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Associations between residential food environment and dietary patterns in urban-dwelling older adults: results from the VoisiNuAge study

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Abstract

Objective: To examine associations between the availability of residential-area food sources and dietary patterns among seniors.
Design: Cross-sectional analyses. Individual-level data from the NuAge study on nutrition and healthy ageing were merged with geographic information system data on food store availability and area-level social composition. Two dietary patterns reflecting lower- and higher-quality diets (respectively designated 'western' and 'prudent') were identified from FFQ data. Two food source relative availability measures were calculated for a 500 m road-network buffer around participants' homes: (i) proportion of fast-food outlets (%FFO) relative to all restaurants and (ii) proportion of stores potentially selling healthful foods (%HFS, healthful food stores) relative to all food stores. Associations between dietary patterns and food source exposure were tested in linear regression models accounting for individual (health and sociodemographic) and area-level (socio-economic and ethnicity) covariates.
Setting: Montréal metropolitan area, Canada.
Subjects: Urban-dwelling older adults (n 751), aged 68 to 84 years.
Results: %FFO was inversely associated with prudent diet ($\beta = -0{\cdot}105$; $P < 0{\cdot}05$) and this association remained statistically significant in models accounting for %HFS. %HFS was inversely associated with lower western diet scores ($\beta = -0{\cdot}124$; $P < 0{\cdot}01$). This latter association no longer reached significance once models were adjusted for area-level covariates.
Conclusions: In Montréal, the food environment is related to the diet of older adults but these links are more complex than straightforward. The absence of significant relationships between healthful food stores and prudent diets, and between fast-food outlets and western diets, deserves further investigation.

Keywords
Food environment
Diet
Older adults
Urban setting

Although it is widely recognized that adequate nutrition plays a fundamental role in the maintenance of health, independence and quality of life among older adults, maintaining healthy dietary patterns is challenging. Physiological changes in functional abilities due to ageing, presence of chronic diseases, cognitive decline, medication use, shrinking of social networks and financial difficulties have an impact on food-related activities (grocery shopping and meal preparation) which can negatively influence food security and nutritional status[1–4]. Furthermore, as changes associated with ageing may accentuate reliance on immediate residential neighbourhood resources, older adults may have more limited access to healthful food[5–7]. Earlier research has shown that shopping activities of older

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adults are often restricted to their home neighbourhood[8,9]. It is thus plausible that greater availability of healthful food sources in the immediate vicinity might influence the ability of seniors to maintain a good diet, independence and quality of life[6,8,9]. Nevertheless, compared with the substantial literature on individual determinants of healthy eating, little is known regarding the influence of the food environments on dietary patterns among seniors[1]. The present study addresses this gap by investigating to what extent the proximate food environment is associated with dietary patterns in a cohort of urban-dwelling seniors.

According to Glass and Balfour's conceptual model[10] of neighbourhood effects on ageing, neighbourhood factors can create environmental 'pressors' or 'buoys' that interact with personal competencies to render behavioural responses either adaptive or maladaptive for health. For example, a healthful food environment (i.e. a buoy) may have positive effects on food consumption in the entire population but even more so among people with mobility limitations[11]. Similarly, a poor food environment (i.e. a pressor) may be associated with food insecurity, especially among seniors with few transportation options[5–7]. Qualitative[6,12] and marketing science studies[13,14] show that a diversified food shopping environment, adequate store size, proximity to supermarkets and other food stores, and convenient means of transportation can support healthful dietary self-management. However, compared with studies of children[15] and of general adult populations[16], few quantitative studies[17,18] of older adults have specifically examined food consumption and its association with the food environment using objective indicators gleaned from a geographic information system (GIS)[19]. In US populations, evidence suggests that density and proximity to supermarkets[20–23] and perceived or directly measured availability of healthy foods in these stores[23–25] are associated with dietary intake, but evidence from other industrialized countries is less consistent[26–29]. Studies of neighbourhood exposure to fast foods and diet quality have similarly produced mixed results[20,30–32], but most such studies did not simultaneously examine exposure to both food stores and restaurants. Further research investigating the relationships between dietary patterns and residential access to different food sources is warranted.

The current investigation

The current study of urban-dwelling seniors examined associations between the availability of residential-area food sources within walking distance from the home and dietary patterns, accounting for both individual-level and residential area-level characteristics. Measures of overall dietary patterns[33,34] were chosen as outcome variables because they have been associated with chronic diseases[34,35]. They may be more sensitive to the food environment than measures of single dietary components (e.g. fruit and vegetable consumption)[23,24,31]. A novel aspect of the current study is its focus on relative availability of local-area food source outlets which include both healthful (e.g. proportion of stores selling potentially healthful foods) and unhealthful options (e.g. proportion of fast-food outlets). In comparison to measures of the absolute density of specific food source outlets, GIS-derived measures of the relative availability of food sources can provide a strong objective depiction of food environments characterized by a wide range of food source options[36].

Methods

The present cross-sectional study was conducted within the context of a larger study called VoisiNuAge – a close homonym of the French word for neighbourhood, which integrates two large research infrastructures, namely person-level data from the Québec Longitudinal Study on Nutrition and Successful Aging (NuAge) cohort[37,38] and area-level data from a GIS[39], to address questions about associations between neighbourhood environments, lifestyle and health among seniors. The study area was Montréal and Laval islands which in 2001 had populations of 1·8 million and 343 000 residents, respectively, among whom 13 % of all residents were aged 65 years and over. These areas are the densest components of the Census Montréal Metropolitan Area (population 3·4 million), Canada's second most populous metropolitan area.

Participants and procedures

The NuAge cohort[37,38] is a 5-year observational study in Quebec, Canada, including 1793 men and women aged 67–84 years who reported good general health at the time of initial recruitment in 2003. Participants are assessed annually using a series of nutritional, functional, medical, biological and social measurements. Computer-assisted interviews were carried out by trained research dietitians and nurses following rigorous standardized procedures[37]. The study was approved by the Ethics Committee of the University Institute of Geriatrics of the Université de Sherbrooke (Institut universitaire de gériatrie de Sherbrooke). All participants signed an informed consent form, which had been approved by the Ethics Committees of the University Institutes of Geriatrics of the Université de Montréal (Institut universitaire de gériatrie de Montréal) and of the Université de Sherbrooke (Institut universitaire de gériatrie de Sherbrooke). The present study involved only participants residing in Montréal and Laval at the study inception (2003) who were geocoded according to valid street addresses and 6-digit Canadian postal codes (n 848). Given the absence of an a priori theory and lack of consensus for defining the relevant residential environments that capture an overall relevant behavioural context[40], an arbitrary road-network buffer of 500 m was calculated around each participant's home. This definition was based on empirical research on older people's travel patterns[41] and corresponds to a reasonable walking distance for an older adult carrying

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Table 1 Foods, food groups and categories of portions created to reduce information prior to analysis of food consumption using categorical principal components analysis among urban-dwelling VoisiNuAge participants (*n* 777)

Food or food groups	Foods included in grouping	Categories of portions/d
Meat sauce	Meat sauces	≤0·07; >0·07
Processed meats	Sausages, hot dog, ham, cold cuts	<0·15; 0·15–0·42; ≥0·43
Potatoes	Boiled, mashed or baked	<0·15; 0·15–0·99; ≥1·00
Red meat	Beef, liver, organ meats, pork, veal, lamb, game, etc.	<0·43; 0·43–0·71; ≥0·72
Candies & added sugars	Candies, chocolate, sugar in coffee/tea or cereals, jam, honey, sweet spreads, maple products	<1·00; 1·00–1·99; ≥2·00
Sweetened beverages	Fruits drinks, regular soft drinks	0; 0·03–0·99; ≥1·00
French fries	French fries or pan-fried potatoes	<0·14; ≥0·14
Milk in coffee/tea	Milk or cream in coffee/tea	0–1·99; ≥2·00
Coffee/tea	Coffee, tea	0–0·99; 1·00–1·99; ≥2·00
Refined-grain bread & breakfast cereals	Refined-grain cold cereals, hot cereals, sliced white breads or rolls, bagels, tortillas, etc.	0–0·99; 1·00–1·99; ≥2·00
Pasta with tomato sauce†	Pasta with tomato sauce with or without meat	<0·15; 0·15–0·57, ≥0·58
Butter	Butter on bread or in cooked vegetables	0–0·99; ≥1·00
Cakes & cookies	Cakes, pies, doughnut, pastries, muffins, cookies, granola bars	<0·43; 0·43–0·99; ≥1·00
Salty snacks	Chips, salted crackers, pretzels, popcorn, etc.	0; 0·03–0·14; ≥0·15
Dairy desserts	Puddings, blancmange, ice cream, ice milk, frozen yoghurt	<0·15; 0·15–0·42, ≥0·43
Eggs	Eggs, omelettes, quiche, etc.	<0·15; 0·15–0·29; ≥0·30
Tomato juice	Tomato or vegetable juices	<0·15; ≥0·15
Pasta with creamy sauce†	Cheese macaroni, white sauce, etc.	0; all others
Pizza†	Pizza	0; 0·01–0·07; ≥0·08
Soups†	Any kind of soups	<0·50; 0·50–0·99; ≥1·00
Vegetables	Green/yellow beans, green peas, corn, tomatoes, lettuce, leafy greens, green salad, broccoli, cauliflower, Brussels sprouts, cabbage and coleslaw, carrots, green/yellow/red sweet peppers, any other vegetable	<1·00; 1–1·99; 2–2·99; ≥3·00
Fruits	Apples, pears, bananas, melons any kind, citrus fruits, berries, any other fruits	<1·00; 1–2·99; ≥3·00
Fish	Any fish and seafood fresh, frozen or canned	<0·15; 0·15–0·29; ≥0·30
Yoghurt	Any kind	<0·15; 0·15–0·57, ≥0·58
Salad dressing	Salad dressings, mayonnaise, dips	<0·30; 0·30–0·57, ≥0·58
Cheese	Any kind	<0·30; 0·30–0·71, ≥0·72
Low-fat milk & soya beverages	2 %, 1 %, skimmed milk or soya drink for drinking	<0·15; 0·15–0·70; 0·71–0·99; ≥1·00
Nuts	Peanut butter, sunflower seeds, nuts, peanuts, other seeds	<0·50; 0·50–0·99; ≥1·00
Beans	Legumes, hummus, beans with pork, tofu and foods with soya or vegetable proteins	<0·15; 0·15–0·29; ≥0·30
Wholegrain bread & breakfast cereals	High-fibre breakfast cereals, whole-wheat, multigrain, rye breads, bagels, pita, tortillas, rolls, etc.	0–0·99; 1·00–1·99; ≥2·00
Rice & other grains	Rice, rice noodles, couscous	<0·15; 0·15–0·99; ≥1·00
Poultry	Chicken, turkey	<0·43; ≥0·43
Margarine	Margarine on breads or in cooked vegetables	0–0·99; ≥1·00
Fruit juices	Fruit juices with no added sugar	0; 0·03–0·99; ≥1·00
Low-calorie beverages	Diet soft drinks	0; all others
Whole milk	Whole milk (3·25 %) for drinking	0; 0·01–0·99; ≥1·00
Alcoholic beverages	Beer, table wine, aperitifs, hard liquor	<0·15; 0·15–0·57; 0·58–1; >1·00

†Mixed dishes in the FFQ were not disaggregated.

grocery bags. Measures of the food environment were computed at the individual level within this buffer.

Measures

Dietary patterns

Dietary data were obtained from a seventy-eight-item semi-quantitative FFQ used to assess usual food consumption over the previous 12 months, developed for and validated among adults[42] using the Block instrument[43] as a template. The FFQ was administered by trained dietitians between December 2003 and April 2005. After data entry, a preliminary analysis of the FFQ data was conducted by the nutrition team to detect outliers and assess the plausibility of the FFQ data based on a set of established criteria[44]. Prior to dietary pattern analysis, the consumption frequency for each item was uniformly converted to frequencies per day and then weighted by the reported serving size. Serving sizes reported as ‘smaller than’, ‘similar to’ or ‘larger than’ the examples provided in the FFQ were weighted by 0·5, 1·0 and 1·5, respectively. Food data were reduced to thirty-seven foods or food groups on the basis of similarities in type of food and nutrient characteristics (see Table 1). Certain questionnaire items constituted a single group because it was not possible to disaggregate all foods included in that line item (e.g. coffee/tea; rice and other grains) and because mixed dishes were not disaggregated into their component parts (e.g. pizza, pasta with creamy sauce).

Data reduction for food consumption was challenging because most of the food and food groups variables followed ordinal or dichotomous distributions. Principal

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Table 2 Factor loadings† for two-factor solution resulting from the application of categorical principal components analysis to the food frequency data among urban-dwelling VoisiNuAge participants (*n* 777)

Food groups	Factor 1: Western diet	Factor 2: Prudent diet
Meat sauce	0·50	–
Processed meats	0·46	–
Potatoes	0·45	–
Red meat	0·45	–
Candies & added sugars	0·44	–
Sweetened beverages	0·43	−0·20
French fries	0·43	–
Milk in coffee/tea	0·40	–
Coffee/tea	0·40	–
Refined-grain bread & breakfast cereals	0·38	−0·26
Pasta with tomato sauce	0·37	0·37
Butter	0·37	–
Cakes & cookies	0·37	–
Salty snacks	0·33	–
Dairy desserts	0·33	–
Eggs	0·31	–
Tomato juice	0·29	0·36
Pasta with creamy sauce	0·25	–
Pizza	0·25	–
Soups	0·24	–
Vegetables	–	0·68
Fruits	–	0·53
Fish	–	0·46
Yoghurt	–	0·43
Salad dressing	–	0·37
Cheese	–	0·35
Low-fat milk & soya beverages	–	0·33
Nuts	–	0·30
Beans	–	0·30
Wholegrain bread & breakfast cereals	–	0·29
Rice & other grains	–	0·26
Poultry	–	0·21
Margarine	–	–
Fruit juices	–	–
Low-calorie beverages	–	–
Whole milk	–	–
Alcoholic beverages	–	–
Eigenvalue	3·08	2·47
% of variance explained	8·31	6·66

†Small positive (<0·20) and negative loadings (>−0·20) were omitted for clarity. The food groups are presented in descending order of loading values on the western diet pattern.

components analysis is inappropriate because the assumption of continuous observations is violated[45]. To overcome this problem, we reduced food frequency data through the application of categorical principal components analysis (CATPCA). This method was developed for the analysis of mixed categorical data (nominal, ordinal and continuous), using optimal scaling or optimal quantification that maximizes the relationships between quantified variables[46]. Unlike principal components analysis, CATPCA does not assume linear relationships for numeric observations and does not require the assumption of multivariate normal distributions. Analyses were performed using the CATPCA program from the statistical software package PASW Statistics 18·0 (SPSS Inc., Chicago, IL, USA). Each of the thirty-seven food frequency measures was first re-coded, based on the observed distributions, as an ordinal variable expressing two to four levels of consumption as illustrated in the third column of Table 1. Solutions ranging from two to four factors were considered. After examination of eigenvalues and the interpretability of the factor solution, an uncorrelated two-factor solution was retained. Table 2 presents factor loadings for the two main dietary patterns. Higher scores on the first pattern indicate higher consumption of processed meats, potatoes, red meat, sweets and refined grains; this pattern was labelled a 'western' diet[33]. For the second pattern, higher scores indicate higher consumption of fruits, vegetables, fish and yoghurt, and low consumption of refined grains and sweetened beverages. This pattern reflects Canadian healthy dietary guidelines[47] and was labelled a 'prudent' diet. Factor scores were saved for each factor for each respondent, and represented standardized variables. These western and prudent diet scores were handled as continuous outcome variables.

Residential-area food source exposure

Information regarding the presence of services and amenities within the vicinity of the participants' homes was

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extracted from the GIS[39]. These initially came from a private business and service registry (Tamec Inc., Zipcom database (2005), Montréal, Canada) containing some 120 000 records for the Montréal metropolitan area, and were geocoded at the address and 6-digit Canadian postal code levels. A validation study of this database indicated percentage agreement of 0·77, sensitivity of 0·84 and positive predictive value of 0·90 for food stores relative to field visits to verify or refute the presence of listed commercial outlets[48]. Records were categorized with Standard Industrial Classification (SIC) Codes and product names corresponding to classifications of the Montréal Yellow Pages directory. Densities of two types of food outlets, namely stores providing foods for home consumption and restaurants offering prepared meals, present within 500 m road-network buffers of participants' homes were calculated. Because data were skewed, outliers were capped at the average plus 3·29 SD[45]. Two food source relative availability measures were then derived for each participant's home-centred buffer: (i) proportion of fast-food outlets (%FFO; i.e. the number of chain and independent fast-food restaurants/total number of restaurants); and (ii) proportion of stores selling potentially healthful foods (%HFS, healthful food stores; i.e. the number of groceries and supermarkets, fruit and vegetable stores, specialty food stores/all food stores including convenience stores). Although these stores sell a range of healthful as well as unhealthful foods, we considered them healthful food stores as they provide the opportunity to purchase healthful food.

Health and sociodemographic characteristics

Sociodemographic variables included sex, marital status (re-coded as married/common law, single, single/separated, widowed), place of birth (re-coded as Canada, elsewhere), educational level (re-coded as 2 to 11 years, 12 to 13 years, 14 years or more) and annual family income (re-coded as below or above the low income cut-off of Statistics Canada, not reported)[49]. Health status dimensions were assessed using the Short-form 36 Health Survey (SF-36) Physical Component Summary and Social Functioning subscale[50], the Geriatric Depression Scale (GDS)[51] and the System for Measuring Functional Autonomy Scale (SMAF)[52].

Social environment

The number of participants' adult children living in the neighbourhood (re-coded as 0, 1, 2 or more) was assessed by the NuAge core questionnaire. The social support variable was the summed value of responses to four items: (i) availability of assistance in case of illness, disability or problem; (ii) someone who could take care of the respondent as long as necessary; (iii) someone who could take care of the respondent for a short period of time; and (iv) someone who could take care of the respondent from time to time (re-coded as presence of support ('yes' to three or four items), little or no support ('yes' to zero, one or two items)).

Residential neighbourhood

Census tract-level data were obtained from the 2001 Statistics Canada Population Census (www12.statcan.ca/english/census01/home/index.cfm). Three variables reflecting compositional structure were derived for home-centred 500 m buffers: (i) a measure of poverty estimated by the proportion of residents in households living below the low income cut-off; (ii) the proportion of households not speaking one of Canada's official languages (i.e. French or English) within the home, this reflecting ethnic diversity by immigration or by secular traditions; and (iii) the proportion of residents with a university degree. Area-weighted proportions were calculated where buffers included more than one census tract.

Analysis

Descriptive and inferential analyses were performed. First, the distribution of all variables was examined for the presence of outliers. Descriptive analyses illustrated respondents' profiles with regard to dietary patterns, proportions of local food sources and covariates. Then, linear regression was used to estimate the associations between food source indices and dietary patterns, before and after adjustment for individual- and residential-area covariates. Predictor variables were mean centred prior to analysis. As values for the GDS, Social Functioning and SMAF measures were not normally distributed, analyses were performed using both raw (original scores) and log-transformed data. Analysis using log-transformed data for these measures produced essentially same results as analyses using original scores; therefore, results for models using original scoring are presented. Statistical significance was set at $P < 0·05$. PASW Statistics 18·0 (SPSS Inc.) was used for statistical analyses. Variables for statistical models were identified based on relevant literature, grouped into conceptual blocks and entered as follows: (i) the two food source indices separately (Models 1a and 1b); (ii) combined food source indices simultaneously (Model 2); (iii) sociodemographic variables (Model 3); and (iv) health and social environment variables (Model 4). Also, because it could be argued that results might not be specific to food source exposure, but rather reflect the socio-economic characteristics of the participants' immediate environment, potential area-level confounders were added in Models 5 and 6. Finally, to assess potential bias associated with spatial autocorrelation, spatial autocorrelation in the residuals of the models was calculated using Moran's I statistic performed with ArcGIS 9·3·1 (ESRI Inc., Redlands, CA, USA).

Results

Of 848 participants, those with implausible dietary information (n 42) and those with FFQ data not adequately completed (n 29) were not retained for analysis, yielding

Table 3 Characteristics of urban-dwelling VoisiNuAge participants (*n* 751)

Characteristic	*n*	%	Mean	SD
Dietary patterns				
Western pattern score				
(range: −2·24, 3·04)			0·0032	0·991
Prudent pattern score				
(range: −2·87, 2·99)			0·0015	0·998
Residential food environment				
%HFS			54·2	15·0
%FFO			21·0	10·9
Sociodemographic characteristics and health				
Age (years)			75·0	4·1
Sex				
Male	356	47·4		
Female	395	52·6		
Country of birth				
Canada	602	80·2		
Elsewhere	149	19·8		
Marital status				
Single	92	12·3		
Widowed	175	23·3		
Divorced/separated	68	9·0		
Married/common law	416	55·4		
Education				
2–11 years	304	40·5		
12–13 years	146	19·4		
14 years or more	301	40·1		
Family income				
Below low income cut-off	111	14·8		
Above low income cut-off	535	71·2		
Income not reported	105	14·0		
SF-36 Physical Component Summary			50·2	7·7
Depression (GDS)			4·9	4·3
Functional status (SMAF)			3·5	3·1
SF-36 Social Functioning			89·9	17·4
Social environment				
No. of children living nearby				
0	272	36·2		
1	199	26·5		
2 or more	280	37·3		
Social support				
Presence of support	591	78·7		
Little or no support	160	21·3		
Residential neighbourhood				
% of residents below low income cut-off			23·9	12·1
% of residents speaking neither French nor English			25·3	15·2
% of residents with university degree			26·5	15·9

%HFS, proportion of healthful food stores; %FFO, proportion of fast-food outlets; SF-36, Short-form 36 Health Survey; GDS, Geriatric Depression Scale; SMAF, System for Measuring Functional Autonomy.

777 questionnaires for the dietary pattern analyses. Of these, twenty-six participants having incomplete data on the variables of interest were further excluded, yielding 751 participants for the inferential analysis. These twenty-six participants with incomplete data did not differ in terms of dietary scores (all $P > 0{\cdot}05$) from participants retained for analysis. Table 3 presents descriptive statistics for outcome variables, measures of the food and residential environment, and personal characteristics. Important between-participant variability is apparent in terms of exposure to food sources and disparities regarding socio-economic status and ethnic diversity, indicated by large ranges and standard deviations. Regarding the social environment, nearly 64 % of participants had at least one adult child or other family member leaving nearby and the majority considered themselves to have good social support. For health status, Physical Component Summary scores were consistent with the SF-36 Canadian normative data[53)] but slightly higher for Social Functioning (89·9 *v.* 86·2). GDS and SMAF scores indicated few cases of depression or disabilities. There was substantial variability across most sociodemographic indicators.

Results of the multivariate linear regression models designed to investigate associations between food source exposure and prudent diet scores, while controlling for personal and residential covariates, are shown in Table 4. Results for western diet scores are presented in Table 5.

Table 4 Results of multiple regression analyses examining associations between %HFS, %FFO and prudent dietary pattern among urban-dwelling VoisiNuAge participants (*n* 751)

	Model 1a†			Model 1b‡			Model 2§			Model 3‖		
	b	SE	*β*	*b*	SE	*β*	*b*	SE	*β*	*b*	SE	*β*
Intercept	0·004	0·036		0·006	0·036		0·007	0·036		1·398*	0·661	
Residential food environment												
%HFS	0·614	0·243	0·092*				0·247	0·274	0·037	0·098	0·279	0·015
%FFO				−1·221	0·332	−0·133***	−1·060	0·377	−0·116**	−1·024	0·382	−0·112**
Individual characteristics												
Sex												
Female										0·408	0·078	0·204***
Age										−0·019	0·009*	−0·081
Country of birth												
Outside Canada										−0·006	0·093	−0·003
Family income												
Below low income cut-off										−0·041	0·106	−0·015
Income not reported										−0·101	0·106	−0·035
Marital status												
Single										0·020	0·121	0·007
Widowed										−0·190	0·095	−0·081*
Divorced/separated										0·012	0·130	0·003
Education												
2–11 years										−0·121	0·085	−0·060
12–13 years										−0·181	0·100	−0·072
SF-36 Physical Component Summary												
Depression (GDS)												
Functional status (SMAF)												
SF-36 Social Functioning												
Social support												
Little or no support												
No. of children living nearby												
2 or more												
1												
Residential neighbourhood												
% below low income cut-off												
% speaking neither French nor English												
% with university degree												
R^2/R^2 adjusted		0·008/0·007			0·018/0·016			0·019/0·016			0·068/0·053	
P for change		0·012			0·000			0·005			0·000	

Table 4 *Continued*

	Model 4¶			Model 5††			Model 6‡‡		
	b	SE	*β*	*b*	SE	*β*	*b*	SE	*β*
Intercept	1·760*	0·771		1·736*	0·770		1·670*	0·773	
Residential food environment									
%HFS	0·153	0·279	0·023	−0·128	0·333	−0·019	−0·252	0·359	−0·038
%FFO	−0·917	0·384	−0·100*	−1·151	0·401	−0·126**	−0·963	0·450	−0·105*
Individual characteristics									
Sex									
Female	0·419	0·081	0·210***	0·413	0·081	0·207***	0·411	0·081	0·206***
Age	−0·017	0·009	−0·068	−0·015	0·009	−0·064	−0·016	0·009	−0·068
Country of birth									
Outside Canada	0·004	0·094	0·002	−0·006	0·095	−0·002	−0·012	0·095	−0·005
Family income									
Below low income cut-off	−0·004	0·106	−0·001	0·029	0·107	0·010	0·033	0·107	0·012
Income not reported	−0·082	0·106	−0·029	−0·063	0·106	−0·022	−0·062	0·106	−0·022
Marital status									
Single	−0·043	0·134	−0·014	0·004	0·137	0·001	−0·003	0·137	−0·001
Widowed	−0·202	0·097	−0·086*	−0·193	0·097	−0·082*	−0·194	0·097	−0·082*
Divorced/separated	−0·049	0·132	−0·014	−0·038	0·132	−0·011	−0·041	0·132	−0·012
Education									
2–11 years	−0·112	0·086	−0·055	−0·113	0·086	−0·056	−0·097	0·087	−0·048
12–13 years	−0·169	0·101	−0·067	−0·177	0·100	−0·070	−0·169	0·101	−0·067
SF-36 Physical Component Summary	0·004	0·005	0·033	0·004	0·005	0·030	0·004	0·005	0·030
Depression (GDS)	−0·030	0·010	−0·131**	−0·030	0·010	−0·129**	−0·031	0·010	−0·132**
Functional status (SMAF)	−0·011	0·012	−0·034	−0·010	0·012	−0·033	−0·010	0·012	−0·033
SF-36 Social Functioning	−0·007	0·002	−0·114**	−0·006	0·002	−0·113**	−0·006	0·002	−0·112**
Social support									
Little or no support	0·067	0·090	0·028	0·064	0·091	0·026	0·062	0·091	0·025
No. of children living nearby									
2 or more	−0·076	0·096	−0·037	−0·073	0·096	−0·036	−0·066	0·097	−0·032
1	−0·059	0·100	−0·026	−0·055	0·101	−0·024	−0·050	0·101	−0·022
Residential neighbourhood									
% below low income cut-off				−0·007	0·004	−0·086	−0·006	0·004	−0·073
% speaking neither French nor English				0·005	0·003	0·071	0·005	0·003	0·076
% with university degree							0·003	0·003	0·048
R^2/R^2 adjusted		0·088/0·064			0·094/0·067			0·095/0·067	
P for change		0·025			0·114			0·357	

b, unstandardized beta coefficient; SE, standard error of the beta coefficient; *β*, standardized beta coefficient; R^2, explained variance; %HFS, proportion of healthful food stores; %FFO, proportion of fast-food outlets; SF-36, Short-form 36 Health Survey; GDS, Geriatric Depression Scale; SMAF, System for Measuring Functional Autonomy.

$^{*}P<0·05$, $^{**}P<0·01$, $^{***}P<0·001$.

†Bivariate model testing the association between %HFS and prudent pattern scores.

‡Bivariate model testing the association between %FFO and prudent pattern scores.

§From model 1a, the combined association between %HFS and %FFO and prudent pattern scores.

||Model 2 with sociodemographic characteristics (sex, age, country of birth, marital status, education, family income).

¶Model 3 with health characteristics (SF-36 Physical Component, depression (GDS), functional status (SMAF), SF-36 Social Functioning) and social support variables (index of social support, number of children living nearby).

††Model 4 with residential neighbourhood % of people below the low income cut-off and % speaking neither French nor English.

‡‡Model 5 with residential neighbourhood % of people with university degree.

Table 5 Results of multiple regression analyses examining associations between %HFS, %FFO and western dietary pattern among urban-dwelling VoisiNuAge participants (*n* 751)

	Model 1a†			Model 1b‡			Model 2§			Model 3‖		
	b	SE	*β*	*b*	SE	*β*	*b*	SE	*β*	*b*	SE	*β*
Intercept	−0·001	0·036		−0·002	0·036		0·003	0·036		1·960	0·641**	
Residential food environment												
%HFS	−1·257	0·238	−0·190***				−1·053	0·270	−0·159***	−0·782	0·271	−0·118**
%FFO				1·277	0·329	0·140***	0·591	0·370	0·065	0·326	0·370	0·036
Individual characteristics												
Sex												
Female										−0·402	0·076	−0·203***
Age										−0·023	0·009	−0·095**
Country of birth												
Outside Canada										−0·278	0·090	−0·112***
Family income												
Below low income cut-off										−0·003	0·103	−0·001
Income not reported										−0·159	0·103	−0·056
Marital status												
Single										0·011	0·118	0·004
Widowed										−0·071	0·093	−0·030
Divorced/separated										−0·086	0·126	−0·025
Education												
2–11 years										0·138	0·082	0·068
12–13 years										0·032	0·097	0·013
SF-36 Physical Component Summary												
Depression (GDS)												
Functional status (SMAF)												
SF-36 Social Functioning												
Social support												
Little or no support												
No. of children living nearby												
2 or more												
1												
Residential neighbourhood												
% below low income cut-off												
% speaking neither French nor English												
% with university degree												
R^2/R^2 adjusted	0·036/0·035			0·020/0·018			0·039/0·037			0·110/0·096		
P for change	0·000			0·000			0·111			0·000		

Table 5 *Continued*

	Model 4¶			Model 5††			Model 6‡‡		
	b	SE	*β*	*b*	SE	*β*	*b*	SE	*β*
Intercept	2·719***	0·746		2·766***	0·746		2·879***	0·748	
Residential food environment									
%HFS	−0·818	0·270	−0·124**	−0·487	0·323	−0·074	−0·275	0·347	−0·042
%FFO	0·310	0·372	0·034	0·422	0·389	0·046	0·101	0·435	0·011
Individual characteristics									
Sex									
Female	−0·422	0·078	−0·213***	−0·424	0·078	−0·214***	0·420	−0·078	−0·212***
Age	−0·032	0·009	−0·134***	−0·032	0·009	−0·133***	−0·030	0·009	−0·127**
Country of birth									
Outside Canada	−0·277	0·091	−0·112**	−0·256	0·092	−0·103**	−0·245	0·092	−0·098**
Family income									
Below low income cut-off	−0·018	0·103	−0·006	−0·035	0·104	−0·013	−0·041	0·104	−0·015
Income not reported	−0·181	0·102	−0·063	−0·194	0·103	−0·068	−0·196	0·103	−0·069
Marital status									
Single	0·064	0·130	0·021	0·054	0·133	0·018	0·067	0·133	0·022
Widowed	−0·023	0·094	−0·010	−0·020	0·094	−0·008	−0·017	0·094	−0·007
Divorced/separated	−0·007	0·127	−0·002	−0·003	0·128	−0·001	0·001	0·128	0·000
Education									
2–11 years	0·161	0·083	0·080	0·169	0·083*	0·084	0·141	0·085	0·070
12–13 years	0·049	0·097	0·019	0·054	0·097	0·021	0·040	0·098	0·016
SF-36 Physical Component Summary	−0·009	0·005	−0·073	−0·009	0·005	−0·070	−0·009	0·005	−0·070
Depression (GDS)	0·004	0·009	0·018	0·004	0·009	0·018	0·005	0·009	0·023
Functional status (SMAF)	0·039	0·012	0·124**	0·038	0·012	0·121**	0·038	0·012	0·121**
SF-36 Social Functioning	0·002	0·002	0·040	0·002	0·002	0·038	0·002	0·002	0·037
Social support									
Little or no support	−0·022	0·087	−0·009	−0·010	0·088	−0·004	−0·006	0·088	−0·002
No. of children living nearby									
2 or more	0·039	0·093	0·019	0·030	0·093	0·015	0·018	0·093	0·009
1	0·026	0·097	0·012	0·014	0·098	0·006	0·005	0·098	0·002
Residential neighbourhood									
% below low income cut-off				0·003	0·004	0·039	0·001	0·004	0·016
% speaking neither French nor English				−0·006	0·003	−0·089	−0·006	0·003	−0·097*
% with university degree							−0·005	0·003	−0·084
R^2/R^2 adjusted		0·133/0·110			0·137/0·112			0·140/0·114	
P for change		0·009			0·174			0·102	

b, unstandardized beta coefficient; SE, standard error of the beta coefficient; *β*, standardized beta coefficient; R^2, explained variance; %HFS, proportion of healthful food stores; %FFO, proportion of fast-food outlets; SF-36, Short-form 36 Health Survey; GDS, Geriatric Depression Scale; SMAF, System for Measuring Functional Autonomy.
*$P < 0·05$, **$P < 0·01$, ***$P < 0·001$.
†Bivariate model testing the association between %HFS and western pattern scores.
‡Bivariate model testing the association between %FFO and western pattern scores.
§From model 1a, the combined association between %HFS and %FFO and western pattern scores.
‖Model 2 with sociodemographic characteristics (sex, age, country of birth, marital status, education, family income).
¶Model 3 with health characteristics (SF-36 Physical Component, depression (GDS), functional status (SMAF), SF-36 Social Functioning) and social support variables (index of social support, number of children living nearby).
††Model 4 with residential neighbourhood % of people below the low income cut-off and % speaking neither French nor English.
‡‡Model 5 with residential neighbourhood % of people with university degree.

Bivariate models (1a and 1b) reveal that living in an area with higher %HFS was associated with higher prudent diet scores (Table 4, $\beta = 0{\cdot}092$; $P < 0{\cdot}05$) and lower western diet scores (Table 5, $\beta = -0{\cdot}190$; $P < 0{\cdot}001$). Living in an area with higher %FFO was associated with lower prudent diet scores (Table 4, $\beta = -0{\cdot}133$; $P < 0{\cdot}001$) and higher western diet scores (Table 5, $\beta = 0{\cdot}140$; $P < 0{\cdot}001$). For prudent diet scores, the model which included both food source indices (Table 4, Model 2) showed that the association between prudent scores and %HFS was attenuated to non-significance while the association with %FFO remained relatively unchanged and statistically significant ($\beta = -0{\cdot}116$; $P < 0{\cdot}001$; i.e. the influence of higher %FFO outweighed the influence of %HFS). In Table 4, adjusting successively for sociodemographic characteristics (Model 3), health and social environment characteristics (Model 4) and residential neighbourhood characteristics (Models 5 and 6) did not substantially affect the size of coefficients for %FFO, which remained relatively stable and statistically significant ($\beta = -0{\cdot}105$, $P < 0{\cdot}05$). Conversely, the additive models for the western diet scores (Table 5, Model 2) indicated an association between higher %HFS and lower western diet scores. The influence of %FFO was outweighed by %HFS ($\beta = -0{\cdot}159$; $P < 0{\cdot}001$). In Table 5, adjusting successively for sociodemographic characteristics (Model 3) and health and social environment characteristics (Model 4) attenuated the association slightly but it remained significant ($\beta = -0{\cdot}124$; $P < 0{\cdot}01$). When residential neighbourhood characteristics (Models 5 and 6) were added, this association was no longer significant.

To examine the influence of outliers for both models, further analyses were performed by removing outliers with the use of a $P < 0{\cdot}001$ criterion for Mahalanobis distance, or with Cook distance above average plus 3 SD (n 29). These analyses produced essentially the same results (available upon request). Results are thus reported including these observations. Spatial autocorrelation in residuals was statistically non-significant in models examining prudent diet scores: Moran's $I = -0{\cdot}050$ ($P = 0{\cdot}54$). However, Moran's I was statistically significantly for residuals of western diet scores ($I = 0{\cdot}22$; two-tailed $P = 0{\cdot}01$), suggesting remaining spatial structure to be explained.

Discussion

The purpose of the present study was to examine associations between dietary patterns and availability of residential-area food sources within residential walking distance in a sample of urban-dwelling seniors, taking into account both personal and community characteristics. The use of relative indices to measure the availability of food sources is innovative in that such metrics have not yet been used in relation to food consumption. These measures have the potential to provide information complementary to traditional measures of the food environment[36] and have been previously linked to obesity[54,55], an important indicator of energy balance-related behaviours. The current study shows, surprisingly, that a less prudent diet was related to a higher proportion of fast-food outlets but not a lesser availability of healthful food stores. These findings suggest that the deleterious effect of fast-food outlets seems to outweigh the health-promoting effect of healthful food stores for the consumption of healthful foods, regardless of personal and community characteristics. Research on school food environments is useful in interpreting this counterintuitive result. When unhealthful options are available in schools, students consume significantly less of the healthy foods (e.g. fruits, non-fried vegetables, milk) in favour of more energy-dense foods and sugar-sweetened beverages[56,57], suggesting the existence of a 'competing food choice' effect[58]. For older adults living in the community, this competing food choice effect might also exist when a higher proportion of fast-food outlets is available to residents. The near absence of fruits and vegetables and low-fat dairy products associated with a prudent diet in fast-food meals might result in a lower consumption of healthful foods, without necessarily translating into a higher consumption of foods linked to a western diet. On the other hand, we found that higher proportions of healthful food stores were associated with lower western diet scores but not prudent diet scores. Food stores are, in themselves, a competitive food environment where many unhealthful and healthful options are available simultaneously. Using food store type as a proxy for healthful food supply is an important limitation of the current study, and might explain the absence of an association between %HFS and prudent diet score. Notably though, in the Multi-Ethnic Study of Atherosclerosis (MESA), Franco *et al.*[24] also found that lesser availability of healthful foods measured directly in food store offerings was statistically associated with a lower-quality dietary pattern but not with the higher-quality diet in 759 participants living in Baltimore, USA. Nevertheless, complementary information related to actual availability of healthful foods relative to less healthful food inside these stores, coupled with geographic mapping of stores, would provide a more informative and highly objective assessment of the food store environment[59].

The association between %HFS and western diet scores was also attenuated and became non-significant when accounting for the sociodemographic characteristics of the residential neighbourhood. In a previous study, we found that distributions of healthful food stores were correlated with the sociodemographic characteristics of the population in the participants' neighbourhood[36]. Future mediational analyses could determine whether or not area-level composition might fully or partially explain the relationship between the food store environment and diet. In addition, for the western diet model Moran's I (0·22) was statistically significant, indicating correlated residuals and thus

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unexplained spatial variation in western diet scores. Further research involving explicit spatial modelling strategies such as geographically weighted regression, and/or inclusion of additional relevant spatial factors such as transportation opportunities[60], could potentially improve the predictive capacity of such models and explain spatial influences otherwise unaccounted for[61].

The present results show some consistency with other investigations of neighbourhood food sources and dietary patterns, even though exposure variables were specified differently[23,24,29,31] and these studies examined only one dimension of the food environment at a time. In a study of 2384 participants from the MESA cohort, Moore *et al.*[23] also found that lesser access to healthful foods was associated with a lower probability of having a healthy diet, characterized by two global dietary measures: an empirically derived dietary pattern reflecting a lower-quality diet and the Alternate Healthy Eating Index reflecting dietary practices recommended for chronic disease prevention[62]. For the exposure to fast foods, the same group of researchers found in another study that greater exposure to fast foods was also associated with lower odds of having a healthy diet[31]. In contrast, a study by Morland *et al.* is notable[20]. After adjustment for types of food stores and restaurants, these researchers found positive associations between presence of supermarkets in the census tract of residence and meeting the US Dietary Guidelines for fruits and vegetables, total fat and saturated fat in a large sample of 10 623 American adults[20]. Contrary to our results, there was no evidence of associations between these indicators and fast-food exposure. The present study reached beyond these previous investigations by simultaneously examining relationships between food stores and restaurants on food consumption, as well as use of 'relative availability' indices of exposure. Replication and extension are nevertheless required, in order to investigate the underlying mechanisms.

The current study has limitations. First, the cross-sectional design limits capacity for causal inference as directionality is uncertain. Longitudinal designs, as well as impact assessments of planned or 'natural' changes[63] of the food landscape, could contribute to the identification of the multiple processes involved in these complex relationships. Second, it should be acknowledged that participants in the NuAge cohort are, on average, wealthier than older adult Quebecers[64]. The effect of exposure to food sources on dietary patterns is likely underestimated as variability in this sample is also less than in the reference population. Third, we used specific indicators of food patterns. Replication with other indicators of eating habits or food provision habits is warranted. Finally, although we examined associations using a 500 m buffer, it is possible that spatial scales for food provision differ according to participants' characteristics[7,65]. Again, replication and extension of findings using various spatial buffers could provide additional support for our results. In this regard, greater attention could be paid to the 'people–place interactions' related to food procurement activities[60,66].

Despite its limitations, the present study makes an important contribution to establishing the direction and magnitude of relationships between relative availability of food sources in the residential environment and dietary patterns among older adults. Of the few publications in this area[17,18], the present one is the first to our knowledge that examines the relationship between spatial access to different food sources in seniors' residential environments and dietary patterns, while simultaneously accounting for important covariates including health status and social support. These two factors are known for their joint influence on both diet[6,67] and access to neighbourhood resources[5,6,11]. From the perspective of public policy and health promotion, development of interventions aimed at food environments may require consideration of both access and diversity of food sources.

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