# The food environment and diet quality of urban-dwelling older women and men: Assessing the moderating role of diet knowledge

Geneviève Mercille, PhD,[1] Lucie Richard, PhD,[2,3] Lise Gauvin, PhD,[1,4,5] Yan Kestens, PhD,[1,4] Bryna Shatenstein, PhD,[6,7] Mark Daniel, PhD,[8,9] Hélène Payette, PhD[10,11]

## ABSTRACT

**OBJECTIVES:** The relationships between local food environments and dietary patterns are important for older adults and could be different in men and women. We examined associations between exposure to neighbourhood food sources and food consumption and the moderating role of diet knowledge separately among older women and men living in Montreal in 2003–2005 ($n = 722$).

**METHODS:** The proportion of fast-food outlets relative to all restaurants (%FFO) and the proportion of healthy food stores relative to all stores (%HFS) were estimated for 500 m buffers around participants' homes. Two dietary patterns, designated "Western" and "prudent", reflecting lower- and higher-quality diets respectively, were identified from food frequency questionnaire data. The unique and interactive effects of diet knowledge and food-source exposure on diet scores were tested with separate linear regression models for women and men.

**RESULTS:** For men, greater %FFO exposure was related to lower prudent diet scores ($\beta = -0.18$, $p = 0.02$), but no effect of %HFS exposure was observed and no interactions were statistically significant. For women, an inverse relationship between %FFO and prudent diet scores was strongest among those with low diet knowledge ($\beta = -0.22$, $p < 0.01$). No other associations were statistically significant.

**CONCLUSION:** Older men's diet patterns may reflect unhealthy cues associated with fast-food outlets. Among women, diet knowledge potentiated both negative and positive relationships with the food environment. In the absence of consistent main effects of the food environment on diet scores, subgroup analysis is a promising avenue for research.

**KEY WORDS:** Diet; older adults; urban population; food supply; effect modifier

La traduction du résumé se trouve à la fin de l'article.

*Can J Public Health* 2016;107(Suppl. 1):eS34–eS41
doi: 10.17269/CJPH.107.5309

Nutrition plays a major role in successful aging and in the prevention and management of chronic diseases.[1] However, national surveys highlight concerns regarding inadequate intakes of several foods and nutrients among independent older adults.[2] With advancing age and the onset of chronic diseases, concerns about health and healthy eating increase. Women are more active seekers of nutrition information in their desire to take responsibility for their health,[3] whereas men pay less attention to their food choices.[4] Diet knowledge differs by sex among seniors[5] and is an independent determinant of food choices.[6]

Although nutrition knowledge does not necessarily translate into healthier diets, it is a prerequisite for the selection of healthy foods in a competitive food environment where healthy and unhealthy food options co-exist.[7] Few studies have investigated the influence of food environment among older adults,[8,9] despite the importance of residential neighbourhood influence posited by ecological models of aging.[10]

Among younger adults, evidence suggests that better access to supermarkets and the availability of healthy foods as measured in grocery stores are associated with more healthy food choices in the US, but this relationship is not observed consistently elsewhere.[11] Inconsistent findings might be linked to incomplete measures of exposure to the food environment, as many studies have often examined only a single dimension. Absolute measures (e.g., density of specific food outlets, distance to food stores) do not account for

**Author Affiliations**

1. Centre de Recherche du Centre Hospitalier de l'Université de Montréal (CRCHUM), Montréal, QC
2. Institut de recherche en santé publique de l'Université de Montréal (IRSPUM), Montréal, QC
3. Faculté des sciences infirmières, Université de Montréal, Montréal, QC
4. Département de médecine sociale et préventive, École de santé publique, Université de Montréal, Montréal, QC
5. Centre de recherche Léa-Roback sur les inégalités sociales de santé de Montréal, Montréal, QC
6. Département de nutrition, Université de Montréal, Montréal, QC
7. Centre de recherche, Institut universitaire de gériatrie de Montréal, Centre intégré universitaire de santé et de services sociaux (CIUSSS) du Centre-Sud-de-l'Île-de-Montréal, Montréal, QC
8. Centre for Population Health Research, University of South Australia, Adelaide, Australia
9. Department of Medicine, St. Vincent's Hospital, The University of Melbourne, Melbourne, Australia
10. Département des sciences de la santé communautaire, Faculté de médecine et des sciences de la santé, Université de Sherbrooke, Sherbrooke, QC
11. Centre de recherche sur le vieillissement, CIUSSS de l'Estrie-Centre hospitalier universitaire de Sherbrooke, Sherbrooke, QC

**Correspondence:** Geneviève Mercille, PhD, CRCHUM, Tour St-Antoine, 850, St-Denis – S02-336, Montréal, QC H2X 0A9, Tel: 514-890-8000, ext. 31450, E-mail: genevieve.mercille.1@umontreal.ca

**Acknowledgements:** This work was supported by the Canadian Institutes of Health Research (grant MOP-173669 to the VoisiNuAge study and MOP-62842 to the NuAge Study, and grant MFE-226542 to GM) and the Fonds de la recherche en santé du Québec (grant #16207 to LR and #20328 to YK). LG held a CIHR/CRPO (Canadian Institutes of Health Research/Centre de recherche en prévention de l'obésité) Applied Public Health Chair on Neighbourhoods, Lifestyle, and Healthy Body Weight. GM was also supported by the Strategic Training Program in Transdisciplinary Research on Public Health Interventions: Promotion, Prevention and Public Policy (4P), a partnership of CIHR and the Québec Population Health Research Network. YK holds a CIHR Applied Public Health Chair on Urban Interventions and Population Health. The results presented in this paper are solely the responsibility of the authors and do not necessarily represent the view of the funders.
**Conflict of Interest:** None to declare.

the complexity of exposure to diverse food sources. Furthermore, because "healthy" and "unhealthy" sources are often spatially correlated in urban areas, relative measures of exposure may be more adapted to tease out effects.[12] A small but growing number of studies have used such metrics to estimate associations with diet-related outcomes.[8,12,13]

Inconsistent findings might also be linked to variations in the dose–response relationship. Ecological models have long recognized dynamic and complex interactions between individuals and their environments.[10] An increasing body of evidence shows a sex-differential impact of the food environment on diet across age groups and socio-economic status.[14–16] Few studies have explored psychological or psychosocial moderators of diet.[15,17]

The current study examined associations between local food-source availability and dietary patterns, and tested the moderating role of diet knowledge within an urban, population-based sample of generally healthy and cognitively intact group of older adults living independently. It sought also to determine how these associations are present in men and women after adjustments for health status and social support, two factors known for their joint influence on both diet and access to neighbourhood food sources.[1]

## METHODS

### Context

The current cross-sectional study is part of the VoisiNuAge study, which integrates person-level data from the Longitudinal Study on Nutrition and Successful Aging (NuAge) cohort, described in detail elsewhere,[18] and area-level data from a geographic information system[19] to address questions on associations between neighbourhood environments and health among seniors. NuAge is a 5-year longitudinal study (2003–2008) of 1,793 community-dwelling men and women aged 67–84 years, drawn from an age- and sex-stratified random sample of the Québec Medicare database for the regions of Montreal, Laval and Sherbrooke. Participants were in good general health, and cognitively and functionally intact at recruitment. Data were collected by trained research assistants at the research centre where recruitment took place. All participants signed an informed consent form approved by the ethics committees of the University Institutes of Geriatrics of Sherbrooke and Montréal. The study area was Montréal and Laval islands (populations of 1.8 million and 343,000 inhabitants respectively in 2001). The current study reports on data gathered on 848 participants at baseline (T1) between December 2003 and April 2005. A road-network buffer of 500 m was computed around each participant's residential address and used to extract area exposures.

### Measures

#### *Diet*

Usual diet over the previous 12 months was assessed by a validated 78-item food frequency questionnaire[20] and further reduced to 37 foods or food groups on the basis of similarity of type of food and nutrient characteristics. Dietary patterns were obtained from a categorical principal components analysis of food groups (see Mercille et al.[8] for a comprehensive description). Standardized scores from a two-uncorrelated factor solution representing "Western" and "prudent" diet patterns were used as continuous outcome variables. Higher scores on the Western pattern indicate greater consumption of processed meats, potatoes, red meat, sweets and refined grains. Higher scores on the prudent pattern represent individuals with healthier food behaviours, higher consumption of fruits, vegetables, fish and yogurt, and lower consumption of refined grains and sweetened beverages.[21]

#### *Residential Food Environment Exposure*

Densities of food stores and restaurants within a 500 m road network buffer of participants' homes were calculated using a commercial inventory of businesses and services (Tamec Inc., Zipcom database 2005, Montréal), validated through field verification.[22] Records were identified through the Standard Industrial Classification Code and the product name, corresponding to the classification system found in the yellow pages directory. Densities were capped at the average plus 3.29 SD to remove extreme outliers and reduce skewness.[23] Two relative availability measures were computed for each participant: 1) the percentage of chain and independent fast-food restaurants out of the total number of restaurants (%FFO) and 2) the percentage of stores selling healthy foods (grocery stores, supermarkets, fruit and vegetable stores, farmers' markets, specialty food stores) of all food stores, including convenience stores (%HFS, healthy food stores). Although grocery stores and supermarkets sell both healthy and unhealthy food, they were classified as healthy because of their importance regarding the purchase of healthy foods in the retail environment.

#### *Diet Knowledge*

The NuAge questionnaire included questions drawn from the American Dietetic Association nationwide consumer opinion survey, conducted periodically since 1991 among a representative sample of the US adult population (including older adults).[24] Diet knowledge measures were obtained from nine questions on knowledge of the health benefits of the following foods or nutrients: soy-based products, low-fat foods, omega-3 fatty acids, green tea, folic acid, lycopene, antioxidants, red wine and berries. For each item, self-reported stated knowledge ranged from 1 (no knowledge) to 5 (yes, a lot). Internal consistency was 0.82. Principal components analysis ($n = 842$ participants with complete data) confirmed the unidimensionality of the scale (total variance explained = 0.42). Given that the scale reflected a single dimension, the component loadings were applied as weights to the sum of responses to the set of questions. Sex-stratified tertiles of diet knowledge scores were then used for analyses.

#### *Participant Characteristics*

Participants provided information on their age, sex, marital status, place of birth, educational level and annual family income. *Health and functional status* was assessed using the SF-36 Physical Component Summary and Social Functioning subscale,[25] the Geriatric Depression Scale (GDS)[26] and the System for Measuring Functional Autonomy scale (SMAF Scale).[27] *Social environment* variables were the number of participants' adult children living in the neighbourhood and a binary variable identifying presence or absence of social support. The social support variable was calculated from the Social Resources Scale of the Older Americans

**Table 1.** Characteristics of participants by sex

| Characteristic | Women (*n* = 381) | | Men (*n* = 341) | | *p* value* |
|---|---|---|---|---|---|
| | % | Mean (SD) | % | Mean (SD) | |
| *Dietary patterns*† | | | | | |
| Western pattern score (range: −2.24; 3.00) | | −0.230 (0.86) | | 0.207 (1.01) | <0.001 |
| Prudent pattern score (range: −2.87; 2.57) | | 0.157 (0.96) | | −0.160 (0.95) | <0.001 |
| *Residential food environment* | | | | | |
| Proportion of healthy food stores (%) | | 55.3 (14.8) | | 53.2 (14.8) | 0.06 |
| Proportion of fast-food outlets (%) | | 20.3 (10.3) | | 21.7 (10.8) | 0.08 |
| *Diet knowledge scores* | | | | | |
| Low level of knowledge | 33.1 | 11.2 (2.1) | 31.4 | 9.8 (1.8) | |
| Intermediate level of knowledge | 33.3 | 16.4 (1.3) | 35.2 | 14.2 (1.2) | |
| High level of knowledge | 33.6 | 22.3 (2.7) | 33.4 | 20.2 (3.2) | <0.001 |
| *Socio-demographic characteristics and health* | | | | | |
| Age, years | | 75.0 (4.2) | | 74.8 (4.0) | 0.48 |
| Country of birth | | | | | |
| Canada | 83.2 | | 76.2 | | |
| Elsewhere | 16.8 | | 23.8 | | 0.02 |
| Marital status | | | | | |
| Single | 15.7 | | 7.9 | | |
| Widowed | 34.9 | | 9.7 | | |
| Divorced/separated | 8.7 | | 7.9 | | |
| Married/common law | 40.7 | | 74.5 | | <0.001 |
| Education | | | | | |
| 2–11 years | 44.6 | | 35.5 | | |
| 12–13 years | 21.5 | | 17.3 | | |
| 14 years or more | 33.9 | | 47.2 | | 0.001 |
| Family income | | | | | |
| <Low income cut-off‡ | 16.8 | | 11.1 | | |
| >Low income cut-off | 64.6 | | 80.6 | | |
| Income not reported§ | 18.6 | | 8.2 | | <0.001 |
| SF-36 Physical Component (0–100) | | 48.4 (8.4) | | 52.1 (6.5) | <0.001 |
| Depression (GDS) (0–30) | | 5.3 (4.6) | | 4.1 (3.6) | <0.001 |
| Functional status (SMAF) (0–87) | | 3.2 (2.8) | | 3.8 (3.4) | 0.01 |
| SF-36 Social Functioning (0–100) | | 88.6 (18.4) | | 92.2 (14.4) | 0.003 |
| *Social environment* | | | | | |
| Children living nearby | | | | | |
| 0 | 41.2 | | 29.6 | | |
| 1 | 26.8 | | 26.7 | | |
| 2 or more | 32.0 | | 43.7 | | 0.001 |
| Social support | | | | | |
| Presence of support | 74.0 | | 85.0 | | |
| Little or no support | 26.0 | | 15.0 | | <0.001 |
| *Residential neighbourhood* | | | | | |
| % of residents below low income cut-off | | 24.2 (12.1) | | 23.0 (11.8) | 0.20 |
| % of residents speaking neither French nor English | | 25.6 (15.2) | | 24.7 (15.0) | 0.41 |
| % of residents with university degree | | 27.4 (16.1) | | 25.3 (15.3) | 0.07 |

* *p* value for differences between men's and women's distributions of variables using $\chi^2$ tests for proportions and *t*-tests or analysis of variance for means.
† Factor scores for dietary patterns represent standardized variables (with mean 0 and standard deviation of 1). Healthier diets are characterized by lower scores on the Western diet pattern (less consumption of red and processed meats, potatoes, sweets and refined grains) and higher scores on the prudent diet pattern (higher consumption of fruits, vegetables, fish and yoghurt and low consumption of refined grains and sweetened beverages).
‡ Statistics Canada. Low income cut-offs 1994–2003 and low income measures 1992–2001. Income research paper series. Ottawa, ON: Statistics Canada, 2004.
§ 105 participants did not report household income but were included in the analyses.

Resources and Services,[28] assessing support from a spouse, a family member or friend in the following situations: 1) availability of help in case of illness, disability or problem, 2) someone who could take care of the respondent as long as necessary, 3) for a short period of time or 4) from time to time. Finally, to account for the socio-demographic characteristics of the residential environment, three *residential neighbourhood* variables were computed using 2001 Census data (www12.statcan.ca/english/census01/home/index.cfm): 1) the proportion of residents in households below the low income cut-off, 2) the proportion of people with a university degree and 3) the proportion of households speaking neither Canadian official language. Area-weighted averages were calculated in which buffers included more than one census tract. All of the above variables were used as covariates in statistical analyses.

### Analysis

Descriptive and bivariate analyses were performed. Examination of bivariate relationships among all variables was performed to assess collinearity. Main and moderating effects of diet knowledge and food-source exposure on diet pattern scores were tested using separate linear regression models accounting for covariates for women and men. Continuous covariates were mean centred by sex to reduce multicollinearity between predictors and to facilitate the creation of the graphs necessary for interpretation of significant interactions. Variables for statistical models were entered as follows: 1) predictor variables (i.e., %HFS or %FFO, and diet knowledge) to test for main effects; 2) two-way products of the predictors (%HFS or %FFO*diet knowledge tertiles) to test for interactions. Interactions were identified by significant increments in $R^2$ in models when two-way products were entered. Finally,

**Table 2.** Sex differences on parameter estimates for main and moderating effects of neighbourhood food source exposure and diet knowledge on prudent diet score*, adjusted for covariates† ($n = 722$)

| **Women ($n = 381$)** | $\beta$ | (95% CI) | $p$ | $\beta$ | (95% CI) | $p$ | $\beta$ | (95% CI) | $p$ |
|---|---|---|---|---|---|---|---|---|---|
| | | **Model 1 (Main)** | | | **Model 2 Knowledge*HFS** | | | **Model 3 Knowledge*FFO** | |
| Intercept | | (0.05, 0.66) | 0.03 | | (0.06, 0.68) | 0.02 | | (0.10, 0.71) | 0.01 |
| Proportion of healthy food stores (%HFS) | −0.07 | (−1.44, 0.48) | 0.33 | −0.22 | (−2.66, −0.17) | 0.03 | −0.07 | (−1.40, 0.51) | 0.36 |
| Proportion of fast-food outlets (%FFO) | −0.11 | (−2.32, 0.25) | 0.11 | −0.10 | (−2.22, 0.34) | 0.15 | 0.12 | (−0.86, 3.14) | 0.26 |
| Low knowledge | −0.25 | (−0.75, −0.26) | <0.001 | −0.25 | (−0.75, −0.26) | <0.001 | −0.26 | (−0.77, −0.29) | <0.001 |
| Intermediate knowledge | −0.08 | (−0.40, 0.07) | 0.16 | −0.09 | (−0.41, 0.05) | 0.12 | −0.10 | (−0.44, 0.02) | 0.08 |
| High knowledge (ref) | 1.00 | | | 1.00 | | | 1.00 | | |
| %HFS*low knowledge | | | | 0.13 | (−0.09, 3.21) | 0.06 | | | |
| %HFS*intermediate knowledge | | | | 0.16 | (0.10, 3.11) | 0.04 | | | |
| %HFS*high knowledge (ref) | | | | 1.00 | | | 1.00 | | |
| %FFO*low knowledge | | | | | | | −0.22 | (−5.79, −1.15) | <0.01 |
| %FFO*intermediate knowledge | | | | | | | −0.16 | (−4.61, −0.05) | 0.05 |
| %FFO*high knowledge (ref) | | | | | | | 1.00 | | |
| $\Delta R^2$ for adding interaction | | | | | 0.013 | 0.08 | | 0.017 | 0.03 |
| $R^2$ ($R^2$ adjusted) | | 0.17 (0.11) | | | 0.18 (0.12) | | | 0.19 (0.13) | |
| **Men ($n = 341$)** | | **Model 4 (Main)** | | | **Model 5 Knowledge*HFS** | | | **Model 6 Knowledge*FFO** | |
| Intercept | | (0.00, 0.60) | 0.05 | | (−0.01, 0.59) | 0.05 | | (0.02, 0.62) | 0.04 |
| Proportion of healthy food stores (%HFS) | −0.04 | (−1.30, 0.80) | 0.64 | 0.01 | (−1.38, 1.46) | 0.96 | −0.04 | (−1.30, 0.80) | 0.64 |
| Proportion of fast-food outlets (%FFO) | −0.18 | (−2.90, −0.27) | 0.02 | −0.17 | (−2.84, −0.20) | 0.02 | −0.04 | (−2.42, 1.71) | 0.74 |
| Low knowledge | −0.27 | (−0.82, −0.29) | <0.001 | −0.27 | (−0.82, −0.29) | <0.001 | −0.28 | (−0.84, −0.31) | <0.001 |
| Intermediate knowledge | −0.11 | (−0.47, 0.02) | 0.07 | −0.11 | (−0.47, 0.03) | 0.08 | −0.12 | (−0.49, 0.00) | 0.05 |
| High knowledge (ref) | 1.00 | | | 1.00 | | | 1.00 | | |
| %HFS*low knowledge | | | | −0.09 | (−2.61, 0.75) | 0.28 | | | |
| %HFS*intermediate knowledge | | | | 0.00 | (−1.67, 1.75) | 0.96 | | | |
| %HFS*high knowledge (ref) | | | | 1.00 | | | | | |
| %FFO*low knowledge | | | | | | | −0.10 | (−4.14, 0.83) | 0.19 |
| %FFO*intermediate knowledge | | | | | | | −0.12 | (−3.93, 0.69) | 0.17 |
| %FFO*high knowledge (ref) | | | | | | | 1.00 | | |
| $\Delta R^2$ for adding interaction | | | | | 0.007 | 0.28 | | 0.007 | 0.28 |
| $R^2$ ($R^2$ adjusted) | | 0.13 (0.06) | | | 0.13 (0.06) | | | 0.13 (0.06) | |

* Factor scores for dietary patterns represent standardized variables (with mean of 0 and standard deviation of 1). Healthier diets are characterized by higher scores on prudent diet pattern (higher consumption of fruits, vegetables, fish and yoghurt and low consumption of refined grains and sweetened beverages).
† Models adjusted for socio-demographic characteristics (sex, age, country of birth, marital status, education, family income), health characteristics (SF36 Physical Component Summary, depression, functional status, SF36 Social Functioning), social environment (support, children living nearby) and residential environment variables (% residents below the low income cut-off, % residents speaking neither French nor English, % residents with university degree).

models were adjusted by adding the remaining variables. Multicollinearity was evaluated by calculating variance inflation factors (VIF) on final models assessing main effects on diet scores. All VIFs were below 2.5, indicating limited multicollinearity. Only significant interactions were illustrated, by plotting diet scores from the regressions equation at ±1 SD of the average food source exposure for each level of knowledge. The influence of outliers was examined by removing extreme values, with the use of a $p < 0.001$ criterion for Mahalanobis distance or leverage values $>2\ p/n$ (where $p$ is the number of regression parameters) and with Cook distance above average plus three SD in further analyses.[23] As analyses done with and without outliers yielded different findings, the results are reported only for analyses conducted with outliers removed. Statistical significance was set at $p < 0.05$. PASW software (PASW Statistics 18.0; SPSS Inc., Chicago, IL) was used for statistical analyses. Spatial autocorrelations in the residuals were assessed with Moran's Index, using ArcGIS 9.3.1 (ESRI Inc., Redlands, CA).

## RESULTS

Of 848 initial participants, 100 were excluded, 71 because of insufficient or implausible dietary information and 29 because of missing data on covariates, leaving 748 participants (392 women and 356 men) for analysis. Removal of outliers (11 women [2.8%] and 15 men [4.2%]) left 722 participants in the final sample (381 women and 341 men). Female outliers had a higher Western diet score (mean 0.96 vs. –0.23; $p = 0.03$) and a higher GDS score (mean 8.3 vs. 5.3; $p = 0.04$), and were less likely to be married (none compared with 41%; $p = 0.004$) than female non-outliers. Male outliers had higher GDS scores (mean 8.6 vs. 4.1; $p = 0.004$), were more likely to live in low-income households (33% vs. 11%; $p = 0.02$) and less likely to be married (40% vs. 75%; $p = 0.006$).

Descriptive statistics are shown in Table 1. Male and female respondents were similar on age and residential characteristics, but important between-sex differences are apparent in Table 1. Women had significantly healthier dietary patterns and higher scores on diet knowledge than men. For men, being more often married and having children living nearby might be related to better social support. Overall health status was good: Physical Component Summary scores were consistent with the SF-36 Canadian normative data,[29] and high Social Functioning scores indicated few limitations in social activities due to health. GDS and SMAF scores were very low, indicating few depressive symptoms or disabilities, and statistically significant differences between sexes were not clinically significant.[26,27]

The results of the multivariate linear regressions are reported for both diet scores separately for men and women. Table 2 presents the results for the prudent diet scores and Table 3 for the Western diet scores. Models 1 and 4 show main effects for women and men respectively. Models 2 and 5 show interactions between %HFS and knowledge, whereas Models 3 and 6 show interactions with %FFO.

**Table 3.** Sex differences on parameter estimates for main and moderating effects of neighbourhood food sources exposure and diet knowledge on Western diet score*, adjusted for covariates† ($n = 722$)

| **Women ($n = 381$)** | *β* | **(95% CI)** | ***p*** | *β* | **(95% CI)** | ***p*** | *β* | **(95% CI)** | ***p*** |
|---|---|---|---|---|---|---|---|---|---|
| | | **Model 1 (Main)** | | | **Model 2 Knowledge*HFS** | | | **Model 3 Knowledge*FFO** | |
| Intercept | | (−0.63, −0.07) | 0.01 | | (−0.60, −0.05) | 0.02 | | (−0.62, −0.06) | 0.02 |
| Proportion of healthy food stores (%HFS) | −0.12 | (−1.16, 0.16) | 0.11 | −0.16 | (−2.05, 0.18) | 0.10 | −0.14 | (−1.66, 0.08) | 0.07 |
| Proportion of fast-food outlets (%FFO) | −0.01 | (−1.29, 1.03) | 0.83 | −0.01 | (−1.20, 1.09) | 0.92 | −0.03 | (−2.04, 1.59) | 0.81 |
| Low knowledge | 0.13 | (0.01, 0.45) | 0.04 | 0.12 | (0.00, 0.44) | 0.05 | 0.13 | (0.02, 0.45) | 0.03 |
| Intermediate knowledge | 0.03 | (−0.16, 0.26) | 0.63 | 0.02 | (−0.16, 0.25) | 0.69 | 0.04 | (−0.14, 0.28) | 0.51 |
| High knowledge (ref) | 1.00 | | | 1.00 | | | 1.00 | | |
| %HFS*low knowledge | | | | −0.10 | (−2.63, 0.32) | 0.13 | | | |
| %HFS*intermediate knowledge | | | | 0.14 | (−0.04, 2.65) | 0.06 | | | |
| %HFS*high knowledge (ref) | | | | 1.00 | | | | | |
| %FFO*low knowledge | | | | | | | 0.10 | (−0.72, 3.49) | 0.20 |
| %FFO*intermediate knowledge | | | | | | | −0.08 | (−3.08, 1.06) | 0.34 |
| %FFO*high knowledge (ref) | | | | | | | 1.00 | | |
| $\Delta R^2$ for adding interaction | | | | | 0.017 | 0.03 | | 0.009 | 0.18 |
| $R^2$ ($R^2$ adjusted) | | 0.14 (0.09) | | | 0.17 (0.11) | | | 0.16 (0.10) | |
| **Men ($n = 341$)** | | **Model 4 (Main)** | | | **Model 5 Knowledge*HFS** | | | **Model 6 Knowledge*FFO** | |
| Intercept | | (−0.07, 0.54) | 0.13 | | (−0.12, 0.50) | 0.22 | | (−0.09, 0.52) | 0.18 |
| Proportion of healthy food stores (%HFS) | 0.06 | (−0.66, 1.51) | 0.44 | 0.01 | (−1.41, 1.52) | 0.94 | 0.06 | (−0.67, 1.50) | 0.45 |
| Proportion of fast-food outlets (%FFO) | −0.02 | (−1.53, 1.18) | 0.80 | −0.02 | (−1.59, 1.13) | 0.74 | −0.08 | (−2.86, 1.39) | 0.50 |
| Low knowledge | 0.05 | (−0.17, 0.38) | 0.44 | 0.05 | (−0.17, 0.38) | 0.45 | 0.05 | (−0.15, 0.40) | 0.37 |
| Intermediate knowledge | 0.04 | (−0.16, 0.35) | 0.47 | 0.04 | (−0.17, 0.34) | 0.50 | 0.04 | (−0.16, 0.35) | 0.47 |
| High knowledge (ref) | 1.00 | | | 1.00 | | | 1.00 | | |
| %HFS*low knowledge | | | | 0.09 | (−0.75, 2.73) | 0.26 | | | |
| %HFS*intermediate knowledge | | | | 0.01 | (−1.61, 1.92) | 0.86 | | | |
| %HFS*high knowledge (ref) | | | | 1.00 | | | | | |
| %FFO*low knowledge | | | | | | | −0.02 | (−2.97, 2.15) | 0.76 |
| %FFO*intermediate knowledge | | | | | | | 0.10 | (−0.86, 3.90) | 0.21 |
| %FFO*high knowledge (ref) | | | | | | | 1.00 | | |
| $\Delta R^2$ for adding interaction | | | | | 0.007 | 0.30 | | 0.013 | 0.10 |
| $R^2$ ($R^2$ adjusted) | | 0.18 (0.12) | | | 0.18 (0.12) | | | 0.18 (0.12) | |

* Factor scores for dietary patterns represent standardized variables (with mean of 0 and SD of 1). Healthier diets are characterized by lower scores on the Western diet pattern (less consumption of red and processed meats, potatoes, sweets and refined grains).
† Models adjusted for socio-demographic characteristics (sex, age, country of birth, marital status, education, family income), health characteristics (SF36 Physical Component Summary, GDS, SMAF, SF36 Social Functioning), social environment (social support, children living nearby) and residential environment (% residents below the low income cut-off, % residents speaking neither French nor English, % residents with university degree).

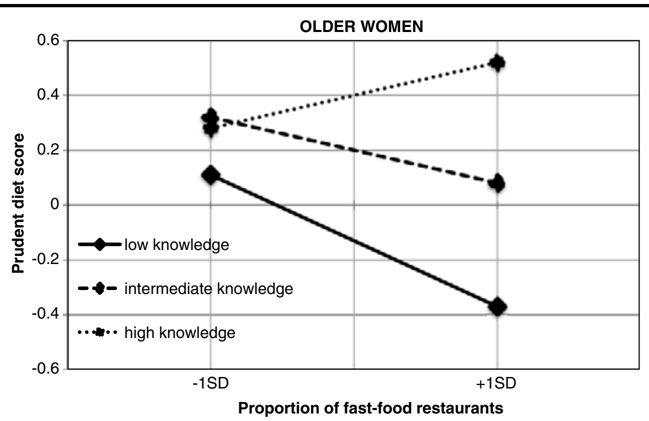


**Figure 1.** Predicted values for the prudent diet score for older women at low, intermediate and high levels of diet knowledge, and for low (−1 SD) and high (+1 SD) proportion of fast-food restaurants

The residential food environment was not associated with diet scores in women for either type of diet (Model 1, Tables 2 and 3). Men exposed to a higher percentage of fast-food outlets had scores lower on prudent diet ($\beta = -0.18$; $p = 0.02$) (Model 4 of Table 2). Going from low %FFO (−1 SD) to high %FFO (+1 SD) exposure was associated with a 0.32 decrease in predicted prudent diet score (range of scores: −2.87 to 2.28). In other words, men's diet quality decreased as exposure to fast-food outlets increased.

Lower diet knowledge was associated with lower diet quality, i.e., both lower prudent and higher Western diet scores in women (Model 1 in Tables 2 and 3). Lower prudent diet scores in men were associated with lower diet knowledge (Model 4 in Table 2). There was no statistically significant interaction between the food environment and diet knowledge for men (Model 5 and Model 6, Tables 2 and 3).

Two significant negative interactions were found for women. The first was between knowledge and %FFO exposure (Model 3, Table 2). As shown in Figure 1, for women with intermediate or high knowledge, greater %FFO exposure was associated with similar prudent diet scores, and for women with low knowledge greater exposure to %FFO was associated with a decrease of 0.48 in prudent diet scores (range of scores: −2.51 to 2.57). A second negative interaction was found between diet knowledge and HFS exposure (Model 3, Table 3). While the individual coefficients for interaction terms did not achieve statistical significance, the results were plotted to interpret the overall pattern of relationships (Figure 2). Among women with high/intermediate diet knowledge,

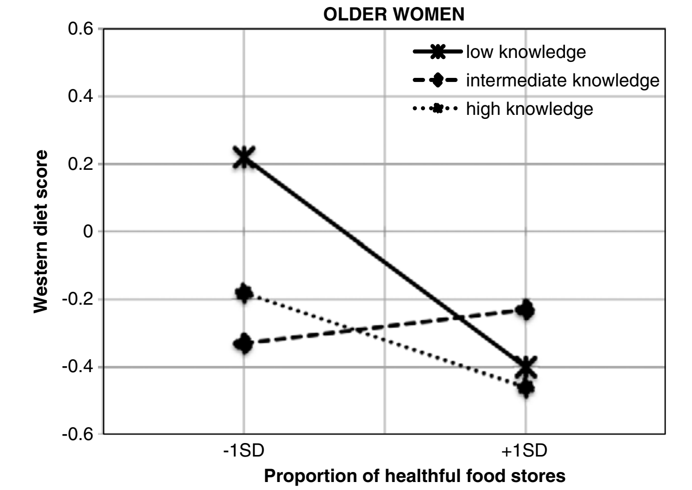


**Figure 2.** Predicted values for the Western diet score for older women at low, intermediate and high levels of diet knowledge, and for low (–1 SD) and high (+1 SD) proportion of healthy food stores

there was little association with access to HFS; however, women with low diet knowledge were sensitive to the presence of HFS, resulting in lower Western diet scores.

Compared with their more knowledgeable counterparts, women with low diet knowledge were slightly older (aged 76.0 vs. 74.6 years; $p = 0.002$) and had higher (but not clinically significant) scores on GDS (mean 6.3 vs. 5.0; $p = 0.01$) and SMAF (mean 3.7 vs. 3.0; $p = 0.04$).[26,27] Finally, spatial autocorrelation measures computed for all models' residuals were non-significant: Moran's I ranged from –0.18 to 0.12 (all $p > 0.13$), indicating that no spatial autocorrelation remained in residuals.

## DISCUSSION

This exploratory study in a healthy sample of urban-dwelling older women and men replicates previous research investigating the role of nutrition knowledge in diet in older adult populations.[3,5] We further extended previous work by considering the local food environment in which many food choices may occur. We observed that lower diet quality was more strongly related to the relative availability of fast food close to home for men. Among women, this relationship was significant only for those with low diet knowledge. These observed associations with prudent diet pattern were weak but similar to the relationship observed in the Multi-Ethnic Study of Atherosclerosis between availability of healthy foods in food store offerings and the dietary patterns of 759 adults.[30]

Existing evidence on the impact of the food environment on diet is conflicting, and the manner in which to test sex differences remains elusive. Two cross-sectional studies in general adult populations[31,32] reported no sex differences between exposure to the fast-food environment and diet, while one longitudinal study showed that low-income men may be responsive to the availability of fast foods.[14] Two other cross-sectional studies observed a relationship between the food store environment and fruit and vegetable intake for men but not women.[12,16]

### Limitations

We chose to stratify but not compare our analyses to separately describe patterns in women and men. We observed a significant moderating effect of diet knowledge among women. When living in a supportive food environment, women with lower knowledge reported less harmful dietary patterns, whereas women living in a less supportive environment reported less healthy eating patterns. Possible explanations might be related to gendered social roles, in which food and health tend to be the domains of women.[15,33] In our cohort, 75% of men were living with a spouse. They may not have developed nutrition-related knowledge for food eaten at home because throughout the years they may have had less responsibility for food shopping and preparation.[33] However, men may be more participative in the selection of food eaten outside the home and may also be more sensitive to unhealthy cues furnished by the presence of fast-food outlets in their environment, regardless of knowledge and marital status.[17,34] Since NuAge food frequency questionnaires did not specifically assess food consumption from restaurants, future studies could distinguish between food eaten at home and food eaten away from home and in fast-food restaurants. Also, there is less socio-demographic variability in the NuAge cohort than in the reference population,[35] and the effect of exposure to food sources on dietary patterns is likely underestimated.[4]

Interestingly, we did not find evidence that HFS exposure influenced prudent diet scores of women or that fast-food outlets exposure influenced Western diet scores differentially as a function of diet knowledge. This result might seem counterintuitive. In the context of metropolitan Montréal, where access to food stores is not generally a problem,[36] the presence of fast-food outlets could prevent the adoption of a healthy diet regardless of the relative availability of HFS. However, using food store type as a proxy for access to healthy food is a limitation of this study. Direct measures of healthy to unhealthy foods stocked in these stores may provide a more nuanced assessment of the food environment, which could improve the assessment of its relation to dietary patterns.[11]

Other limitations include the cross-sectional design, which precludes causal inference, and the applicability of our results to cohorts of older urban adults recruited more recently, who may differ from those analyzed here. Our study context was also limited to 248 of a total of 862 census tracts in which our respondents resided in the Montreal metropolitan area and may not be representative of variation in food environments in the entire region. Other important neighbourhood characteristics related to food access, such as safety of walking routes, were not accounted for in our analyses. However, given that there was no spatial autocorrelation in the residuals in final models, these influences may be limited.

## CONCLUSION

To date, few studies have investigated interactions between the food environment and psychosocial moderators of adults' diet, such as self-efficacy and social support[15] or other psychological factors,[17] especially among older adults. Subgroup analysis is a promising avenue for food environment research, especially as such work could inform targeted interventions. Better understanding of the psychosocial moderators in the environmental context where people make food choices could provide valuable insights for public health policy. Older adults are receptive to health education interventions,[37] and strategies aimed at changing perceptions about the cost, availability and access of healthy food in local stores may be valuable.[38] Reducing the imbalance between the supply of healthy and unhealthy foods in neighbourhoods with a high concentration of seniors, or increasing access to healthy food in the vicinity, for example, by establishing mobile vendors of fruits and vegetables, could be considered as potential intervention approaches.[39] More evidence from longitudinal research and intervention studies is needed.

## REFERENCES


1. Payette H, Shatenstein B. Determinants of healthy eating in community-dwelling elderly people. *Can J Public Health* 2005;96(S3):S27–31. PMID: 16042161.
2. Garriguet D. Canadians' eating habits. *Health Rep* 2007;18(2):17–32. PMID: 17578013.
3. Ree M, Riediger N, Moghadasian MH. Factors affecting food selection in Canadian population. *Eur J Clin Nutr* 2007;62:1255–62. PMID: 17671441. doi: 10.1038/sj.ejcn.1602863.
4. Hughes G, Bennett KM, Hetherington MM. Old and alone: Barriers to healthy eating in older men living on their own. *Appetite* 2004;43:269–76. PMID: 15527929. doi: 10.1016/j.appet.2004.06.002.
5. Baker AH, Wardle J. Sex differences in fruit and vegetable intake in older adults. *Appetite* 2003;40(3):269–75. PMID: 12798784. doi: 10.1016/S0195-6663(03)00014-X.
6. Guillaumie L, Godin G, Vezina-Im L-A. Psychosocial determinants of fruit and vegetable intake in adult population: A systematic review. *Int J Behav Nutr Phys Act* 2010;7:12. PMID: 20181070. doi: 10.1186/1479-5868-7-12.
7. McEntee J. Highlighting food inadequacies: Does the food desert metaphor help this cause? *Br Food J* 2009;111:349–63. doi: 10.1108/00070700910951498.
8. Mercille G, Richard L, Gauvin L, Kestens Y, Shatenstein B, Daniel M, Payette H. Associations between residential food environment and dietary patterns in urban-dwelling older adults: Results from the VoisiNuAge study. *Public Health Nutr* 2012;15(11):2026–39. PMID: 22789436. doi: 10.1017/S136898001200273X.
9. Sharkey JR, Johnson CM, Dean WR. Food access and perceptions of the community and household food environment as correlates of fruit and vegetable intake among rural seniors. *BMC Geriatr* 2010;10:32. PMID: 20525208. doi: 10.1186/1471-2318-10-32.
10. Glass TA, Balfour JL. Neighborhoods, aging, and functional limitations. In: Kawachi I, Berkman LF (Eds.), *Neighborhoods and Health*. New York, NY: Oxford University Press, 2003.
11. Caspi CE, Sorensen G, Subramanian SV, Kawachi I. The local food environment and diet: A systematic review. *Health Place* 2012;18:1172–87. PMID: 22717379. doi: 10.1016/j.healthplace.2012.05.006.
12. Clary CM, Ramos Y, Shareck M, Kestens Y. Should we use absolute or relative measures when assessing foodscape exposure in relation to fruit and vegetable intake? Evidence from a wide-scale Canadian study. *Prev Med* 2015;71:83–87. PMID: 25481095. doi: 10.1016/j.ypmed.2014.11.023.
13. Mason KE, Bentley RJ, Kavanagh AM. Fruit and vegetable purchasing and the relative density of healthy and unhealthy food stores: Evidence from an Australian multilevel study. *J Epidemiol Community Health* 2013;67:231–36. PMID: 23100382. doi: 10.1136/jech-2012-201535.
14. Boone-Heinonen J, Gordon-Larsen P, Kiefe CI, Shikany JM, Lewis CE, Popkin BM. Fast food restaurants and food stores: Longitudinal associations with diet in young to middle-aged adults: The CARDIA Study. *Arch Intern Med* 2011; 171:1162–70. PMID: 21747011. doi: 10.1001/archinternmed.2011.283.
15. Hermstad AK, Swan DW, Kegler MC, Barnette JK, Glanz K. Individual and environmental correlates of dietary fat intake in rural communities: A structural equation model analysis. *Soc Sci Med* 2010;71:93–101. PMID: 20462682. doi: 10.1016/j.socscimed.2010.03.028.
16. Macdonald L, Ellaway A, Ball K, Macintyre S. Is proximity to a food retail store associated with diet and BMI in Glasgow, Scotland? *BMC Public Health* 2011; 11:464. PMID: 21663674. doi: 10.1186/1471-2458-11-464.
17. Paquet C, Daniel M, Knauper B, Gauvin L, Kestens Y, Dube L. Interactive effects of reward sensitivity and residential fast-food restaurant exposure on fast-food consumption. *Am J Clin Nutr* 2010;91:771–76. PMID: 20089726. doi: 10.3945/ajcn.2009.28648.
18. Gaudreau P, Morais JA, Shatenstein B, Gray-Donald K, Khalil A, Dionne I, et al. Nutrition as a determinant of successful aging: Description of the Quebec longitudinal study Nuage and results from cross-sectional pilot studies. *Rejuvenation Res* 2007;10:377–86. PMID: 17708689. doi: 10.1089/rej.2007.0596.
19. Daniel M, Kestens Y. *Montreal Epidemiological and Geographical Analysis of Population Health Outcomes and Neighbourhood Effect: MEGAPHONE (Copyright #1046898)*. Montréal, QC: Centre de recherche du Centre hospitalier de l'Université de Montréal, 2007.
20. Shatenstein B, Nadon S, Godin C, Ferland G. Development and validation of a food frequency questionnaire. *Can J Diet Pract Res* 2005;66:67–75. PMID: 15975195. doi: 10.3148/66.2.2005.67.
21. Slattery ML, Boucher KM, Caan BJ, Potter JD, Ma K-N. Eating patterns and risk of colon cancer. *Am J Epidemiol* 1998;148:4–16. PMID: 9663397. doi: 10.1093/aje/148.1.4-a.
22. Paquet C, Daniel M, Kestens Y, Leger K, Gauvin L. Field validation of listings of food stores and commercial physical activity establishments from secondary data. *Int J Behav Nutr Phys Act* 2008;5:58. PMID: 19000319. doi: 10.1186/1479-5868-5-58.
23. Tabachnick BG, Fidell LS. *Using Multivariate Statistics*, 5th ed. Boston, MA: Allyn and Bacon, 2007.
24. American Dietetic Association. Nutrition and you: Trends 2002. Final Report of Findings. Chicago, IL: American Dietetic Association, 2002. Available at: http://www.eatrightpro.org/resources/media/trends-and-reviews/trends-survey (Accessed January 13, 2016).
25. Ware JE Jr, Sherbourne CD. The MOS 36-item short-form health survey (SF-36): I. Conceptual framework and item selection. *Med Care* 30;1992:473–83. PMID: 1593914. doi: 10.1097/00005650-199206000-00002.
26. Yesavage JA, Brink T, Rose TL, Lum O, Huang V, Adey M, et al. Development and validation of a geriatric depression screening scale: A preliminary report. *J Psychiatr Res* 1983;17:37–49. PMID: 7183759. doi: 10.1016/0022-3956(82)90033-4.
27. Hébert R, Desrosiers J, Dubuc N, Tousignant M, Guilbeault J, Pinsonnault E. Le système de mesure de l'autonomie fonctionnelle (SMAF). *Revue de Gériatrie* 2003;28(4):323–36.
28. Fillenbaum GG, Smyer MA. The development, validity, and reliability of the OARS multidimensional functional assessment questionnaire. *J Gerontol* 1981; 36(4):428–34. PMID: 7252074. doi: 10.1093/geronj/36.4.428.
29. QualityMetric Incorporated. SF-36® PCS, MCS and NBS Calculator, 2010. Available at: http://www.sf-36.org/nbscalc/index.shtml (Accessed February 17, 2010).
30. Franco M, Diez-Roux AV, Nettleton JA, Lazo M, Brancati F, Caballero B, et al. Availability of healthy foods and dietary patterns: The Multi-Ethnic Study of Atherosclerosis. *Am J Clin Nutr* 2009;89:897–904. PMID: 19144728. doi: 10.3945/ajcn.2008.26434.
31. Moore LV, Diez Roux AV, Nettleton JA, Jacobs DR, Franco M. Fast-food consumption, diet quality, and neighborhood exposure to fast food. *Am J Epidemiol* 2009;170:29–36. PMID: 19429879. doi: 10.1093/aje/kwp090.
32. Pearce J, Hiscock R, Blakely T, Witten K. A national study of the association between neighbourhood access to fast-food outlets and the diet and weight of local residents. *Health Place* 2009;15:193–97. PMID: 18499502. doi: 10.1016/j.healthplace.2008.04.003.
33. Flagg LA, Sen B, Kilgore M, Locher JL. The influence of gender, age, education and household size on meal preparation and food shopping responsibilities. *Public Health Nutr* 2014;17:2061–70. PMID: 23988018. doi: 10.1017/S1368980013002267.
34. Cohen D, Farley T. Eating as an automatic behavior. *Prev Chronic Dis* 2008; 5(1):A23. PMID: 18082012.
35. Daveluy C, Pica L, Audet N, Courtemanche R, Lapointe F. *Enquête sociale et de santé 1998, 2e éd.* Québec, QC: Institut de la statistique du Québec, 2000.
36. Apparicio P, Cloutier MS, Shearmur R. The case of Montreal's missing food deserts: Evaluation of accessibility to food supermarkets. *Int J Health Geogr* 2007;6:4. PMID: 17295912. doi: 10.1186/1476-072X-6-4.
37. Manilla B, Keller HH, Hedley MR. Food tasting as nutrition education for older adults. *Can J Diet Pract Res* 2010;71(2):99–102. PMID: 20525423. doi: 10.3148/71.1.2010.99.
38. Gustafson AA, Sharkey J, Samuel-Hodge CD, Jones-Smith JC, Cai J, Ammerman AS. Food store environment modifies intervention effect on fruit and vegetable intake among low-income women in North Carolina. *J Nutr Metab* 2012;2012. PMID: 22315676. doi: 10.1155/2012/932653.
39. Jennings A, Cassidy A, Winters T, Barnes S, Lipp A, Holland R, et al.Positive effect of a targeted intervention to improve access and availability of fruit and vegetables in an area of deprivation. *Health Place* 2012;18(5):1074–78. PMID: 22705164. doi: 10.1016/j.healthplace.2012.05.001.


## RÉSUMÉ


**OBJECTIFS :** Les liens entre les environnements alimentaires locaux et les habitudes alimentaires sont importants pour les personnes âgées et pourraient différer selon le sexe. Nous avons examiné séparément pour des femmes et des hommes âgés vivant à Montréal en 2003–2005 ($n = 722$) les associations entre l'exposition aux commerces alimentaires du quartier, la consommation d'aliments et le rôle modérateur des connaissances en nutrition.

**MÉTHODE :** Nous avons estimé la proportion de débits de restauration rapide (DRP) par rapport à l'ensemble des restaurants et la proportion de magasins d'alimentation pouvant offrir des aliments sains (MAS) par rapport à l'ensemble des magasins dans un rayon de 500 m autour du domicile des participants. Deux types d'habitudes alimentaires, qualifiées d' « occidentales » et de « prudentes » pour indiquer les régimes de qualité inférieure et supérieure, respectivement, ont été cernés à partir des données de questionnaires sur la fréquence de consommation des produits alimentaires. Les effets uniques et interactifs des connaissances en nutrition et de l'exposition aux commerces alimentaires sur les scores des habitudes alimentaires ont été analysés selon des modèles de régression linéaire distincts selon le sexe.

**RÉSULTATS :** Chez les hommes, un pourcentage supérieure d'exposition aux DRP était lié à des notes plus faibles pour le régime « prudent » ($\beta = -0{,}18$, $p = 0{,}02$), mais nous n'avons observé aucun effet du pourcentage d'exposition aux MAS, et aucune interaction n'était significative. Chez les femmes, la relation inverse entre le %DRP et le régime « prudent » était la plus forte chez les participantes dont les connaissances en nutrition étaient faibles ($\beta = -0{,}22$, $p < 0{,}01$). Aucune autre association n'était significative.

**CONCLUSION :** Les habitudes alimentaires des hommes peuvent s'expliquer par des repères malsains associés aux débits de restauration rapide. Chez les femmes, les connaissances en nutrition peuvent entraîner à la fois des relations négatives et positives avec l'environnement alimentaire. En l'absence d'effets principaux cohérents de l'environnement alimentaire sur les scores des habitudes alimentaires, l'analyse par sous-groupe est une piste de recherche prometteuse.

**MOTS CLÉS :** régime alimentaire; personne âgée; population urbaine; approvisionnement en nourriture; effets modificateurs