cohesion, network size and social isolation), have been shown to contribute positively or negatively to nutritional risk in middle-aged and older aged individuals (7).

Figure 1: Visualization of Social Cognitive Theory
Adapted from: H Chin & S Mansori, 2018 (28)



Psychological factors such as depression, isolation and grief present in the aging population can negatively contribute to nutritional risk status, and according to recent literature, 62% of older aged individuals with depression were at nutritional risk compared to 33% of older aged individuals without depression (1). Nonetheless, population-based research suggests that rates of depression and anxiety may be lower among older adults compared to their younger counterparts (29). The occurrence of adverse psychological factors may depend, in part, on the social situations of older individuals (30). Nutritional risk can be reduced by increasing individual economic status and by providing support for single individuals or those who live alone, or are widowed or divorced (31).

Social Network Size, Social Isolation and Nutritional Risk

The principle of social network size is comprised of several components including individuals who occupy main social roles with high impact, i.e., close friends and family members within the household (32). The main social roles that constitute an individual's social networks subserve all the other factors that create an individual's social environment: social support, social cohesion and social isolation. Complimentary to the principle of social network size, the principle of social isolation is comprised of multiple components, including poor social networks, inadequate social support, unfulfilling social engagement and geographical isolation (7). Social isolation is associated with increased risk for mortality from coronary heart disease/stroke, all-cause mortality, suicide, rehospitalization, falls, cognitive decline and poor nutritional behaviours (33).

According to one study, a greater proportion of older aged individuals living alone were at nutritional risk relative to the proportion of older aged individuals who lived with partners or in group settings (1). Older aged men living alone are twice as likely to be at nutritional risk compared to older aged men who live with others; taking demographic factors and mental/physical health into account, social isolation and sporadic social contact were significantly associated with an increased likelihood of being at nutritional risk (1). Moreover, in a systematic literature review of 24 studies evaluating the association between marital status and malnutrition risk, nearly half of the studies identified a significant association between marital status and malnutrition risk; single, divorced or widowed elderly individuals had an increased risk for malnutrition compared to their married counterparts (31).

A cross-sectional survey issued within 28 Japanese primary care clinics aimed to assess the association between patient experience and social isolation in elderly primary care patients

(33). The abbreviated Lubben Social Network Scale (LSNS-6) was used to evaluate social isolation in elderly individuals (≥65 years old) by assessing the perceived adequacy of social support from family and friends by gauging the size, closeness and frequency of contact in a respondent's social network (33). Patient experience was assessed using the Japanese version of the Primary Care Assessment Tool (JPCAT) (33). Social isolation was inversely associated with perceived satisfaction with primary care received, signifying the importance of social networks and targeted interventions for socially isolated older aged individuals (33).

Social Support and Nutritional Risk

The concept of social support is multidimensional, reliant on the intersection and proper identification of the primary markers indicative of level of social support: the perception that one receives personal appraisal support, guidance and feedback, emotional support, informational support, instrumental assistance, and companionship (34). These primary markers indicative of the level of social support can be further consolidated into four subscales of social support: tangible social support, affection, positive social interaction and emotional or informational support (34). Tangible social support includes the provision of material aid or behavioural assistance, affection involves the expression of love and care, positive social interaction includes the availability of other persons with whom positive interaction can occur, and emotional or informational support involves the expression of positive affect, compassionate understanding and the encouragement of expressions or feelings or the offering of advice, information, guidance or feedback (34, 35).

Social support can be considered a protective social factor (36), and preceding literature supports the association between social support and positive health outcomes: as individuals age, their need for social support increases (7). Likewise, research indicates that older-aged adults who perceive greater adequacy of their social support networks are more likely to engage in health-enhancing behaviours compared to their counterparts who perceive lower network adequacy (26). Social support also plays a crucial role in mortality risk; individuals with higher perceived adequacy of social support have a 50% increased odds of survival (37).

Preceding research has acknowledged the positive association between satisfactory social support, improved nutritional outcomes and diet quality (38). In a study by Silverman et al., a ’Dietary Change Model’ was developed based on a sample of 298 randomly selected older adults (≥ 60 years old) residing in rural Oregon, to assess the impact of social support on nutritional risk and supplementary factors that can impact dietary change. Results from this analysis revealed that those most likely to implement positive dietary changes were women, married and living in smaller households (39). According to this same research, lack of dietary change could be most heavily influenced by the size of the respondent’s social support network, the range of the respondent’s social support network, and the frequency of contact with the respondent’s social support network (39).

Social Cohesion and Nutritional Risk

Social support is part of a larger social structure called social cohesion, consisting of community resources that are available for individual and group participation (7). Social cohesion consists of three levels, the individual level, the group level and the community level (7). The primary benefits associated with social cohesion stem from individual participation within the larger community through the observance of social norms and community support (7). Additionally, positive nutritional status has been associated with a variety of indicators of social cohesion such as religious organisations, socially unified neighbourhoods and a sense of trust in the community (7). Furthermore, less than weekly social engagement in community activities has been associated with increased nutritional risk (1).

Social Environment and Dietary Intake

The foundational components forming the social environment (social support, social cohesion, social isolation and social network size) independently influence the likelihood of being at nutritional risk and as such, may also influence diet and nutrient intake. The social environment serves as an important determinant of diet quality and as such, has the potential to positively or negatively impact the quality and quantity of nutrients consumed (40). Dietary Reference Intakes (DRIs), assist in optimal dietary planning, ensuring the maintenance of dietary balance (41). DRIs promote consumption levels that allow for an acceptably low probability of nutrient inadequacy while simultaneously minimizing the risks of nutrient excess (41). Fruit and vegetable consumption plays a crucial role in optimal dietary intake; satisfactory consumption of fruits and vegetables has been linked to reductions in cancer, stroke and all-cause mortality (42). Unfortunately, recent literature suggests that less than half of older-aged Canadians meet the standard international guidelines for consumption, consuming less than 5 servings of fruits and vegetables per day (42). One study found that in both older-aged men and women, adequate fruit and vegetable consumption was positively associated with emotional/informational support (42). Conversely, this same study found that in women, but not men, tangible social support was positively associated with adequate fruit and vegetable consumption (42). Low social support and social isolation are considered barriers to satisfactory nutritional status, and recent literature suggests that more exploration is needed to understand the nuanced mechanisms through which the social factors that form social environment (social support, social cohesion, and social isolation) work in combination to impact nutritional risk and dietary intake (42).

Theoretical Models of Dietary Behaviour Change

The social factors that form the social environment work in combination to influence the likelihood of being at nutritional risk, therefore the proper identification of individuals at nutritional risk, via nutritional risk screening, is essential for timely intervention. Nutritional risk screening serves as the initial step in the identification of malnutrition in older and at-risk adults, and immediate nutritional intervention should be a priority for those identified as being at risk (43). The timely identification of persons at nutritional risk is pertinent to the execution of appropriate nutritional interventions and is a central component of disease prevention and management (44). Successful nutritional interventions take many forms and must skillfully employ relevant theories of dietary behaviour change to yield appropriate and sustainable changes in eating patterns (44). There are three theoretical models that have proven especially useful in understanding the processes of changing dietary behaviours and eating patterns in community and healthcare settings: the transtheoretical model, the health belief model and the social cognitive theory (45-47). The transtheoretical model, the health belief model and the social cognitive theory all consider the influence of social relationships on change, however, the health belief model and the transtheoretical model do not consider the social context or behaviour change related to non-health related reasons, such as those due to a change in income or socioeconomic status (45-47). The social cognitive theory, formerly the social learning theory, proves to be the most comprehensive behavioural change model, considering individuals' dynamic social environments and their influence on behaviour change (45-47).

Considering social factors such as the social environment is essential when developing appropriate nutritional intervention plans utilizing theoretical models to produce sustained dietary behaviour change (43). Nutritional intervention in the form of meal programs can help reduce or maintain nutritional risk for at-risk seniors by reducing frequent meal skipping (48). Older-aged adults, who require formal or informal support for meal preparation and food shopping, can benefit from meal programs such as Meals on Wheels to maintain or improve their nutritional status (48).

A study by Sorensen et al. used the transtheoretical model to evaluate the associations between reported social support and readiness to increase fruit and vegetable consumption in a worksite-based interventional program (49). This study reported significant bivariate associations between readiness for dietary change and race/ethnicity, income, education and smoking status (49). Participants already consuming five or more daily servings of fruits and vegetables were more likely to be nonsmokers and professionals with higher household income (49). Furthermore, in bivariate analysis adequate social support from coworkers and members of the participants' household was significantly associated with readiness for dietary change (49) emphasizing the importance of social support on dietary behaviour (49). Furthermore, a systematic review by Robinson et al. (50), revealed that perceived dietary norms supplemented by supportive dietary environments readily influence eating behaviours, emphasizing the crucial impact of adequate social support on dietary behaviour and eating habits.

The Current Study: Rationale, Objectives and Hypothesis

The relationships between individual social factors and nutritional risk status have been previously evaluated, however, the coinciding relationship between multiple social factors (social support, social isolation, social cohesion, and social network size) and their overall contribution to the strength of the social environment has not been considered. An investigation that assesses multiple social factors in combination is warranted as social factors may act synergistically to affect nutritional outcomes (10). The primary objective of the current study was to assess the relationship between distinct strength of social environment groups and nutritional risk status among Canadian adults. Furthermore, as a secondary objective, the consumption of major food groups (whole grains, protein foods, dairy products, and fruits and vegetables) by strength of social environment and nutritional risk status was evaluated.

It was hypothesized that the weakest strength of social environment group, compared to the highest strength of social environment group, would have higher nutritional risk status and lower consumption of healthful foods. To test this hypothesis, the current study takes advantage of the CLSA, which is an extensive dataset containing exhaustive information regarding individuals' social environment, nutritional risk status as well as their dietary intake. The CLSA is a national, long term, comprehensive study that aims to understand the physiological, dietary, social and sociodemographic factors that determine why some people age healthily while others do not (51). The CLSA aims to improve the lives of people living in Canada by tracking the health trajectory of the Canadian population as it ages, capturing further insights into healthy aging, the relationship between mental health and aging, the identification of age-friendly environments and the assessment of nutritional status (51) . Therefore, the CLSA dataset proves an invaluable resource in exploring the associations between strength of social environment, nutritional risk and dietary intake across different stages of life, allowing for the analysis of both middle aged (45-64 years) and older-aged (≥65 years) subgroups.

CHAPTER 3: METHODOLOGY

Study Population

This cross-sectional analysis utilized baseline data from the Canadian Longitudinal Study on Aging (CLSA). Upon recruitment, baseline data were collected via telephone survey in 2011 and completed in 2015, assessing the physical, economic, psychological, demographic, behavioural and social aspects of 51,338 study participants between the ages of 45-86 (51, 52). A subset of study participants formed the Comprehensive Cohort (n = 30,097) with more in-depth data collected through in-home interviews and at Data Collection Sites including in-person physical examinations, assessment of food intake, and collection of biospecimen samples. For the present study, data from the Comprehensive Cohort were analyzed given the requirement for food intake assessment. Participants with data available for the required variables (sociodemographic, social network measures, nutritional risk status, and food intake) were included in analyses (n=20,786). Subgroup analyses by middle-aged (40-64 years, n=13,060) and older-aged adults (≥65 years, n=7,726) were performed to determine whether observations varied according to stage of life. Ethics approval was obtained from the McGill University Faculty of Agricultural and Environmental Sciences Research Ethics Board (Protocol # 477-0519).

Social Network Measures

A total of 24 discrete social network measures that were surveyed within CLSA were condensed to form seven indicator social network latent class subgroups: network size, social support (for which positive social interaction, tangible social support, affection, and emotional/informational support were each used as a separate indicator), social cohesion, and the social isolation index (**Table 1)**.

Table 1: Social variables used for latent class analysis

Construct	Variables
Network Size	Number of close friends Number of people in household
Social Isolation	Frequency of participation in family/ friends activities out of household (past 12 months), Frequency of participation in religious activities (past 12 months), Frequency of participation in sports or physical activities with others (past 12 months), Frequency of participation in educational or cultural activities (past 12 months), Frequency of participation in clubs or fraternal organization activities (past 12 months), Frequency of participation in association activities (past 12 months), Frequency of participation in volunteer or charity work (past 12 months), Frequency of participation in other recreational activities (past 12 months) Marital/partner status Last get together with neighbours (6 months or less) Last get together with close friends outside of household (6 months or less) Last get together with relatives outside of household (6 months or less) Last get together with siblings outside of household (6 months or less) Last get together with children outside of household (6 months or less)
Social Support	Positive Social Interaction - MOS Subscale Tangible Social Support - MOS Subscale Affection - MOS Subscale Emotional and Informational Support - MOS Subscale
Social Cohesion	Lots of people in local area who would help if in trouble Feel part of local area Most people in local area can be trusted Most people in local area are friendly

The CLSA included social network measures related to four main themes: network size, social support, social cohesion, and social isolation. Social network size accounts for the number of individuals occupying preidentified roles (i.e., number of close family in household, number of close friends) under the assumption that the individuals occupying these roles are most relevant to the individual of interest (53). Network size was created as a composite score ranging from 0 to 15 using responses from two sets of questions: total number of close friends and total number of people in household.

Social support includes perceived adequacy of support provided through emotional support, tangible support (instrumental assistance, personal appraisal support, guidance and feedback, informational support) and the consistency of contact with others at the individual level (7, 54). The 19-item self-administered Medical Outcomes Study (MOS) Social Support questionnaire provides indicators of four functional social support subscales within CLSA (positive social interaction, affection, tangible social support and emotional/informational support) (54). Functional social support subscales were rated on a five-point Likert scale (i.e., 1=Not at all, 2=A little of the time, 3=Some of the time, 4=Most of the time; and 5=All of the time) to allow for the formation of transformed scores for each social support subscale (54) The transformed social support scores for each subscale was obtained using the following formula: 100 * (observed score – minimum possible score) / (maximum possible score – minimum possible score) (55). The composite social support scores for each subscale, subsequent to this transformation, ranged from 0-100 but were modified to a score out of 10 for the present analysis.

Social cohesion, consisting of community resources available for individual and group participation, is rooted in the concepts of social trust and unity at the societal level (56). Thus, a social cohesion score was used to wholly assess individual cohesion and form a composite social cohesion score reflecting reciprocity, altruism and values/norms shared within a community (57). A composite social cohesion score was composed based on scores from four questions categories: i) People in local area would help if in trouble, ii) Feel part of local area, iii) Most people in local area can be trusted, iv) Most people in local area are friendly (58). The four social cohesion questions were scored on a Likert scale ([1] Strongly agree, [2] Agee, [3] Disagree, [4] Strongly disagree) and then summed to form a total score that ranged from 0 to 16 for each participant. To utilize the social cohesion score as a variable where a higher score indicated stronger cohesion, the resulting sum was reverse scored. Specifically, the total social cohesion score for each participant was subtracted from the maximum possible score of 16 with higher scores indicating higher cohesion.

Social isolation is comprised of multiple components, including poor social networks, inadequate social support, unfulfilling social engagement, and geographical isolation (59). Furthermore, social isolation can be additionally partitioned into the frequency of contact with friends and neighbours, family members, community participation, marital status and household size. The Social Isolation Index was constructed according to methodology from Menec et al. (60) using responses to five groups of questions regarding participants' household size, marital status, frequency of contact with relatives and friends, and social participation (i.e., frequency of participation in community activities). The index was scored from 0 to 5, a score from 0 to 2 resulting in a classification of not socially isolated (coded as 0) and a score from 3 to 5 resulting in a classification of socially isolated (coded as 1) (60).

Nutritional Risk Assessment

The primary outcome of interest was high nutritional risk status, identified using the *Seniors in the Community Risk Evaluation for Eating and Nutrition II- Abbreviated* (SCREEN-II-AB) (21). The SCREEN-II-AB is comprised of eight questions, and up to three follow-up questions dependent upon responses, and pertains to weight changes, frequency of skipped meals, appetite, ability to chew and/or swallow, fruit and vegetable consumption, fluid consumption, time spent eating alone, and meal preparation (61). The values for each individual response to SCREEN-II-AB items were summed to form a composite variable with a maximum score of 48. A score < 38 indicates high nutritional risk status (14).

The AB-SCREEN II uses the following questions to assess nutritional risk: a) "Compared with six months ago, have you gained weight, lost weight, or stayed about the same? i) ...how much weight did you lose/gain in the past 6 months?"; b) "In general, how.... i) often do you skip meals?, ii) would you describe your appetite?, iii) often do you cough, choke, or have pain when swallowing food or fluid?, iv) many servings of fruits and vegetables do you eat in a day?, v) much fluid do you drink in a day?, vi) often do you eat at least one meal each day with someone at least once a day?"; c) "Do you usually cook your own meals?"; d) "Which of the following statements best describes meal preparation for you?"; e) "Which of the following statements best describes meals prepared for you?" (14).

Consumption of Major Food Groups

The secondary outcome of interest was the consumption of products from major food groups. The CLSA surveyed participants on frequency of food consumption through a 36-item Short Dietary Questionnaire (SDQ) (**Table 2**), which was developed specifically for the Comprehensive Cohort to determine frequency of specific food consumption (61, 62).

Table 2: Individual food items comprising food groups from Short Dietary Questionnaire

Food Group	**Individual food items**
Whole Grains	High fibre breakfast cereals, whole wheat breads/bran breads/multigrain breads/ryebreads
Proteins	Beef/pork, other meats (veal, lamb, game), chicken/turkey, fish (fresh/frozen/canned), sausages/hot dogs/smoked ham/bacon,

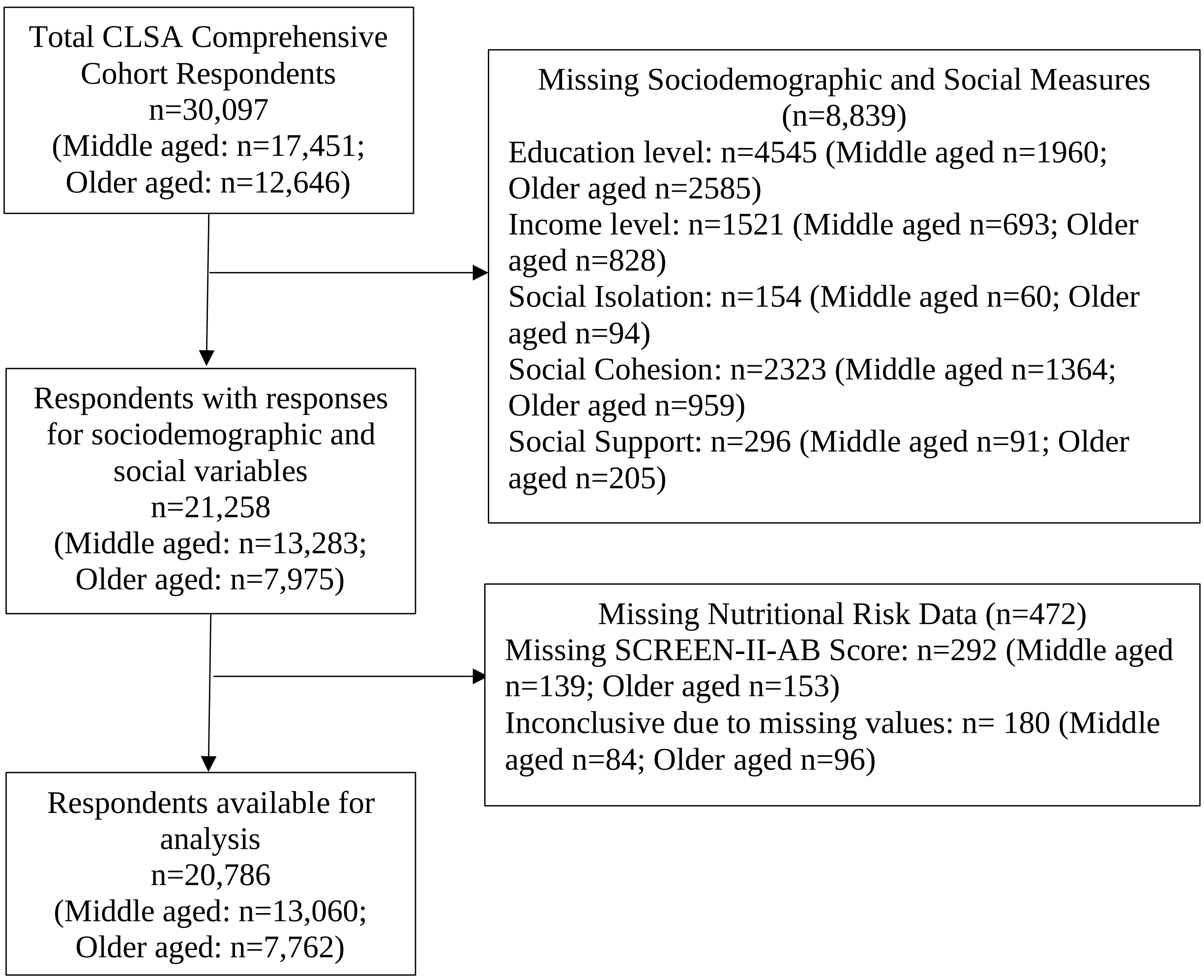
	pates/cretons/terrines, omega-3-eggs, all egg dishes except omega-3-eggs, legumes (beans/peas/lentils), nuts/seeds/peanut butter
Dairy	Low-fat cheeses, regular cheeses, yogurt (low-fat), yogurt (regular), butter/margarine, calcium-fortified milk (35% more calcium), whole milk (3.25% milk fat), 2%/1%/skim milk
Fruits and Vegetables (with juices)	Fruit, green salad, potatoes, carrots, other vegetables (except carrots, potatoes or salad), 100% pure fruit juices, calcium fortified juices
Fruits and Vegetables (without juices)	Fruit, green salad, potatoes, carrots, other vegetables (except carrots, potatoes or salad)
Food items not considered	Salty snacks, baked goods, chocolate bars, ice cream or milk-based desserts, vinaigrettes/dressings/dips, french fries/pan-fried potatoes, sauces/gravies, calcium-fortified non-dairy foods, calcium-fortified non-dairy beverages.

The SDQ measured consumption frequency, defined as the number of times per day each food item was reportedly consumed (times eaten/day). Four major food groups were created for the present analysis based on population-based recommendations for healthy eating and included whole grain products, protein foods (non-dairy), dairy foods, and fruits and vegetables (including juices). An additional group for fruits and vegetables excluding juices was evaluated for a sensitivity analysis. Dairy foods were evaluated as an individual category (i.e., separate from protein foods) due to evidence supporting the importance of dairy intake for healthful aging (63). The food groups were constructed using 27 of the 36 SDQ questions. Food items that are not promoted in healthy eating recommendations were excluded (n=9).

Statistical Analysis

Descriptive statistics were computed for sociodemographic characteristics and nutritional risk measures. Independent t-tests and Chi-square tests of independence were performed to compare continuous and categorical characteristics, respectively, between the middle-aged and older-aged subgroups. Characteristics between CLSA participants included vs. excluded from the present analysis were also compared to assess the potential for bias in data available for analyses, see **Figure 2** for additional details about the number of respondents with data available for analyses.

Figure 2: Flowchart of CLSA respondents with data available for analyses



Analyses were performed using R software (packages ‘poLCA’, ‘dplyr’ ‘ggplot2’, ‘car’, ‘broom’, ‘sjstats’, ‘emmeans’, ‘pwr’). All reported p-values correspond to two-tailed tests. Given the number of statistical comparisons performed as part of this investigation, statistical significance was set at $p<0.01$ to reduce the potential for type I error.

For each age subgroup, CLSA participants were classified according to the strength of their social environment by considering all available social environment variables and using a dimensionality reduction method. Dimensionality reduction methods are commonly used techniques for multidimensional data visualization, classification and analysis (64, 65). Dimensionality reduction refers to the transformation of high dimension data into representative, yet dimensionally reduced data, that corresponds with the intrinsic dimensionality of the original dataset (65). Conventional dimensionality reduction utilizes linear techniques including Factor Analysis (FA) and Principal Component Analysis (PCA) (65). FA and PCA both aim to reduce a large number of variables into a smaller number of elements and identify patterns of correlations amongst the observed variables (66). FA and PCA are similar statistical approaches, from a theoretical perspective, however, they differ in the reasoning underlying why variables are associated with a factor or component (66). In FA, factors are thought to be the cause of variables, while in PCA, variables produce the component (66). An additional dimensionality reduction technique is latent class analysis (LCA) (67). LCA identifies the underlying and unobservable patterns that exist between subjectively different population subgroups that share outwardly observable similarities (68-70). LCA is a person-centered mixture modeling approach that detects latent subpopulations (or classes) within a sample, based on patterns of responses to observed variables (69, 71). LCA operates under the assumption that membership in these unobserved classes can cause or explain patterns across the observed variables, i.e., survey questions or assessment indicators (69, 71). While FA and LCA both aim to identify latent relationships between variables, FA is not a suitable technique to posit groups of people (72). For this reason, LCA was applied to the present investigation, which enabled a more comprehensive assessment of the overall strength of social environment compared to other statistical methodologies.

LCA was performed to classify participants into strength of social environment groups using data on the social factors used to form indicators (network size, social support, social cohesion, and social isolation). The LCA model was created according to methodology put forth by Jung and Wickrama (73) taking a person-centered analytical approach focusing on relationships between individual responses from participants. The seven-indicator social network latent class subgroups described above were specified as predictors to determine the likelihood of class membership. The ideal number of social environment latent classes was determined by lower values of Akaike (AIC) and Bayesian (BIC) information criteria, high posterior probabilities, high entropy, and absence of groups with less than 1% of the total sample size (23). Descriptive statistics and Chi-square tests of independence (or the Cochran-Armitage test for trend for items with ordinal scales) were conducted to compare responses to the eight main items of the SCREEN-II-AB between the resulting social environment groups.

Analysis of covariance (ANCOVA) models were conducted to compare adjusted mean nutritional risk scores according to the social environment groups created from the LCA. When necessary, square root transformations were applied to outcome variables to improve normality of model residuals, but back transformed values are presented for interpretation. The nutritional risk score variable was continuous and ranged from 0 to 48. Pairwise comparisons of social environment groups with a Bonferroni correction were further conducted for ANCOVA models that indicated a significant association between the social environment predictor variable and nutritional risk score. Three ANCOVA models were performed for the total analytical sample, as well as for the age subgroups, with increasing levels of statistical adjustment for relevant covariates as follows: Model 1 (minimally adjusted): adjusted for age, sex, and province of recruitment; Model 2 (adjusted for additional sociodemographic factors): model 1 + income, education, marital status, self-reported ethnicity, immigration status, and urban/rural residence; Model 3 (additionally adjusted for smoking status): model 2 + smoking status.

ANCOVA models with the same adjustments were conducted to compare mean consumption of the four food groups by social environment group, as well as by nutritional risk status (at risk (SCREEN-II-AB <38) vs. not at risk (SCREEN-II-AB ≥38). This allowed for comparison of any observed associations between social environment groups and food group consumption with patterns of consumption by nutritional risk status groups, where respondents classified as at high nutritional risk were expected to have lower consumption frequency. Sensitivity analyses for the fruits and vegetables food group that excluded consumption of fruit and vegetable juices were performed to assess results for whole fruits and vegetables alone. In all models, age was included as a continuous covariate. The remaining covariates were categorical and were included as follows: sex (male, female), income level (<$20,000, $20,000-$49,999, $50,000-$99,999, $100,000-$149,999, ≥$150,000), educational level (secondary school or less, certificate or diploma (college or university level below bachelor’s degree), bachelor’s degree or above), marital status (married, single or never married, divorced/separated/widowed), province of recruitment (Ontario, Quebec British Columbia, Prairie Region, Atlantic Region), urban/rural residence (urban or rural), ethnicity (Caucasian or Non-Caucasian), immigration status (immigrant or non-immigrant), and smoking status (current smoker, former smoker, never smoked).

CHAPTER 4: RESEARCH FINDINGS

Respondent Characteristics and Strength of Social Environment Groups

Characteristics of the complete sample as well of age subgroups are shown in **Table 3**. Middle-aged adults comprised 63% of the sample and 37% were older-aged adults. The average age (mean ± standard deviation) of the complete sample was 61.8 ± 9.9 years with approximately equal proportions of sex groups. Certain sociodemographic variables significantly differed between the age subgroups, with the older-aged subgroup having overall lower total income and education level, and higher prevalence of being divorced, separated, or widowed and higher prevalence of being an immigrant, compared to the middle-aged subgroup. The mean ± standard deviation nutritional risk score was 39.4 ± 5.9 and the average score did not differ significantly between the age subgroups.

Table 3: Participant characteristics for total cohort and middle-aged and older-aged subgroups

Characteristic	**Total (n=20,786)**	**Middle-Aged (n=13,060)**	**Older-Aged (n=7,726)**	**p-value**
Age	61.8 ± 9.9	55.4 ± 5.4	72.5 ± 5.6	<0.0001
Biological Sex				<0.0001
Male	10604 (51.0%)	4160 (53.8%)	6444 (49.3%)	
Female	10182 (49.0%	3566 (46.2%)	6616 (50.7%)	
BMI†	29.7 ± 8.6	28.1 ± 10.2	27.8 ± 4.9	0.004
Total Household Income				<0.0001
<$20,000	732 (3.5)	404 (3.1%)	328 (4.2%)	
$20,000-$49,999	3848 (18.5%)	1612 (12.3%)	2236 (28.9%)	
$50,000-$99,999	7467 (35.9%)	4137 (31.7%)	3330 (43.1%)	
$100,000-$149,999	4551 (21.9%)	3350 (25.7%)	1201 (15.5%)	
≥$150,000	4188 (20.1%)	3557 (27.2%)	631 (8.2%)	
Education				<0.0001
Secondary school or less	1760 (8.5%)	979 (7.5%)	781 (10.1%)	
Certificate or diploma	7715 (37.1%)	2878 (37.0%)	2878 (37.3%)	
Bachelor's degree or above	11311 (54.4%)	4067 (55.5%)	4067 (52.6%)	
Marital Status†				<0.0001
Married	15122 (72.8%)	9952 (76.2%)	5170 (66.9%)	

Single/Never married	1682 (8.1%)	1264 (9.7%)	418 (5.4%)	
Divorced/Separated/Widowed	3977 (19.1%)	1839 (14.5%)	2138 (27.7%)	
Province of recruitment				
Ontario	4502 (21.7%)	2821 (21.6%)	1681 (21.8%)	0.011
Quebec	3964 (19.1%)	2572 (19.7%)	1392 (18.0%)	
British Columbia	4495 (21.6%)	2760 (21.1%)	1735 (22.5%)	
Other‡	7825 (37.6%)	4907 (37.6%)	2918 (37.8%)	
Immigration status†				<0.0001
Immigrant	3687 (17.7%)	1882 (14.4%)	1805 (23.4%)	
Not Immigrant	17096 (82.3%)	11175 (85.6%)	5921 (76.6%)	
Ethnicity				0.002
Caucasian	19954 (96.0%)	12494 (95.7%)	7460 (96.6%)	
Non-Caucasian	832 (4.0%)	566 (4.3%)	266 (3.4%)	
Smoking status				0.706
Never Smoked	9827 (47.3%)	6180 (47.3%)	3647 (47.2%)	
Current Smoker	1887 (9.1%)	1169 (9.0%)	718 (9.3%)	
Former Smoker	9072 (43.6%)	5711 (43.7%)	3361 (43.5%)	
Urban vs. Rural Residence				
Urban	18884 (90.8%)	11796 (90.3%)	7088 (91.7%)	0.001
Rural	1902 (9.2%)	1264 (9.7%)	638 (8.3%)	
Nutritional Risk Status				0.639
High Nutritional Risk	6787 (32.7%)	4249 (32.5%)	2538 (32.9%)	
Not High Nutritional Risk	13999 (67.3%)	8811 (67.5%)	5188 (67.1%)	
SCREEN-II-AB Score	39.4 ± 5.9	39.4 ± 6.0	39.3 ± 5.8	0.253
Social environment group				
Low	3635 (17.5%)	2153 (16.5%)	1482 (19.2%)	<0.0001
Medium	8329 (40.1%)	5081 (38.9%)	3248 (42.0%)	
High	8822 (42.4%)	5826 (44.6%)	2996 (38.8%)	

Note. Values are n (%) except for age, body mass index (BMI) and SCREEN-II-AB score, which are presented as mean (± standard deviation). †Missing responses (n=69 no BMI value; n=5 did not specify marital status; n= 3 did not specify immigration status); participants with missing responses not included‡. Other provinces include Alberta, Manitoba, Saskatchewan, Newfoundland and Labrador, New Brunswick, Nova Scotia, and Prince Edward Island.

The LCA identified three distinct groups that differed in the overall strength of their social environment: low, medium, and high. These groups comprised 18%, 40%, and 42%, respectively, of the total sample. **Figures 3 and 4** illustrate the distribution of the seven LCA social indicators for each age subgroup. Compared to the middle-aged subgroup, a significantly lower proportion of older-age participants were classified into the high strength of social environment group.

Figure 3: Latent Class Analysis Model – Middle-Age Population

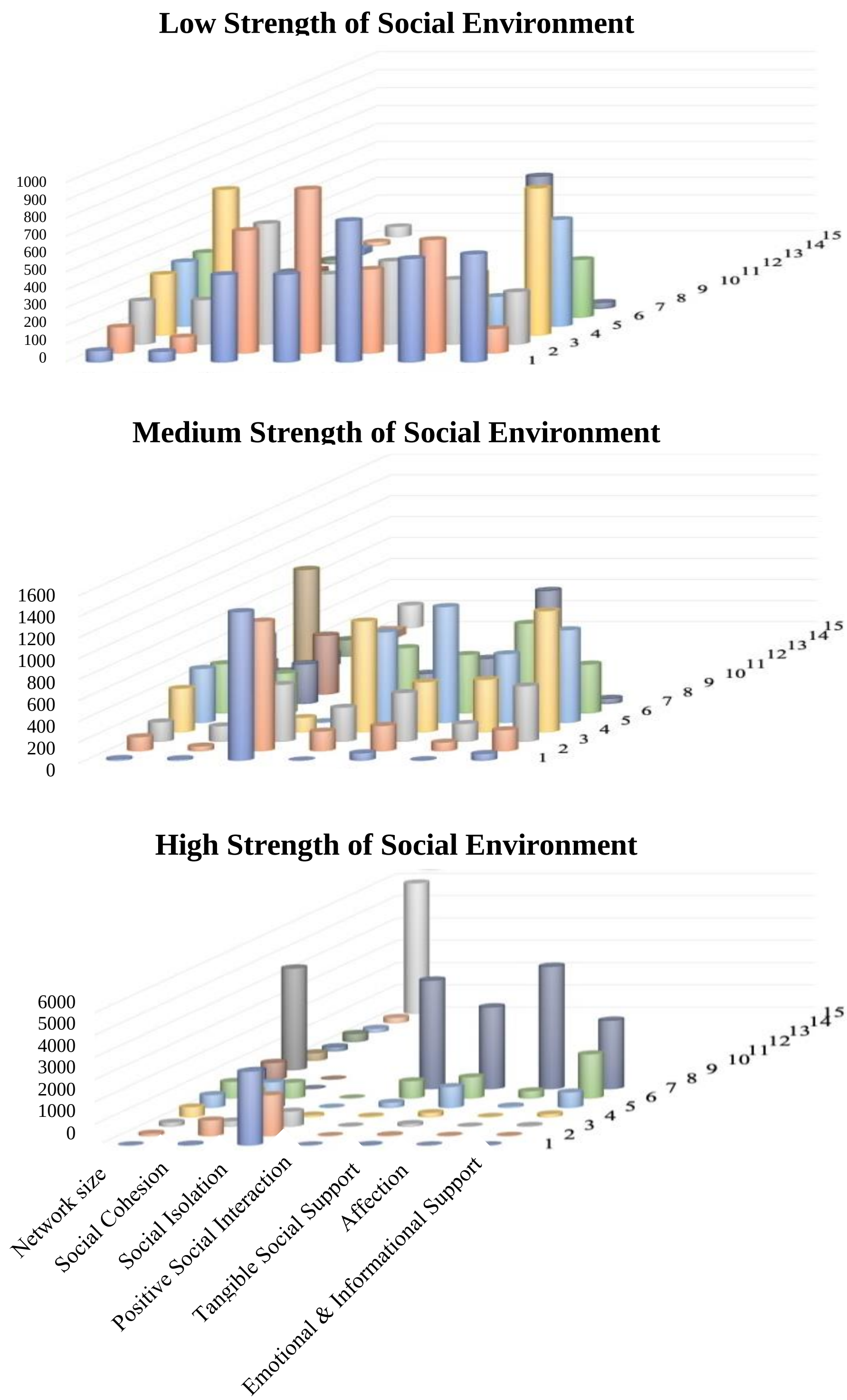
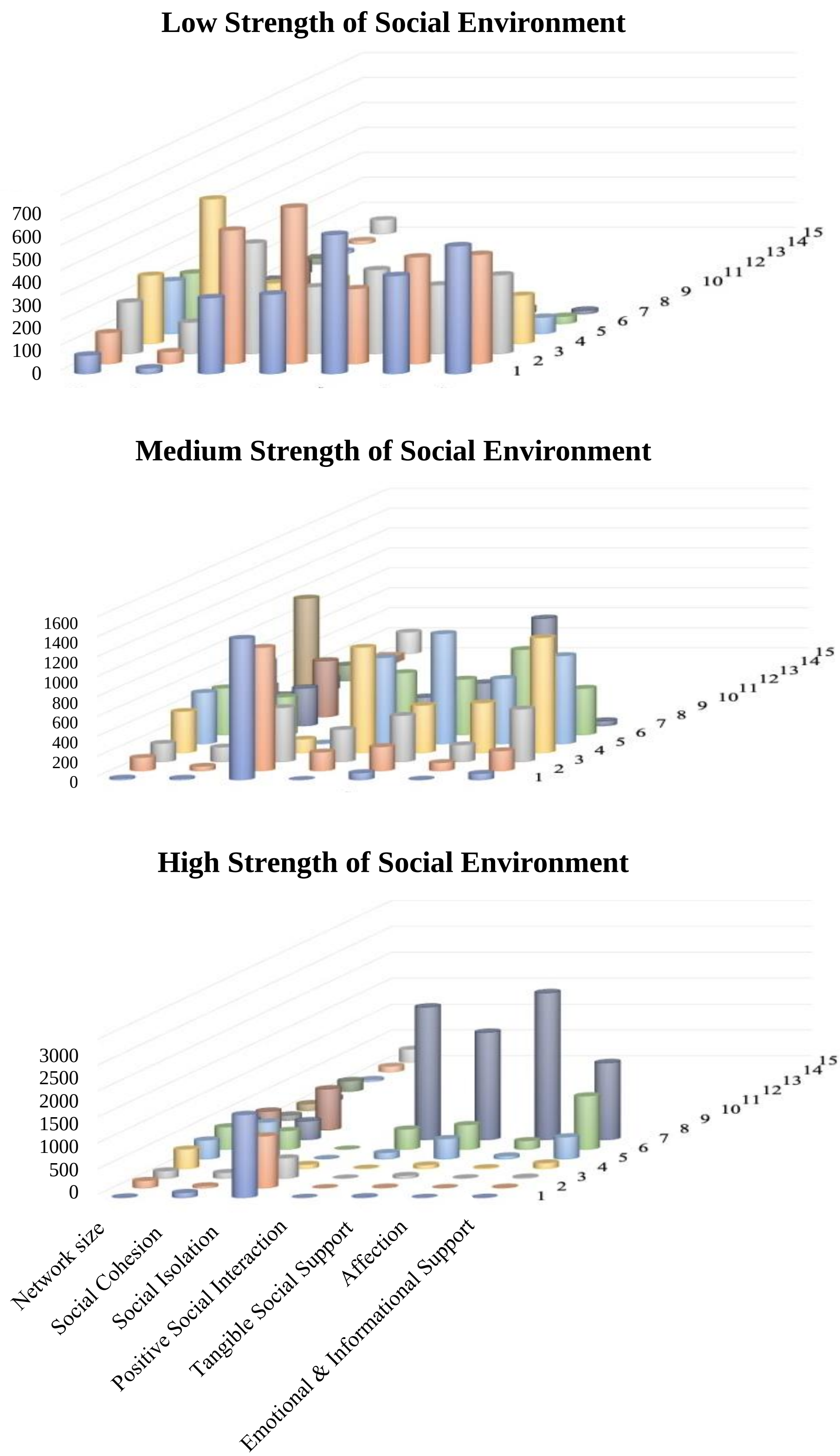


Figure 4: Latent Class Analysis Model – Older-Age Population



Note. X-axis variables: Seven indicator variables comprised of Network Size, Social Cohesion Score, Social Isolation Score, Tangible Social Support, Affection, Emotional & Information Support. Y-axis variables: Number of participants. Z-axis variables: Score on scale

Several characteristics differed between CLSA participants included in the present analyses versus excluded due to missing required data (**Table 4**). The most pronounced differences were that excluded participants were significantly older, of lower income and education, and with a higher proportion being divorced, separated, or widowed, as well as of female sex. A significantly greater proportion of excluded participants were classified as being at high nutritional risk. Characteristics also significantly differed (modestly) by province of recruitment and ethnicity, but did not significantly differ by immigration status, smoking status, or urban/rural residence.

Table 4: Characteristics of included and excluded CLSA participants

Characteristic	**Included (n=20,786)**	**Excluded (n=9,311)**	**p-value**
Age	61.8 ± 9.9	65.6 ± 10.5	<0.0001
Biological Sex			<0.0001
Male	10604 (51.0%)	4173 (44.8%)	
Female	10182 (49.0%)	5138 (55.2%)	
BMI	28.0 ± 8.6	28.4 ± 5.6	<0.0001
Missing (n)	69	66	
Total Household Income			<0.0001
<$20,000	732 (3.5%)	834 (9.0%)	
$20,000-$49,999	3848 (18.5%)	2512 (27.0%)	
$50,000-$99,999	7467 (35.9%)	2440 (26.2%)	
$100,000-$149,999	4551 (21.9%)	973 (10.5%)	
≥$150,000	4188 (20.1%)	611 (6.6%)	
Don’t know/No Answer	0	811 (8.7%)	
Refused to answer	0	1130 (12.1%)	
Education			<0.0001
Secondary school or less	1760 (8.5%)	482 (10.0%)	
Certificate or diploma	7715 (37.1%)	2023 (42.1%)	
Bachelor’s degree or above	11311 (54.4%)	2261 (47.0%)	
Other	0	39 (0.8%)	
Don’t know/No Answer	0	4 (0.1%)	
Missing (n)	0	4502	

Marital Status			<0.0001
Married	15122 (72.8%)	5529 (59.4%)	
Single/Never married	1682 (8.1%)	972 (10.4%)	
Divorced/Separated/Widowed	3977 (19.1%)	2807 (30.1%)	
Refused to answer (n)	5	3	
Province of recruitment			
Ontario	4502 (21.7%)	1916 (20.6%)	<0.0001
Quebec	3964 (19.1%)	2099 (22.5%)	
British Columbia	4495 (21.6%)	1759 (18.9%)	
Other‡	7825 (37.6%)	3537 (38.0%)	
Immigration status			0.046
Immigrant	3687 (17.7%)	1762 (18.9%)	
Not Immigrant	17096 (82.2%)	7548 (81.1%)	
Missing (n)	3	1	
Ethnicity			<0.0001
Caucasian	19954 (96.0%)	8817 (94.7%)	
Non-Caucasian	832 (4.0%)	494 (5.3%)	
Smoking status			0.826
Never Smoked	9827 (47.3%)	4415 (47.4%)	
Current Smoker	1887 (9.1%)	823 (8.8%)	
Former Smoker	9072 (43.6%)	4073 (43.7%)	
Urban vs. Rural Residence			
Urban	18884 (90.8%)	8411 (90.3%)	0.155
Rural	1902 (9.2%)	900 (9.7%)	
Nutritional Risk Status†			<0.0001
High Nutritional Risk	6787 (32.7%)	3332 (41.6%)	
Not High Nutritional Risk	13999 (67.3%)	4357 (54.4%)	
Inconclusive due to missing SCREEN-II-AB values	0	314 (3.9%)	
Missing (n)	0	1308	
SCREEN-II-AB Score*	39.4 ± 5.9	37.8 ± 6.6	<0.0001
Missing (n)	0	2134	

Note. Values are n (%) except for age, body mass index (BMI) and SCREEN-II-AB score, which are presented as mean (± standard deviation). ‡Other provinces include Alberta, Manitoba, Saskatchewan, Newfoundland and Labrador, New Brunswick, Nova Scotia, and Prince Edward Island. †Nutritional risk status calculated for n=8003 excluded respondents with a conclusive nutritional risk score. *Mean calculated for n=7177 excluded respondents with SCREEN-II-AB score available (score not available for: missing item(s) but conclusive high nutritional risk classification (n=512); missing item(s) and inconclusive high nutritional risk classification (n= 314)).

Social Environment and Nutritional Risk Status

Table 5 shows the descriptive statistics for responses to the eight main items of the SCREEN-II-AB by strength of social environment group. Responses significantly differed by social environment for all items, with the low social strength group indicating greater frequency of skipping meals, having a poorer appetite, difficulty swallowing food, and cooking their own meals compared to the other social groups. For the low strength group, 8.7% of respondents indicated that they skipped meals almost every day, almost two times greater than the high strength group with only 4.5% of respondents indicating that they skipped meals almost every day. For the low strength group, 2.3% of respondents reported having a poor appetite, nearly four times the number the respondents who indicated having a poor appetite in the high strength group (0.6%). Furthermore, 53.3% of respondents in the low strength group indicated never having difficulty chewing and swallowing food often, whereas 2.6% of respondents indicated difficulty often or always. This was markedly different compared to the high strength group where 67.2% indicated never having difficulty chewing or swallowing and only 1.4% of respondents indicated difficulty often or always.

Table 5: SCREEN-II-AB item responses by strength of social environment group

SCREEN-II-AB Item	Low	Medium	High	p-value
(1) Gained, lost, or stayed the same weight in the last six months				<0.0001
Gained weight	653 (18.0%)	1280 (15.4%)	1252 (14.2%)	
Lost weight	688 (18.9%)	1611 (19.3%)	1675 (19.0%)	
Stayed about the same	2294 (63.1%)	5438 (65.3%)	5895 (66.8%)	
(2) Skipped Meals†				<0.0001
Almost every day	317 (8.7%)	451 (5.4%)	397 (4.5%)	
Often	276 (7.6%)	438 (5.3%)	381 (4.3%)	
Sometimes	610 (16.8%)	1208 (14.5%)	1113 (12.6%)	
Rarely	1330 (36.6%)	3466 (41.6%)	3471 (39.3%)	
Never	1102 (30.3%)	2766 (33.2%)	3460 (39.2%)	
(3) Describe Appetite†				<0.0001
Very good	1704 (46.9%)	4708 (56.5%)	5673 (64.3%)	

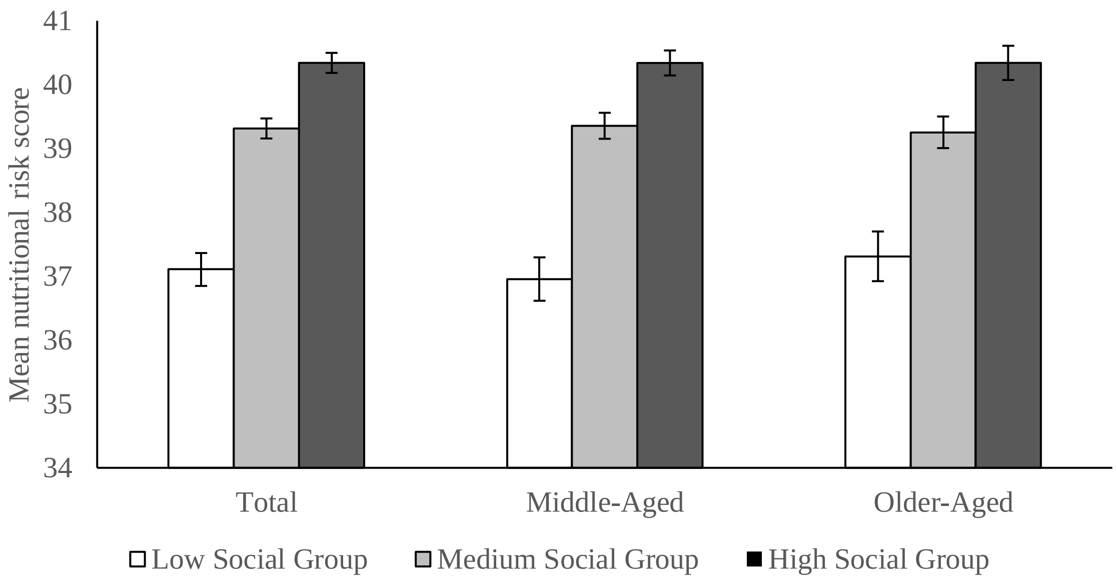
Good	1583 (43.5%)	3222 (38.7%)	2820 (32.0%)	
Fair	266 (7.3%)	313 (3.8%)	275 (3.1%)	
Poor	82 (2.3%)	86 (1.0%)	54 (0.6%)	
(4) Cough, choke, or pain when swallowing food†				<0.0001
Often or always	94 (2.6%)	157 (1.9%)	120 (1.4%)	
Sometimes	450 (12.4%)	694 (8.3%)	604 (6.8%)	
Rarely	1152 (31.7%)	2546 (30.6%)	2169 (24.6%)	
Never	1939 (53.3%)	4932 (59.2%)	5929 (67.2%)	
(5) Servings fruits and vegetables per day†				<0.0001
Seven or more	349 (9.6%)	992 (11.9%)	1304 (14.8%)	
Six	344 (9.5%)	972 (11.7%)	1134 (12.9%)	
Five	585 (16.1%)	1586 (19.0%)	1688 (19.1%)	
Four	631 (17.4%)	1585 (19.0%)	1575 (17.9%)	
Three	672 (18.5%)	1434 (17.2%)	1488 (16.9%)	
Two	591 (16.3%)	1132 (13.6%)	1080 (12.2%)	
Less than two	463 (12.7%)	628 (7.5%)	553 (6.3%)	
(6) Cups of fluid per day†				<0.0001
Eight or more cups	1178 (32.4%)	2913 (35.0%)	3280 (37.2%)	
Five to seven cups	1657 (45.6%)	3846 (46.2%)	4018 (45.5%)	
Three to four cups	707 (19.4%)	1439 (17.3%)	1406 (15.9%)	
About two cups	80 (2.2%)	107 (1.3%)	97 (1.1%)	
Less than two cups	13 (0.4%)	24 (0.3%)	21 (0.2%)	
(7) Meals with someone at least once a day†				<0.0001
Almost always	1178 (32.4%)	2913 (35.0%)	3280 (37.2%)	
Often	1657 (45.6%)	3846 (46.2%)	4018 (45.5%)	
Sometimes	707 (19.4%)	1439 (17.3%)	1406 (15.9%)	
Rarely	80 (2.2%)	107 (1.3%)	97 (1.1%)	
Never	13 (0.4%)	24 (0.3%)	21 (0.2%)	
(8) Cook own meals				<0.0001
Yes	2992 (82.3%)	6228 (74.8%)	6249 (70.8%)	
No	636 (17.5%)	2087 (25.1%)	2552 (28.9%)	
Don’t know/No answer	7 (0.2%)	14 (0.2%)	21 (0.2%)	

Note. Values are n (%). P-values generated from Chi-square test of independence (†Cochran-Armitage test for trend).

The low strength of social environment group indicated lower daily servings of fruits and vegetables, cups of fluids, and the consumption of meals with others. For the low strength group, 12.6% of respondents indicated less than two servings per day of fruits and vegetables, which was more than twice the number of respondents who indicated less than two servings per day of fruits and vegetables in the high strength group (6.3%). For the low strength group, 0.4% of respondents reported never having meals with someone at least once per day, which was twice the number of respondents who reported never having meals with someone at least once per day in the high strength group (0.2%). Patterns were similar for fluid consumption, with 0.4% of respondents indicating less than two cups of fluid per day compared to 0.2% of respondents in the high strength group.

Nutritional risk scores significantly differed between social environment groups in a dose-response manner, with the low social strength group having an adjusted mean score indicating high nutritional risk (**Figure 5**).

Figure 5: Adjusted nutritional risk scores by strength of social environment for the fully adjusted model (Model 3)



Note. Error bars represent 99% confidence interval. Nutritional risk score <38 indicates risk of poor nutritional state. Mean nutritional risk score values differed significantly between each social environment group among the total sample and both age subgroups ($p<0.0001$).

Results were consistent across all three ANCOVA models and for both age subgroups (**Table 6**). In Model 1, the minimally adjusted model, the mean difference in nutritional risk score was slightly larger compared to Model 3, the fully adjusted model. In Model 1, the mean adjusted nutritional risk score for the total sample was 36.1 [99% CI; 35.9,36.4] for the low strength of social environment group and 40.7 [99% CI; 40.6, 40.9] ($p<0.001$) for the high strength of social environment group; in Model 3 for the total sample, the mean adjusted nutritional risk score was 37.1 [99% CI; 36.8, 37.4] for the low strength of social environment group and 40.3 [99% CI; 40.2, 40.5] for the high strength of social environment group ($p<0.001$). In Model 1, the minimally adjusted model of the complete sample, there was a 4.6-point difference in the SCREEN-II-AB score between the high and low social environment groups; in the fully adjusted model of the complete sample, there was a 3.2-point difference in SCREEN-II-AB score between the high and low social environment groups (Cohen's d = 0.55). For the same comparison of effect size among the age subgroups (high vs. low social environment group), Cohen's d was 0.57 (3.3-point difference in SCREEN-II-AB score) and 0.47 (3-point difference in SCREEN-II-AB score) for the middle- and older-aged groups, respectively.

Table 6: Adjusted mean nutritional risk scores by strength of social environment group

	Social environment			p-value
	Low	**Medium**	**High**	
Model 1 (adjusted for age, sex, and province of recruitment)				
Total	36.1[a] (35.9, 36.4)	39.3[b] (39.2, 39.5)	40.7[c] (40.6, 40.9)	<0.0001
Middle-aged	35.9[a] (35.6, 36.2)	39.4[b] (39.2, 39.6)	40.7[c] (40.6, 40.9)	<0.0001
Older-aged	36.5[a] (36.2, 36.9)	39.2[b] (39.0, 39.5)	40.8[c] (40.5, 41.0)	<0.0001
Model 2 (additionally adjusted for income, education, marital status, urban/rural residence, ethnicity, and immigration status)				
Total	37.1[a] (36.8, 37.4)	39.3[b] (39.2, 39.5)	40.3[c] (40.2, 40.5)	<0.0001

Middle-aged	37.0[a] (36.6, 37.3)	39.4[b] (39.2, 39.6)	40.3[c] (40.2, 40.5)	<0.0001
Older-aged	37.4[a] (37.0, 37.8)	39.2[b] (39.0, 39.5)	40.3[c] (40.0, 40.6)	<0.0001
Model 3 (additionally adjusted for smoking status)				
Total	37.1[a] (36.8, 37.4)	39.3[b] (39.2, 39.5)	40.3[c] (40.2, 40.5)	<0.0001
Middle-aged	37.0[a] (36.6, 37.3)	39.4[b] (39.1, 39.6)	40.3[c] (40.2, 40.5)	<0.0001
Older-aged	37.3[a] (36.9, 37.7)	39.2[b] (39.0, 39.5)	40.3[c] (40.1, 40.6)	<0.0001

Note. Values are mean (99% confidence interval). Nutritional risk score <38 indicates risk of poor nutritional state. Different letter superscripts indicate statistically significant differences identified from pairwise comparisons (p<0.01). Total respondents, n=20,786 (3635, 8329, 8822 for low, medium, and high strength of social environment groups, respectively); Middle-aged, n = 13,060 (2153, 5081, and 5826 for low, medium and high strength of social environment groups, respectively); Older-aged, n = 7,726 (1482, 3248, and 2996 for low, medium and high strength of social environment groups, respectively).

Food Group Consumption

Since ANCOVA results for the primary outcome of interest were consistent across all three statistical models, only the fully adjusted model (model 3) was performed for the food group analyses. Aligning with the observations between the social environment groups and nutritional risk, respondents in the low social strength group had significantly lower consumption frequency of the proteins, dairy, and fruits and vegetables food groups (including and excluding juices) compared to the medium and high social strength groups (**Table 7**).

Table 7: Food group consumption frequency (in times/day) by strength of social environment group

	Social environment			p-value
	Low	Medium	High	
Whole Grains				
Total	1.0 ± 0.2	1.0 ± 0.1	1.0 ± 0.1	0.194
Middle-aged	0.9 ± 0.2	0.9 ± 0.2	0.1 ± 0.2	0.590
Older-aged	1.2 ± 0.2	1.2 ± 0.2	1.2 ± 0.2	0.072
Protein Foods				

Total	2.2 ± 0.1[a]	2.2 ± 0.1[b]	2.2 ± 0.1[bc]	0.001
Middle-aged	2.2 ± 0.1	2.2 ± 0.1	2.2 ± 0.1	0.042
Older-aged	2.1 ± 0.1	2.2 ± 0.1	2.2 ± 0.1	0.043
Dairy				
Total	2.3 ± 0.2[a]	2.4 ± 0.2[b]	2.4 ± 0.2[bc]	0.002
Middle-aged	2.2 ± 0.2[a]	2.3 ± 0.2[bc]	2.3 ± 0.2[c]	<0.0001
Older-aged	2.5 ± 0.2	2.5 ± 0.2	2.5 ± 0.2	0.749
Fruits and Vegetables (with juices)				
Total	3.7 ± 0.2[a]	3.9 ± 0.2[b]	4.1 ± 0.2[c]	<0.0001
Middle-aged	3.6 ± 0.2[a]	3.9 ± 0.2[b]	4.0 ± 0.2[c]	<0.0001
Older-aged	3.7 ± 0.2[a]	4.0 ± 0.2[b]	4.2 ± 0.2[c]	<0.0001
Fruits and Vegetables (without juices)				
Total	3.3 ± 0.2[a]	3.5 ± 0.2[b]	3.7 ± 0.2[c]	<0.0001
Middle-aged	3.2 ± 0.2[a]	3.5 ± 0.2[b]	3.6 ± 0.2[c]	<0.0001
Older-aged	3.3 ± 0.4[a]	3.5 ± 0.2[b]	3.7 ± 0.1[c]	<0.0001

Note. Values are mean ± standard deviation estimated from fully adjusted ANCOVA model (model 3). Food group variables were transformed with the square root function and back-transformed values are presented. Different letter superscripts indicate statistically significant differences between social groups ($p<0.01$). Total respondents, n = 20,786 (3635, 8329, 8822 for low, medium, and high strength of social environment groups, respectively); Middle-aged, n = 13,060 (2153, 5081, and 5826 for low, medium and high strength of social environment groups, respectively); Older-aged, n = 7,726 (1482, 3248, and 2996 for low, medium and high strength of social environment groups, respectively).

For the complete, middle-aged and older-aged samples, differences in fruit and vegetable consumption (with juices) were most pronounced for the low, medium and high strength groups. Consumption frequency for fruits and vegetables (with juices) for the total sample was reported as 3.7 ± 0.2 (times per day) for the low strength group compared to 4.1 ± 0.2 (times per day) for the high strength group ($p<0.001$). Furthermore, for the middle-aged cohort consumption frequency (times per day) was reported as 3.6 ± 0.2 (times per day) for the low strength group compared to 4.0 ± 0.2 (times per day) for the high strength group ($p<0.001$). Results were similar for the older-aged sample, with consumption reported as 3.7 ± 0.2 (times per day) for the low strength group compared to 4.2 ± 0.2 (times per day) for the high strength group ($p<0.01$). Additionally, results were similar for fruit and vegetable consumption (without juices) for the middle aged and older aged samples; for the middle-aged sample consumption frequency of fruits and vegetables (times per day) for the low strength group was reported as 3.2 ± 0.2 (times per day) compared to 3.6 ± 0.2 (times per day) for the high strength group ($p<0.001$). For the older-aged sample, consumption frequency was reported as 3.3 ± 0.4 (times per day) for the low strength group compared to 3.7 ± 0.1 (times per day) for high strength group ($p<0.001$). For protein foods, significant differences in consumption (times per day) were observed for the total sample, however, significant differences in consumption were not observed in subgroup analysis of the middle-aged and older-aged populations. For dairy, significant differences in consumption (times per day) were observed for the total and middle-aged samples, however, significant differences in consumption (times per day) were not observed for the older-aged population. Consumption frequency of whole grains did not differ significantly between social groups. The results were generally consistent within age subgroups, with the exception that the differences were attenuated in both age subgroups compared to the complete sample for consumption of the proteins food group and attenuated for the dairy food group among the older-aged subgroup.

Consumption frequencies of the four food groups according to nutritional risk status are shown in **Table 8**. Consumption frequency significantly differed between groups for the whole grains, protein foods, and fruits and vegetables (including and excluding juices) groups, where participants classified as being at high nutritional risk had lower consumption frequencies than those not at high risk. The most prominent differences in consumption were observed in protein food consumption for the complete, and older-aged cohorts; for the total sample protein food consumption was reported as 2.3 ± 0.1 (times per day) for those not at high nutritional risk, compared to 2.1 ± 0.1 for respondents in the total sample considered at high nutritional risk ($p<0.001$).

Table 8. Food group consumption frequency (in times/day) by nutritional risk status

Food group	High Nutritional Risk: No	High Nutritional Risk: Yes	p-value
Whole Grains			
Total	1.1 ± 0.1	0.9 ± 0.2	<0.0001
Middle-aged	1.0 ± 0.1	0.8 ± 0.2	<0.0001
Older-aged	1.3 ± 0.2	1.1 ± 0.2	<0.0001
Protein Foods			
Total	2.3 ± 0.1	2.1 ± 0.1	<0.0001
Middle-aged	2.3 ± 0.1	2.1 ± 0.1	<0.0001
Older-aged	2.2 ± 0.1	2.1 ± 0.1	<0.0001
Dairy			
Total	2.4 ± 0.2	2.3 ± 0.2	0.015
Middle-aged	2.3 ± 0.2	2.3 ± 0.2	0.129
Older-aged	2.5 ± 0.2	2.5 ± 0.2	0.022
Fruits and Vegetables (with juices)			
Total	4.2 ± 0.2	3.5 ± 0.2	<0.0001
Middle-aged	4.2 ± 0.2	3.4 ± 0.2	<0.0001
Older-aged	4.2 ± 0.2	3.6 ± 0.2	<0.0001
Fruits and Vegetables (without juices)			
Total	3.8 ± 0.2	3.1 ± 0.2	<0.0001
Middle-aged	3.8 ± 0.2	3.0 ± 0.2	<0.0001
Older-aged	3.8 ± 0.1	3.2 ± 0.2	<0.0001

Note. Values are mean ± standard deviation estimated from fully adjusted ANCOVA model (model 3). Food group variables were transformed with the square root function and back-transformed values are presented. Total respondents, n = 20,786 (13,199 and 6787 for no and yes groups, respectively); Middle-aged, n = 13,060 (8811 and 4249 for no and yes groups, respectively); Older-aged, n = 7,726 (5188 and 2538 for no and yes groups, respectively).

For protein consumption for the total sample, the 0.2 difference in consumption frequency (times per day) translates to an additional consumption frequency of 1.4 times per week between those considered not at high nutritional risk compared to those at high nutritional risk. For the older-aged cohort, consumption frequency was reported as 2.2 ± 0.1 (times per day) for those not at high nutritional risk and 2.1 ± 0.1 (times per day) for those at high nutritional risk ($p<0.001$). For the older aged cohort, the 0.1 difference in consumption frequency (times per day) translates to an additional consumption frequency of 0.70 times per week between those considered not at high nutritional risk compared to those at high nutritional risk. The most distinguishing differences in consumption were also observed for fruits and vegetables (with and without inclusion of juices) for the complete, middle-aged and older-aged samples. For the complete sample, consumption of fruits and vegetables (with juices) was 4.2 ± 0.2 (times per day) for those not at high nutritional risk compared to 3.5 ± 0.2 (times per day) for those at high nutritional risk ($p<0.001$). For the complete sample, the 0.7 difference in consumption frequency (times per day) translates to an additional consumption frequency of 4.9 times per week between those considered not at high nutritional risk compared to those at high nutritional risk. For the middle-aged cohort, consumption of fruits and vegetables (with juices) was reported as 4.2 ± 0.2 (times per day) for those not at high nutritional risk compared to 3.4 ± 0.2 (times per day) for those at high nutritional risk; for the older-aged cohort consumption was reported as 4.2 ± 0.2 for those not at high nutritional risk compared to 3.6 ± 0.2 for those at high nutritional risk. For the middle-aged cohort, the 0.8 difference in consumption frequency (times per day) translates to an additional consumption frequency of 5.6 times per week between those considered not at high nutritional risk compared to those at high nutritional risk. For the older-aged cohort, the 0.6 difference in consumption frequency (times per day) translates to an additional consumption frequency of 4.2 times per week between those considered not at high nutritional risk compared to those at high nutritional risk. Noteworthy differences in consumption in the complete, middle-aged and older-aged samples were also observed for fruits and vegetables (without juices) for those considered at nutritional risk compared to those not at nutritional risk. For the complete sample, consumption was reported as 3.8 ± 0.2 (times per day) for those not at risk compared to 3.1 ± 0.2 (times per day) for those at nutritional risk ($p < 0.001$). For the total sample, the 0.7 difference in consumption frequency (times per day) translates to an additional consumption frequency of 4.9 times per week between those considered not at high nutritional risk compared to those at high nutritional risk. Furthermore, for the middle-aged sample, consumption was reported as 3.8 ± 0.2 for those not at risk compared to 3.0 ± 0.2 for those at risk; for the older-aged cohort, consumption was reported as 3.8 ± 0.1 (times per day) for those not at risk compared to 3.2 ± 0.2 (times per day) for those at risk ($p<0.001$). For the middle-aged cohort, the 0.8 difference in consumption frequency (times per day) translates to an additional consumption frequency of 5.6 times per week between those considered not at high nutritional risk compared to those at high nutritional risk. For the older-aged cohort, the 0.6 difference in consumption frequency (times per day) translates to an additional consumption frequency of 4.2 times per week between those considered not at high nutritional risk compared to those at high nutritional risk. Significant differences in consumption were observed for whole grains, however, differences were not as pronounced as those for protein and fruits and vegetables (with and without the inclusion of juices). No significant difference was observed for consumption of the dairy food group; results were consistent within both age subgroups.

CHAPTER 5: DISCUSSION

This study aimed to examine the relationship between strength of the social environment and nutritional risk among middle-aged and older-aged adults. To our knowledge, this is the first investigation that used multiple social factors in combination to classify individuals into different social environment groups, providing a comprehensive representation of the overall strength of the social environment and assessing its association with nutritional outcomes pertinent to aging. Findings from this investigation indicate that nutritional risk scores varied significantly between social environment groups in a dose-response manner among both middle-aged and older-aged individuals, with a medium effect size (74). The weakest social strength group also scored poorest on each item of the SCREEN-II-AB, suggesting that the social environment is pertinent to the full set of risk factors and determinants that encompass nutritional risk.

Nutritional risk is a significant public health issue and the identification of actionable targets for intervention is a high priority to support healthful aging and aging in place (75, 76). Indeed, a previous cross-sectional survey of n=15,669 seniors aged 65 and older in Canada concluded that approximately 33% of the participants were at nutritional risk with 4.5 kilogram weight loss/gain in the past six months and frequent meal skipping being the two main contributors to nutritional risk (1). Furthermore, nutritional risk has been significantly associated with time to death (23). Results from the present analysis suggest that the social environment is important for nutritional status in middle-age as well as older-age and indicate a need for future research to investigate the relationships between social factors and nutritional outcomes across different stages of life. Moreover, the present findings suggest that public health efforts may benefit from surveying nutritional risk among middle-aged individuals to assist in prevention of unsatisfactory nutritional status later in life.

The results of the present study are supported by previous research that has investigated individual social factors and nutritional risk. Ramage-Morin et al. (1) previously reported that low social support, social isolation and sporadic social contact were each individually and independently associated with nutritional risk. In a study of 1,000 American black and white men and women aged 65 and older, indicators of social isolation and social support were associated with nutritional risk among certain ethnic and gender subgroups (7). Furthermore, in a study by Boulos et al. (77), social isolation was independently associated with higher risk for malnutrition in a population cohort of 1,200 elderly Lebanese community-dwelling men and women. These findings suggest that social isolation is a particularly relevant dimension of the social environment for nutritional risk status. Furthermore, the exacerbation of malnutrition in older aged adults during the COVID-19 pandemic, while in part due to social isolation, can also be attributed to decreased food security and intensified social inequities and inequalities (78). Healthcare programs and policies, such as Medicare, are uniquely beneficial for targeting nutrition-related inequalities due to their potential implementation of supplemental nutrition-related programs, creating strong community partnerships that extend beyond clinical care alone (78) This is an important observation given the unique societal experiences of different sociodemographic groups over the course of the COVID-19 pandemic, and highlights the importance of targeting more isolated and food insecure groups for prioritized surveillance and research on nutritional risk.

According to previously published literature from Hwang et al., loneliness oftentimes coincides with social isolation, both of which are unfortunately incredibly prevalent in older adults. While they are distinct concepts that frequently co-occur, they both exert detrimental health effects through concurrent yet recognizably different pathways (79, 80). The suggested mechanisms for the adverse health impacts of social isolation can be associated with behavioural changes, namely the adoption of unhealthy lifestyle changes such as lower physical activity, smoking, poor dietary choices, alcohol consumption and noncompliance with prescribed medications (79, 81, 82). Furthermore, prolonged social isolation, such as that experienced during the COVID-19 pandemic, has the potential to adversely impact emotional and physical health, altering nutritional and dietary patterns, sleep, and reducing opportunities for movement (83, 84).

While we observed a strong and consistent pattern of increased nutritional risk with lower strength of social environment, our findings may underestimate the true relationship due to lower inclusion of socially isolated participants in the CLSA Comprehensive Cohort. Indeed, among the full CLSA Tracking Cohort, the prevalence of social isolation was reported to be 5.1% (85), while in the Comprehensive Cohort the prevalence was reported as 1.2% (60). Our investigation required use of the Comprehensive Cohort to assess dietary intake, as the SDQ was not completed by Tracking Cohort participants (52).

Significant differences were observed in the consumption frequencies of certain food groups according to the social environment group, and for most food groups according to nutritional risk status. The largest observed differences were for fruit and vegetable consumption, where consumption frequency significantly differed in a dose-response manner between all social strength groups, and between nutritional risk status groups. This finding is relevant for considering the links between social factors and health as insufficient consumption of fruits and vegetables has been linked with poor indicators of metabolic and cognitive health among older adults (86, 87). Research indicates that higher levels of social ties and social participation are associated with higher levels of fruit and vegetable intake (88, 89) while conversely, social isolation has been reported to be a strong risk factor for insufficient intake (90). Socialization and companionship are important contributors to the observed benefits of social engagement on fruit and vegetable intake (48, 91-93).

Of relevance, in the present investigation, a significant difference in consumption frequency of dairy foods was not observed between nutritional risk groups or between social environment groups among the older-aged participants. This suggests that dairy foods may be a particularly feasible source of protein and other beneficial nutrients (e.g., fatty acids) for adults, and specifically for older-aged adults. This observation is notable and timely given the most recent 2019 Canada's Food Guide, which no longer includes dairy as a food group category (94). Rather, dairy foods are promoted as part of a broader group of "protein foods", yet our observation illustrates that protein sources other than dairy were less frequently consumed among participants at high nutritional risk and somewhat lower among the low social strength group (when evaluating the complete sample). Compared to other sources of protein, dairy foods can be less costly, require less preparation time, and have physical properties that may be easier to consume for older-aged individuals (95). Dairy products are rich in nutrients that help to promote and maintain optimal bone health and reduce risk of bone fractures and osteoporosis in older age adults, including potassium, phosphorous, protein, calcium and vitamin D (96, 97). Therefore, dietary guidelines may benefit from continuing to promote dairy foods, at least through targeted recommendations according to stage of life. Indeed, positive effects of dairy products have been reported on muscle strength, muscle mass and measures of functionality in the aging population (80, 98). According to literature put forth by Kongerslev Thorning et al. (96), dairy intake has been shown to facilitate weight loss during times of caloric restriction and improve body composition. Additionally, milk and dairy intake was inversely associated with risk for breast cancer, colorectal cancer, gastric cancer and bladder cancer and not associated with risk for ovarian cancer, lung cancer or pancreatic cancer. Furthermore, milk and dairy intake was associated with reduced risk of type II diabetes and cardiovascular disease (96).

Strengths and Limitations of Present Study

Strengths of the present study include use of data from a large, comprehensive and well characterized cohort, the CLSA. Furthermore, this analysis evaluated more than one stage of life, assessing the associations between strength of social environment and nutritional risk in middle aged and older aged Canadians. This analysis provided a comprehensive assessment of social factors; historically, LCA has not been utilised to classify participants into strength of social environment groups based on multiple social variables in combination.

Several limitations must be acknowledged including the cross-sectional nature of the study design, preventing conclusions regarding causality and the directionality of association between the social environment and nutritional risk. The majority of participants were Caucasian and so our findings may not be generalizable to other ethnicities. Participants excluded from the present analyses had more disadvantaged sociodemographic characteristics and a higher prevalence of nutritional risk. Thus, selection bias is a limitation; however, we anticipate that the observed associations would be in the same direction and potentially more pronounced had our analytical sample been comprised of a more complete set of CLSA participants. The SDQ assessed frequency of food item consumption, but not portion size. Therefore, although food group consumption frequencies were mostly lower among participants at nutritional risk and those with a weak social environment, we are unable to determine whether the intakes were insufficient. A study by Shatenstein and Payette assessed the validity of the Short Dietary Questionnaire in the assessment of consumption frequency and addressed the limitations associated with not measuring portion size. This analysis imputed a standard (medium) portion size in grams regarded as consumption as one time per day (62). Operating under the preestablished assumption that frequency of consumption of one time per day equates roughly to one medium portion size, we may infer that the significant differences in frequency of consumption observed in the present study (between those at high nutritional risk compared to those not at nutritional risk) may translate to significant and impactful differences in intake. Nevertheless, the analyses of consumption frequency measures were secondary and intended to compliment the interpretation of results from the primary analysis conducted in this investigation (i.e., the relationships between the strength of the social environment and nutritional risk). Other diet-related factors such as frequency of eating meals with others and enjoyment from eating may be important to further understand the relationships between the social environment and nutritional risk.

We acknowledge that the SCREEN-II-AB tool to assess nutritional risk has been previously validated with dietary intake in community-dwelling older adults aged 55 years and above (21). Thus, our observations among the middle-aged subgroup require confirmation. Furthermore, recent literature has evaluated the sensitivity of the SCREEN-II-AB compared to its abridged version, the three-item SCREEN-III, in the identification of nutritional risk, utilizing baseline data from the CLSA Tracking and Comprehensive cohorts (99). The SCREEN-III contains three questions from the SCREEN-II-AB, with questions regarding weight changes, difficulties chewing/swallowing and appetite (99). The SCREEN-III utilizes a cut-off nutritional risk score of 22, as opposed to 38, the value used in the SCREEN-II-AB (99). The SCREEN-III, compared to the SCREEN-II-AB, performed better on measures of sensitivity and specificity and based on this analysis, it is possible to conclude that the SCREEN-II-ABI is more adept at identifying nutritional risk compared to the SCREEN-II-AB, opening up the possibility for its utilization in future research. Lastly, while we lowered our threshold for deeming statistical significance to alpha of 0.01 considering the number of comparisons performed, in order to avoid further issues related to multiplicity, we did not evaluate whether the individual social variables were associated with nutritional risk status. It is possible that certain social factors are more relevant than others, and this remains a question for future investigation. Furthermore, each strength of social environment group was created separately within each age subgroup, therefore "low strength of social environment" was not necessarily entirely consistent across the middle aged and older aged populations.

Future Research

This analysis was performed on population of middle aged and older aged Canadian adults; the weakest strength of social environment group associated with greater likelihood of nutritional risk across the middle aged and older aged populations. This stresses the importance of early nutritional intervention, in middle age or earlier, and further research could benefit from assessing the associations between strength of social environment and nutritional risk in middle aged and older aged non-Canadian populations. Furthermore, as individuals age, increased medication usage can interfere with the absorption and metabolism of key nutrients (1). Future research may benefit from assessing the impact of medication usage on nutrient absorption in middle-aged and older-aged populations and its impact on nutritional risk and dietary intake. Furthermore, previous literature from Rugel et al.(42) proposes that there are gender differences in the relationship between food intake and social support. Future research may benefit from evaluating the influence of gender on dietary intake as the type of social support received or requested may differ according to gender (42).

The CLSA included only a small percentage (3.7%) of Indigenous individuals of First Nation, Metis and Inuit origin in its sample. In recent years, the dietary intake of Indigenous Peoples in Canada has shifted, from a diet predominantly comprised of nutrient-rich, low-fat and high-protein foods, to one that consists of high sugar and fat consumption (100, 101). This transition has been attributed to a loss of sustaining environmental resources, the introduction of Western foods and the development of dependence on market foods (100, 102). Dietary surveys indicate that the dietary intakes of Indigenous communities do not meet dietary recommendations for saturated fat, fibre, sodium, fruits and vegetables (100, 103). While issues related to food access and food security are key factors implicated in Indigenous People's nutrition, research that considers the social environment of Indigenous communities in nutrition outcomes may be an area of interest for future work given the findings of the present study (104).

CHAPTER 6: FINAL CONCLUSION AND SUMMARY

The primary objective of this analysis was to evaluate the associations between strength of social environment and nutritional risk in a cohort of middle-aged and older aged Canadian adults. Participants were classified into three strength of social environment groups (low, medium and high) using LCA and subsequently, ANCOVA models were conducted to compare adjusted mean nutritional risk scores according to the social environment groups created from the LCA. Pairwise comparisons of social environment groups were conducted with nutritional risk scores varying significantly between social environment groups; the lowest social strength group having an adjusted mean nutritional risk score indicating high nutritional risk. The consumption of major food groups (whole grains, protein foods, dairy products, and fruits and vegetables) by strength of social environment group and nutritional risk status was evaluated as a secondary objective. Results indicate that when compared to the medium and high social strength groups, respondents in the low social strength group had significantly lower consumption frequency of the proteins, dairy, and fruits and vegetable food groups. Furthermore, respondents considered at nutritional risk had significantly lower consumption frequency of protein, dairy and fruits and vegetable food groups compared to their counterparts not considered at risk.

Strategies for reducing nutritional risk may benefit from considering social factors as targets for interventional or community-based programs. Indeed, previous literature indicates that there is not one conclusive intervention to address social insufficiencies and therefore, future research is needed to develop appropriate strategies for interventions aimed towards at-risk groups while providing diverse and appropriate nutritional education (105). Meal programs are one strategy that can improve nutritional risk status among seniors by reducing frequent meal skipping and easing the burden of grocery shopping and meal preparation (92). However, the consideration of social factors in the design and/or evaluation of meal programs is an avenue for future work. Overall, additional investigations of novel strategies that consider access, preparation, and/or physical food properties to promote good nutrition among older populations are warranted.

REFERENCES

1. Ramage-Morin P, Garriguet D. Nutritional risk among older Canadians. Health Reports. 2013;24(3):3-13.

2. Pilgrim A, Robinson S, Sayer A, Roberts J. An overview of appetite decline in older people. Nursing older people. 2015;27(5):29-35. doi: 10.7748/nop.27.5.29.e697. PubMed Central PMCID: PMC4589891.

3. Volkert D. Malnutrition in older adults - urgent need for action: a plea for improving the nutritional situation of older adults. Gerontology. 2013;59(4):328-33. doi: 10.1159/000346142.

4. Kiecolt-Glaser J, McGuire L, Robles T, Glaser R. Emotions, morbidity, and mortality: new perspectives from psychoneuroimmunology. Annual review of psychology. 2002;53:83-107. doi: 10.1146/annurev.psych.53.100901.135217.

5. Seeman T, Lusignolo T, Berkman L. Social relationships, social support, and patterns of cognitive aging in healthy, high-functioning older adults: MacArthur studies of successful aging. Health Psychology. 2001;20(4):243-55. doi: 10.1037//0278-6133.20.4.243.

6. Cramm J, van Dijk H, Nieboer A. The importance of neighborhood social cohesion and social capital for the well being of older adults in the community. Gerontologist. 2013;53(1):142-52. doi: 10.1093/geront/gns052.

7. Locher J, Richie C, Roth D, Bodner E, Allman R. Social Isolation, Support and Capital and Nutritional Risk in an Older Sample: Ethnic and Gender Differences. Social Science & Medicine. 2005;60(4):747-61. doi: 10.1016/j.socscimed.2004.06.023. PubMed Central PMCID: PMC2763304.

8. Umberson D, Montez J. Social relationships and health: a flashpoint for health policy. Health and Social Behavior. 2010. doi: 10.1177/0022146510383501. PubMed Central PMCID: PMC3150158.

9. Berkman L, Syme S. Social networks, host resistance, and mortality: a nine-year follow-up study of Alameda County residents. American journal of Epidemiology. 1979;109(2):186-204. doi: 10.1093/oxfordjournals.aje.a112674.

10. Conklin A, Forouhi N, Surtees P, Khaw K, Wareham N, Monsivais P. Social relationships and healthful dietary behaviour: Evidence from over-50's in the EPIC cohort, UK. Social Science & Medicine. 2014;100:167-75. doi: 10.1016/j.socscimed.2013.08.018. PubMed Central PMCID: PMC3969105.

11. Saunders J, Smith T. Malnutrition: causes and consequences. Clinical Medicine. 2010;10(6):624-7. doi: 10.7861/clinmedicine.10-6-624.

12. Elia M, Zellipour L, Stratton R. To screen or not to screen for adult malnutrition? Clinical Nutrition. 2005;6(24):867-84.

13. Reber E, Ivanova A, Cadisch P, Stirnimann J, Perrig M, Roten C, et al. Does multifaceted nutritional education improve malnutrition management? . Nutrition. 2020;78. doi: 10.1016/j.nut.2020.110810.

14. Using and Scoring Screen [Internet]. Seniors in the Community: Risk Evaluation for Eating and Nutrition (SCREEN) [cited 2022 Jun 12]. Available from: www.olderadultnutritionscreening.com/faq/.

15. Ferguson M, Capra S, Bauer J, Banks M. Development of a valid and reliable malnutrition screening tool for adult acute hospital patients. Nutrition. 1999;15(6):458-64. doi: 10.1016/s0899-9007(99)00084-2.

16. Karsegard V, Ferlay O, Maisonneuve N, Kyle U, Dupertuis Y, Genton L, et al. Simplified malnutrition screening tool: Malnutrition Universal Screening Tool (MUST). Revue medicale de la Suisse romande. 2004;124(10):601-5.

17. Kaiser M, Bauer J, Ramsch C, Uter W, Guigoz Y, Cederholm T, et al. Validation of the Mini Nutritional Assessment short-form (MNA-SF): a practical tool for identification of nutritional status. Nutrition, Health & Aging. 2009;13(9):782-8.

18. Kondrup J, Hojgaard Rasmussen H, Hamberg O, Stanga Z. Nutritional risk screening (NRS 2002): a new method based on an analysis of controlled clinical trials. Clinical Nutrition. 2003;22(3):321-36. doi: 10.1016/s0261-5614(02)00214-5.

19. Kruizenga H, Seidell J, de Vet H, Wierdsma N, van Bokhorst-de van der Schueren M. Development and validation of a hospital screening tool for malnutrition: the short nutritional assessment questionnaire (SNAQ). Clinical Nutrition. 2005;24(1):75-82. doi: 10.1016/j.clnu.2004.07.015.

20. Laporte M. The Canadian Nutrition Screening Tool. Advances in skin and woundcare. 2017;30(2):64-5. doi: 10.1097/01.ASW.0000511698.41409.4a.

21. Keller H, Goy R, Kane S. Validity and reliability of SCREEN II (Seniors in the Community: Risk evaluation for eating and nutrition, Version II). European Journal of Clinical Nutrition. 2005;59:1149-57. doi: 10.1038/sj.ejcn.1602225.

22. Keller H, McKenzie J, Goy R. Construct validation and test-retest reliability of SCREEN (Seniors in the Community: Risk Evaluation for Eating and Nutrition). The Journals of Gerontology. 2001;56(9):M552-M8. doi: doi.org/10.1093/gerona/56.9.M552.

23. Keller H, Ostbye T, Goy R. Nutritional risk and time to death; predictive validity of SCREEN (Seniors in the Community Risk Evaluation for Eating and Nutrition). Nutrition, Health & Aging. 2003;7(4):4-9.

24. Islam M. Social Determinants of Health and Related Inequalities: Confusion and Implications. Front Public Health. 2019;7. doi: 10.3389/fpubh.2019.00011. PubMed Central PMCID: PMC6376855.

25. Graham H. Social determinants and their unequal distribution: clarifying policy understandings. 82. 2004;1:101-24. doi: 10.1111/j.0887-378x.2004.00303.x. PubMed Central PMCID: PMC2690205.

26. Loprinzi P, Ford M. Effects of Social Support Network Size on Mortality Risk: Considerations by Diabetes Status. 2018;Diabetes Spectrum. doi: doi.org/10.2337/ds17-0056.

27. Bandura A. Self-efficacy: Toward a unifying theory of behavioral change. Psychological Review. 1977;84(2). doi: doi.org/10.1037/0033-295X.84.2.191.

28. Chin H, Mansori S. Determinants in Social Cognitive Theory. 2018.

29. Charles S, Mather M, Carstensen L. Aging and emotional memory: The forgettable nature of negative images for older adults. Journal of Experimental Psychology: General. 2003;132(2):310-24. doi: doi.org/10.1037/0096-3445.132.2.310.

30. Dent E, Hoogendijk E. Psychosocial factors modify the association of frailty with adverse outcomes: a prospective study of hospitalised older people. BMC Geriatrics. 2014. doi: 10.1186/1471-2318-14-108.

31. Besora-Moreno M, Llaurado E, Tarro L, Sola R. Social and Economic Factors and Malnutrition or the Risk of Malnutrition in the Elderly: A Systematic Review and Meta-Analysis of Observational Studies. Nutrients. 2020;12(3). doi: 10.3390/nu12030737.

32. Cohen S, Doyle W, Skoner D, Rabin B, Gwaltney J. Social Integration and Network Size. 1997.

33. Aoki T, Yamamoto Y, Ikenoue T, Urushihara-Miyachi Y, Kise M, Fujinuma Y, et al. Social Isolation and Patient Experience in Older Adults. Annals of Family Medicine. 2018;16(5). Epub September 2018. doi: 10.1370/afm.2257.

34. Canadian Longitudinal Study on Aging, Social Support Questionnaire (Baseline) adapted from the Medical Outcomes Study (MOS) Social Support Survey.

35. Sherbourne C. The MOS social support survey. Social Science & Medicine. 1991;32(6):705-14. doi: 10.1016/0277-9536(91)90150-b.

36. Braveman P, Gottlieb L. The Social Determinants of Health: It's Time to Consider the Causes of the Causes. Public Health Rep. 2014;129:19-31. PubMed Central PMCID: PMC3863696.

37. Holt-Lunstad J, Smith T. Social Relationships and Mortality Risk: A Meta-analytic Review. PLOS Medicine. 2010. doi: doi.org/10.1371/journal.pmed.1000316.

38. Pieroth R, Radler D, Guenther P, Brewster P, Marcus A. The Relationship between Social Support and Diet Quality in Middle-Aged and Older Adults in the United States. Journal of the Academy of Nutrition and Dietetics. 2017;117(8):1272-8.

39. Silverman P, Hecht L, McMillin D. Social support and dietary change among older adults. Ageing & Society. 2002;22(1):29-59. doi: doi.org/10.1017/S0144686X02008590.

40. Holmes B, Roberts C. Diet quality and the influence of social and physical factors on food consumption and nutrient intake in materially deprived older people. European Journal of Clinical Nutrition. 2011;65:538-45. doi: doi.org/10.1038/ejcn.2010.293.

41. DRI Dietary Reference Intakes. National Academies Press. 2000.

42. Rugel E, Carpiano R. Gender differences in the roles for social support in ensuring adequate fruit and vegetable consumption among older adult Canadians. Appetite. 2015;92(1):102-9. doi: doi.org/10.1016/j.appet.2015.05.011.

43. Haslinda Hamirudin A, Charlton K, Walton K. Outcomes related to nutrition screening in community living older adults: A systematic literature review. Archives of gerontology and geriatrics. 2016;62:9-25. doi: 10.1016/j.archger.2015.09.007.

44. Glanz K. Nutrition in the Prevention and Treatment of Disease. 2001;Nutrition in the Prevention and Treatment of Disease:83-93. doi: doi.org/10.1016/B978-012193155-1/50008-8.

45. Bandura A. Social foundations of thought and action: A social cognitive theory. 1986.

46. Prochaska J, Velicer W. The transtheoretical model of health behavior change. American journal of Health Promotion. 1997;12(1):38-48. doi: 10.4278/0890-1171-12.1.38.

47. Rosenstock I, Strecher V, Becker M. Social learning theory and the Health Belief Model. Health education quarterly. 1988;15(2):175-83. doi: 10.1177/109019818801500203.

48. Keller H. Meal Programs Improve Nutritional Risk: A Longitudinal Analysis of Community-Living Seniors. Journal of American Dietetic Association. 2006;106(7):1042-8. doi: 10.1016/j.jada.2006.04.023.

49. Sorensen G, Stoddard A, Macario E. Social support and readiness to make dietary changes. Health education & behavior. 1998;25(5):586-98. doi: 10.1177/109019819802500506.

50. Robinson E, Thomas J, Aveyard P, Higgs S. What everyone else is eating: a systematic review and meta-analysis of the effect of informational eating norms on eating behavior. J Acad Nutr Diet. 2014;114(3):414-29. doi: 10.1016/j.jand.2013.11.009.

51. Raina P, Wolfson C, Kirkland S, Griffith L, Balion C, Cossette B, et al. Cohort Profile: The Canadian Longitudinal Study on Aging (CLSA). Int J Epidemiol. 2019;48(6):1752-3. doi: doi.org/10.1093/ije/dyz173.

52. About the CLSA Canadian Longitudinal Study on Aging [Internet]. Canadaian Longitudinal Study on Aging, 2022 [cited 2022 Jun 12]. Available from: www.clsa-elcv.ca/about-us/about-clsa.

53. Berkman L, Kawachi I. Social Epidemiology. Oxford Press2000.

54. Robitaille A, Orpana H, McIntosh C. Psychometric properties, factorial structure, and measurement invariance of the English and French versions of the Medical Outcomes Study social support scale. Health Rep. 2011;22:33-40.

55. RAND Corporation: Social Support Survey Instrument Scoring Instructions. Available from: https://www.rand.org/health-care/surveys_tools/mos/social-support/scoring.html.

56. Fonseca X, Lukosch S, Brazier F. Social cohesion revisited: a new definition and how to characterize it. Innovation. 2018:231-53.

57. Urzua C, Ruiz M, Pajak A, Kozela M, Kubinova R, Malyutina S, et al. The prospective relationship between social cohesion and depressive symptoms among older adults from Central and Eastern Europe. J Epidemiol Community Health. 2019;73:117-22. doi: 10.1136/jech-2018-211063.

58. Smith J, Ryan L, Fisher G, Sonnega A, Weir D. HRS Psychosocial and Lifestyle Questionnaire 2006-2016. Ann Arbor, Michigan: Survey Research Center, Institute for Social Research, University of Michigan, 2017.

59. Courtin E, Knapp M. Social isolation, loneliness and health in old age: a scoping review. Health Soc Care Community. 2017;25:799-812. doi: 10.1111/hsc.12311.

60. Menec V, Newall N, Mackenzie C, Shooshtari S, Nowicki S. Examining individual and geographic factors associated with social isolation and loneliness using Canadian Longitudinal Study on Aging (CLSA) data. PLoS One. 2019;14(2). doi: 10.1371/journal.pone.0211143. PubMed Central PMCID: PMC6358157.

61. Derived Variables — Nutritional Risk (NUR): Canadian Longitudinal Study on Aging; 2015 [cited 2022]. Available from: https://www.clsa-elcv.ca/doc/2526.

62. Shatenstein B, Payette H. Evaluation of the Relative Validity of the Short Diet Questionnaire for Assessing Usual Consumption Frequencies of Selected Nutrients and Foods. Nutrients. 2015;7(8):6362-74. Epub 20150804. doi: 10.3390/nu7085282. PubMed PMID: 26247965; PubMed Central PMCID: PMC4555121.

63. van Staveren W, de Groot L. Evidence-based dietary guidance and the role of dairy products for appropriate nutrition in the elderly. Journal of the American College of Nutrition. 2011;30(5):429S-37S. doi: 10.1080/07315724.2011.10719987.

64. Fujiwara T, Shilpika J, Xu P, Ren L, Ma K. An Incremental Dimensionality Reduction Method for Visualizing Streaming Multidimensional Data. IEEE Trans Vis Comput Graph. 2020;26(1):418-28. doi: 10.1109/TVCG.2019.2934433.

65. van der Maaten L, Postma E, van den Herik J. Dimensionality Reduction: A Comparative Review. 2009.

66. Tabachnick B, Fidell L. Using Multivariate Statistics. 6 ed: Pearson Education 2013. 983 p.

67. Uebersax J. Dimension Reduction and Latent Class Analysis: A Simple Method for Interpretation of Latent Class Analysis Parameters, with Possible Implications for Factor

Analysis of Dichotomous and Ordered-Category Measures. Department of Public Health Sciences1992.

68. Karnowski V. Latent Class Analysis. The International Encyclopedia of Communication Research Methods. 2017. doi: doi.org/10.1002/9781118901731.iecrm0130.

69. BE Weller NB, SJ Faubert. Latent Class Analysis: A Guide to Best Practice. Journal of Black Psychology. 2020;46(4):287-311. doi: 10.1177/0095798420930932.

70. Hagenaars J, McCutcheon A. Applied Latent Class Analysis: Cambridge University Press; 2002.

71. Muthen B, Muthen L, Asparouhov T. Estimator choices with categorical outcomes. 2015.

72. Additional Information about Factor Analysis and Cluster Analysis. Veterans CotDoaCCDfCMIi-GW, editor: National Academies Press; 2014.

73. Jung T, Wickrama K. An Introduction to Latent Class Growth Analysis and Growth Mixture Modeling. Compass. 2007;2(1):302-17. doi: 10.1111/j.1751-9004.2007.00054.x.

74. Sullivan G, Feinn R. Using Effect Size—or Why the P Value Is Not Enough. Journal of Graduate Medical Education. 2012;4(3):279-82. doi: 10.4300/JGME-D-12-00156.1. PubMed Central PMCID: PMC3444174.

75. Shlisky J, Bloom D, Beaudreault A, Tucker K, Keller H, Fruend-Levi Y, et al. Nutritional Considerations for Healthy Aging and Reduction in Age-Related Chronic Disease. Adv Nutr. 2017;8:17-26. doi: 10.3945/an.116.013474.

76. Action for Seniors Report: Government of Canada; 2021 [cited 2022 Jun 12]. Available from: https://www.canada.ca/en/employment-social-development/programs/seniors-action-report.html

77. Boulos C, Salameh P, Barberger-Gateau P. Social isolation and risk for malnutrition among older people. Geriatrics & gerontology international. 2017;17(2):286-94. doi: 10.1111/ggi.12711.

78. Arensberg M, Saal-Ridpath K, Kerr K, Phillips W. Opportunities to Improve Quality Outcomes: Integrating Nutrition Care Into Medicare Advantage to Address Malnutrition and Support Social Determinants of Health. Inquiry. 2022. doi: 10.1177/00469580221081431. PubMed Central PMCID: PMC8908402.

79. Hwang T, Rabheru K, Peisah C, Reichman W, Ikeda M. Loneliness and social isolation during the COVID-19 pandemic. Int Psychogeriatr. 2020:1-4. doi: 10.1017/S1041610220000988. PubMed Central PMCID: PMC7306546.

80. Fakoya O, McCorry N, Donnelly M. Loneliness and social isolation interventions for older adults: a scoping review of reviews. BMC Public Health. 2020;20(129). doi: 10.1186/s12889-020-8251-6.

81. Kobayashi L, Steptoe A. Social isolation, loneliness, and health behaviors at older age: longitudinal cohort study. Annals of Behavioral Medicine. 2018;52:582-93. doi: 10.1093/abm/kax033.

82. Leigh-Hunt N, Bagguley D, Bash K, Turner V, Turnbull S, Valtorta N, et al. An overview of systematic reviews on the public health consequences of social isolation and loneliness. Public Health 2017:157-71. doi: 10.1016/j.puhe.2017.07.035.

83. Pietrabissa G, Simpson S. Psychological Consequences of Social Isolation During COVID-19 Outbreak. Frontiers in Psychology. 2020. doi: doi.org/10.3389/fpsyg.2020.02201.

84. Cacioppo J, Hawkley L. Social isolation and health, with an emphasis on underlying mechanisms. Perspect Biol Med. 2003;46:S39-52.

85. Chuang Y, Chuang K, Yang T. Social cohesion matters in health. International Journal for Equity in Health. 2013;12(87):2-12. doi: 10.1186/1475-9276-12-87.

86. Papaioannou K, Kadi F, Nilsson A. Benefits of Fruit and Vegetable Consumption on Prevalence of Metabolic Syndrome Are Independent of Physical Activity Behaviors in Older Adults. Nutrients. 2022;14. doi: 10.3390/nu14020263. PubMed Central PMCID: PMC8782048.

87. Zhou Y, Wang J, Cao L, Shi M, Liu H, Zhao Y, et al. Fruit and Vegetable Consumption and Cognitive Disorders in Older Adults: A Meta-Analysis of Observational Studies. Front Nutr. 2022;9: 871061. doi: 10.3389/fnut.2022.871061.

88. Sorensen G, Stoddard A, Dubowitz T, Barbeau E, Bigby J, Emmons K, et al. The influence of social context on changes in fruit and vegetable consumption: results of the healthy directions studies. Am J Public Health. 2007;97:1216-27.

89. Lindstrom M, Hanson B, Wirfalt E, Ostergen P. Socioeconomic differences in the consumption of vegetables, fruit and fruit juices. The influence of psychosocial factors. Eur J Public Health. 2001;11:51-9. doi: 10.1093/eurpub/11.1.51.

90. Sahyoun N, Zhang X, Serdula M. Barriers to consumption of fruits and vegetables among older adults. Nutrition for the Elderly. 2005;24(4):5-21. doi: 10.1300/j052v24n04_03.

91. Devine C, Wolfe W, Frongillo E, Bisogni C. Life-course events and experiences: association with fruit and vegetable consumption in 3 ethnic groups. Journal of American Dietetic Association. 1999;99(3):309-14. doi: 10.1016/S0002-8223(99)00080-2.

92. Darmon N, Drewnowski A. Contribution of food prices and diet cost to socioeconomic disparities in diet quality and health: a systematic review and analysis. Nutrition Reviews. 2015;73(10):642-60. doi: 10.1093/nutrit/nuv027. PubMed Central PMCID: PMC4586446.

93. Canada's food guide: Government of Canada; 2022 [cited 2022]. Available from: https://food-guide.canada.ca/en/.

94. Best R, Appleton K. The consumption of protein-rich foods in older adults: an exploratory focus group study. Nutrition Education and Behavior. 2013;45(6):751-5. doi: 10.1016/j.jneb.2013.03.008.

95. Appleton K. Barriers to and Facilitators of the Consumption of Animal-Based Protein-Rich Foods in Older Adults. Nutrients. 2016;8:187. doi: 10.3390/nu8040187.

96. Kongerslev Thorning T, Raben A, Tholstrup T, Soedamah-Muthu S, Givens I, Astrup A. Milk and dairy products: good or bad for human health? An assessment of the totality of scientific evidence. Food Nutr Res. 2016;60. doi: 10.3402/fnr.v60.32527. PubMed Central PMCID: PMC5122229.

97. Rizzoli R. Dairy products, yogurts, and bone health. The American Journal of Clinical Nutrition. 2014;99(5):1256S-62S. doi: doi.org/10.3945/ajcn.113.073056.

98. Hanach N, McCullough F, Avery A. The Impact of Dairy Protein Intake on Muscle Mass, Muscle Strength, and Physical Performance in Middle-Aged to Older Adults with or without Existing Sarcopenia: A Systematic Review and Meta-Analysis. Advanced Nutrition. 2019;10(1):59-69. doi: 10.1093/advances/nmy065. PubMed Central PMCID: PMC6370271.

99. Morrison J, Laur C, Keller H. SCREEN III: working towards a condensed screening tool to detect nutrition risk in community-dwelling older adults using CLSA data. European Journal of Clinical Nutrition. 2019;73:1260-9. doi: doi.org/10.1038/s41430-019-0411-3.

100. Earle L. Traditional Aboriginal Diets and Health. 2012.

101. Reading J. The Crisis for Chronic Disease among Aboriginal Peoples: A Challenge for Public Health, Population Health and Social Policy.

102. Conti K. Diabetes Prevention in Indian Country: Developing Nutrition Models to Tell the Story of Food-System Change Transcultural Nursing. 2006;17(3):234-45.

103. Ho L, Gittelsohn J, Sharma J, Cao S, Treuth X, Rimal M. Food-Related Behavior, Physical Activity, and Dietary Intake in First Nations - a Population at Risk for Diabetes. Ethnicity & Health. 2008;13(4):335-49.

104. Shafiee M, Keshavarz P, Lane G, Pahwa P, Szafron M, Jennings D, et al. Food Security Status of Indigenous Peoples in Canada According to the 4 Pillars of Food Security: A Scoping Review. Advances in Nutrition. 2022. doi: doi.org/10.1093/advances/nmac081.

105. Keller H, Hedley M, Wong S, Vanderkooy P, Tindale J, Norris J. Community Organized food and nutrition education: participation, attitudes, and nutritional risk in seniors. The Journal of Nutrition, Health & Aging. 2006;10(1):15-20.