Preventive Medicine 71 (2015) 83–87

Contents lists available at ScienceDirect

Preventive Medicine

journal homepage: www.elsevier.com/locate/ypmed

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

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ARTICLE INFO

Available online 4 December 2014

Keywords:
Food environment
Exposure
Relative measures
Fruit and vegetable intake
Gender
Canadian cities

ABSTRACT

Objective. This paper explores which of absolute (i.e. densities of "healthy" and "unhealthy" food outlets taken separately) or relative (i.e. the percentage of "healthy" outlets) measures of foodscape exposure better predicts fruit and vegetable intake (FVI), and whether those associations are modified by gender and city in Canada.

Methods. Self-reported FVI from participants of four cycles (2007–2010) of the repeated cross-sectional Canadian Community Health Survey living in the five largest metropolitan areas of Canada ($n = 49{,}403$) was analyzed. Absolute and relative measures of foodscape exposure were computed at participants' residential postal codes. Linear regression models, both in the whole sample and in gender- and city-stratified samples, were used to explore the associations between exposure measures and FVI.

Results. The percentage of healthy outlets was strongly associated with FVI among men both in Toronto/Montreal ($\beta = 0.012$; $P < 0.001$), and in Calgary/Ottawa/Vancouver ($\beta = 0.008$; $P < 0.001$), but not among women. Observed associations of absolute measures with FVI were either weak or faced multicollinearity issues. Overall, models with the relative measure showed the best fit.

Conclusions. Relative measures should be more widely used when assessing foodscape influences on diet. The absence of a single effect of the foodscape on diet positions sub-group analysis as a promising avenue for research.

Introduction

Over the last decade, a growing body of research has explored the potential influences of the foodscape – defined as "the multiplicity of sites where food is displayed for purchase and where it may also be consumed" (Winson, 2004) – on diet (Caspi et al., 2012). Conflicting findings (Caspi et al., 2012) have, however, led to question the traditional way of modeling the foodscape–diet relationship (Lytle, 2009).

Foodscape exposure has mostly been assessed using absolute measures of access to either "healthy" food outlets — overlooking "unhealthy" sources, or "unhealthy" outlets — ignoring "healthy" ones (Charreire et al., 2010). Yet, since individuals tend to get exposed simultaneously to "healthy" and "unhealthy" food sources (Kestens and Daniel, 2010), "unhealthy" outlets are likely to act as a proxy measure of "healthy" stores (and inversely) (Leal et al., 2012). A few studies (e.g. (Morland et al., 2002)) did control for the overall outlet density in an attempt to address this model misspecification. However, precisely because of high spatial correlation between outlet categories, problems of multicollinearity are likely to be introduced. Combining two collinear variables into an index has been proposed as a valuable method (York, 2012). From that perspective, relative exposure measures, such as the percentage of food outlets considered "healthy" would be more appropriate. Only a few studies have compared relative to absolute measures, though (Mason et al., 2013; Zenk et al., 2014). Furthermore, little is known about the consistency of associ'ations between diet and those relative measures across populations and space. Yet, territorial variations in the foodscape–diet relationship within homogeneous groups of individuals have been highlighted (Fraser et al., 2012), while non-uniform responses from individuals who share the same environment have been observed (Entwisle, 2007; Thompson et al., 2013). As an example, gender differences have been pointed out (Macdonald et al., 2011; Sharkey et al., 2011).

Abbreviations: AIC, Akaike Information Criterion; CCHS, Canadian Community Health Survey; CMA, Census Metropolitan Area; EPOI, Enhanced Points of Interest; FFQ, Food Frequency Questionnaire; FFR, fast-food restaurants; FSR, full-service restaurants; FVI, fruit and vegetable intake; FVS, fruit and vegetable store; NFS, natural food stores; SIC, Standard Industrial Classification.; VIF, Variance Inflation Factor.

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http://dx.doi.org/10.1016/j.ypmed.2014.11.023
0091-7435/

Drawing on those limitations, the present paper aimed to explore whether relative measures of foodscape exposure are overall better correlates of fruit and vegetable intake (FVI) than absolute measures. Furthermore, the consistency of the relationship between those exposure measures and FVI is tested by gender and city in Canada.

Methods

Data sources

Individual data was drawn from the Canadian Community Health Survey (CCHS) (Beland, 2002), a repeated cross-sectional survey led by Statistics Canada and representative of the non-institutionalized Canadian population aged 12 and above. Initiated in 2000, the CCHS collects information related to socio-demographics, health outcomes, and health determinants, in a sample of approximately 65,000 Canadians each year. Four CCHS cycles (2007 to 2010) were combined for the present study. Adults 18 years and over living in the five largest Census Metropolitan Areas (CMAs) in Canada — Toronto, Montreal, Vancouver, Ottawa, and Calgary — were considered for inclusion in the analyses.

Foodscape data was obtained from the 2010 DMTI Spatial® EPOI (Enhanced Points of Interest) file, a commercial dataset of businesses across Canada. For each listed food business, the EPOI file provides the name, geographic coordinates, and between one and six Standard Industrial Classification (SIC) codes based on the economic activities declared (OSHA, US, 2008). Using a SIC code- and name-based assignment method of categorization, ten categories of food outlets – supermarkets, grocery stores, convenience stores, bakeries, fruit and vegetable stores (FVS), specialty stores (e.g. butcher), natural food stores (NFS), fast-food restaurants (FFR), full-service restaurants (FSR) and cafés – were extracted from the EPOI dataset (see (Clary and Kestens, 2013) for more details). The dataset, validated in 2010 using ground-truthing, has shown a good capacity to assess local densities of outlets. Representativity of the dataset, that is, concordance between outlets present on the EPOI list and outlets observed on the field was 77.7% when relaxing on business names, small imprecisions in location (i.e. within the same census tract), and when compensating false negatives with false positives within the same outlet category and census tract (see (Clary and Kestens, 2013) for more details).

Each outlet category was further classified as a "healthy" or an "unhealthy" food source. The term "healthy" restrictively referred to "outlets that allow for complete meals with fruit and vegetable options", and included supermarkets, FVS, NFS, and grocery stores. Inversely, "outlets allowing for complete meals but offering few or no fruit and vegetable options" were termed "unhealthy". They encompassed convenience stores and FFR. Bakeries and specialty stores were excluded from analyses as they do not allow for complete meals. FSR and cafés were also trimmed, as the assignment method used to categorize those outlets was insensitive regarding how much fruit and vegetable options they offer.

Measures

Dependent variables

Fruit and vegetable intake (FVI) was computed by adding up consumption of the four following items collected in the CCHS Food Frequency Questionnaire (FFQ): the number of portions of "fruits (excluding fruit juices)", "green salad", "carrots", and "other vegetables (excluding carrots, potatoes, and green salad)". Respondents were free to report the number of portions they ate either per month, per week or per day. All data were transformed into daily consumptions and summed up to obtain a FVI variable.

Independent variables

Foodscape exposure around home. For each food outlet category, a continuous density surface was computed in Crimestat v.3.3 using a quartic kernel with an adaptive search radius distance – or bandwidth (Carlos et al., 2010) – including 5% of the closest neighbors (Kestens et al., 2012; Lebel et al., 2012). Measures of density for each outlet category were computed and linked to each participant's 6-digit postal code using ArcGIS v10.1. The densities of supermarkets, FVS and FFR, and the sum of densities of all healthy and all unhealthy food outlets were used as absolute measures in the analyses. A relative measure was computed, measured as the percentage of healthy outlets — i.e. summed density of healthy stores divided by the sum of densities of all considered outlets.

Covariates. Gender, age ([18–29], [30–44], [45–64], [65 and over]), educational level (less than secondary grade, secondary degree, post-secondary grade, post-secondary degree), ethnic origin (White, Asian, Black, others), marital status (single, couple, couple with children, single parent, other), household size adjusted income (low, mid-low, mid-high, high), CMA of residence, and both material and social neighborhood deprivations were included in the models. Household size adjusted income was computed using both annual household income (12 categories) and the number of household members (three categories). The 2006 material and social dimension of the Pampalon deprivation index (Pampalon et al., 2009) available at the dissemination area level were extracted at the 6-digit postal code level to provide neighborhood material deprivation and neighborhood social deprivation variables.

4.6% of the dataset values were missing, affecting 12,386 participants (23.59%) (Table 1). To avoid deleting one quarter of the sample, we performed Multiple Imputation then Deletion (MID) (Von Hippel, 2007) with 5 imputations, using SPSS v20. In short, all observations and variables were used for multiple imputation but, following imputation, cases with imputed FVI values were excluded from the analysis.

Because the sample encompassed four waves of the CCHS survey, temporal variations might have been expected. Dummy variables for each survey cycle were included in preliminary analyses, but excluded from models since they were not significant.

Statistical analysis

First, six linear regression models were built to estimate the associations between each of the six exposure measures and FVI in the whole population sample, using SPSS v.20. All regression models were adjusted for gender, age, educational level, marital status, ethnic origin, income, CMA of residence, and neighborhood material and social deprivations.

Second, the interactive effects of each of the six foodscape exposure measures with gender and CMAs were tested, with "women" and "Montreal" chosen as reference groups. When interactions were significant, the population sample was stratified in consequence, and estimates of the association between exposure measures and FVI were re-assessed in each subsample.

Spatial autocorrelation analyses of standardized residuals were performed with GeoDa v.0.9.9.8, using Moran's Index. Due to data clustering linked to the treatment of distinct CMAs that were distant from each other, spatial autocorrelation analyses were performed separately for each CMA. Spatial weights were row-standardized (i.e. each neighbor weight for an observation was divided by the sum of all neighbor weights for that observation) and Euclidean inverse distance-based, with the bandwidth chosen to ensure that each location had at least one neighbor.

Because original CCHS weights were aimed to be applied to the complete sample, they were not adapted to our subsample. All analyses were therefore performed without weighting.

Results

Out of the 52,510 participants aged 18 or more and living in the five CMAs, 3107 participants had a missing FVI and were deleted. Our final sample encompassed 49,403 individuals.

Descriptive analyses

The average FVI of participants was 3.98 portions per day (Table 1). Women were more likely to eat fruit and vegetables than men ($P < 0.001$). FVI also varied by CMA ($P < 0.001$), with Montreal having the highest (4.14 portions/day) and Toronto the lowest (3.86 portions/day) FVI.

As expected, positive correlations between the sum of healthy and sum of unhealthy outlet densities (Pearson correlation coefficient = 0.947, $P < 0.001$) were found, suggesting that participants with higher (lower) exposure to unhealthy outlets around home were also more likely to have higher (lower) exposure to healthy outlets. Gender-differences in foodscape exposure were found only for absolute measures, men being exposed to higher densities of both healthy and unhealthy outlets than women (see Appendix A). CMA-differences were also observed, with Montreal, Toronto and Vancouver having greater densities of

Table 1
Socio-demographic characteristics and dietary intakes of CCHS participants, Canada, 2007–2010.

	Total	
	(N = 49,403)	
	n	%
Gender		
Women	27,241	55.1
Men	22,162	44.9
Age group		
[18–29]	8610	17.4
[30–44]	13,826	28.0
[45–64]	16,429	33.3
[65 +]	10,538	21.3
Ethnic origin		
White	36,233	73.3
Asian	7385	14.9
Black	1615	3.3
Others	2057	4.2
Missing	2113	4.3
Marital status		
Single	14,750	29.9
Couple	13,359	27.0
Couple with children	13,418	27.2
Single parent	3414	6.9
Other	4297	8.7
Missing	165	0.3
Education level		
Less than secondary	6211	12.6
Secondary graduate	7531	15.2
Other post-secondary grade	3804	7.7
Post-secondary graduate	30,440	61.6
Missing	1417	2.9
Household size adjusted income		
Low	2946	6.0
Mid-low	6300	12.7
Mid-high	12,344	25.0
High	19,532	39.5
Missing	8281	16.8

Daily fruit and vegetable intake (portion)*,**	Mean	SD	Min–max[a]
Whole population	3.98	2.34	0–21.2
By gender			
Men (n = 22,162)	3.47	2.20	0–19.5
Women (n = 27,241)	4.39	2.37	0–20.1
By Census Metropolitan Area			
Calgary (n = 4038)	3.93	2.40	0–14.9
Montreal (n = 12,309)	4.14	2.54	0–18.7
Ottawa (n = 5589)	4.03	2.41	0–16.3
Toronto (n = 17,290)	3.86	2.25	0–20.1
Vancouver (n = 10,177)	3.98	2.34	0–16.3

[a] Due to restrictions on the dissemination of CCHS data imposed by the provider Statistics Canada, maximum values are the averaged maximum values of the fifteen individuals with the highest fruit and vegetable intake.
* Gender-differences significant at $P < 0.001$.
** CMA-differences significant at $P < 0.001$.

both healthy and unhealthy outlets, as well as a higher percentage of healthy outlets.

Regression analyses using the whole sample

In the whole sample (Table 2), the percentage of healthy outlets was positively associated with FVI ($\beta = 0.005$; $P < 0.001$). Similarly, absolute FFR density ($\beta = -0.039$; $P < 0.001$) and FVS density ($\beta = 0.026$; $P = 0.047$) were associated with FVI when models were adjusted for the overall outlet density. The FFR density model did, however, present some multicollinearity issues (Variance Inflation Factor (VIF) value of 11.1).

Overall, the Akaike Information Criterion (AIC) indicated the best model fit (i.e. lowest AIC) when using the relative measure, both with and without adjusting for overall outlet density.

Interaction analyses (results not shown in table)

Significant interactions between gender and exposure variables were found only with relative measures $\beta = 0.011$; $P < 0.001$, the percentage of healthy food outlets being more strongly related to FVI for men than for women. The interaction between CMA and relative measures of exposure, tested separately for men and women, was not significant among women. Inversely, for men, associations between the percentage of healthy outlets and FVI were weaker in Calgary ($\beta = -0.015$; $P < 0.05$), Ottawa ($\beta = -0.016$; $P < 0.01$), and Vancouver ($\beta = -0.011$; $P < 0.05$), but not different in Toronto, compared to associations observed in Montreal.

Three population subsamples were therefore established to test relative measure-FVI associations: men from Calgary/Ottawa/Vancouver, men from Montreal/Toronto, and women from all five CMAs.

Regression analyses in the gender- and CMA-stratified samples (Table 3)

The percentage of healthy outlets was positively associated with FVI among men both in Toronto/Montreal ($\beta = 0.012$; $P < 0.001$) and in Calgary/Ottawa/Vancouver ($\beta = 0.008$; $P < 0.001$). Among women, the association was marginal ($\beta = 0.004$; $P = 0.051$).

Except for models run in Vancouver, Toronto and Ottawa among women, regression residuals were not spatially correlated, suggesting that the spatial structure was overall well accounted for by our modeling.

Discussion

In the whole population sample, the percentage of healthy outlets was strongly associated with FVI ($\beta = 0.005$; $P < 0.001$). FFR density ($\beta = -0.039$; $P < 0.001$) and FVS density ($\beta = 0.026$; $P = 0.047$) were also related to FVI when models were adjusted for the overall outlet density, but those associations either faced multicollinearity issues or were weak. Overall, AIC indicated the best model fit when using the relative measure.

Table 2
Associations between foodscape exposure and daily fruit and vegetable intake — whole sample, Canada, 2007–2010 (N = 49,403).

Foodscape exposure measures	β[a]	95% CI	VIF	AIC
Supermarkets' density (nb/km^2)				
Model 1[b]	0.058	(−0.021; 0.138)	1.2	65,611
Model 2[c]	0.122	(−0.005; 0.249)	3.2	65,612
Fruit and vegetable stores' density (nb/km^2)				
Model 1[b]	0.024	(0.000; 0.048)	1.0	65,612
Model 2[c]	0.026*	(0.000; 0.051)	1.2	65,614
Fast-food restaurants' density (nb/km^2)				
Model 1[b]	−0.003	(−0.010; 0.004)	1.1	65,615
Model 2[c]	−0.039***	(−0.060; −0.017)	11.1	65,608
Sum of healthy outlets' densities (nb/km^2)				
Model 1[b]	0.005	(−0.004; 0.013)	1.1	65,613
Model 2[c]	0.012	(−0.004; 0.028)	4.4	65,615
Sum of unhealthy outlets' densities (nb/km^2)				
Model 1[b]	0.000	(−0.006; 0.005)	1.2	65,615
Model 2[c]	−0.013	(−0.032; 0.005)	13.8	65,615
Percentage of healthy outlets (%)[b]	0.005***	(0.002; 0.008)	1.5	65,600

[a] Unstandardized regression coefficient.
[b] Model adjusted for gender, age, education level, marital status, ethnic origin, household size adjusted income, CMA of residence, and neighborhood material and social deprivations.
[c] Model adjusted for gender, age, education level, marital status, ethnic origin, household size adjusted income, CMA of residence, neighborhood material and social deprivations, and overall outlet density.
* $P < 0.05$.
*** $P < 0.001$.

In this study, the relative measure of exposure was a better correlate of FVI than absolute measures, in line with recent work exploring absolute and relative exposures in Australia (Mason et al., 2013) and in the USA (Zenk et al., 2014). Whereas improved statistical significance may be an important aspect, use and usefulness of relative measures also require better conceptual integration. So far, most research looking at the relationship between absolute measures of exposure and diet was driven by the "gravity model" which asserts that closer destinations are more attractive because their access requires less financial and travel time investment (Glanz et al., 2005). However, relative measures of exposure may be less prone to a strict 'proximity' justification of use. The fact that individuals tend to be exposed simultaneously to both healthy and unhealthy food outlets points towards the relevance of looking at foodscape exposure from a competitive food choice environment viewpoint (Kubik et al., 2003; Fox et al., 2009). As the sight of calorie-dense food cues promotes the automatic desire for eating (Cohen and Farley, 2008), unhealthy food choices may, to some extent, outweigh healthy ones. In parallel, the consumption norm, through the predominant food supply in the environment, drives messages about acceptable and unacceptable behaviors (Wansink, 2004; Cohen and Farley, 2008). To conform to the apparent norm, individuals who live in environments with a strong predominance of healthy food stores may adopt healthier diets than others living in environments with a predominance of unhealthy outlets.

Such statements should, however, be interpreted in the light of contextual factors which may modify the foodscape–FVI relationship. Indeed, the percentage of healthy outlets was strongly associated with FVI for men, but not for women. Women have been reported more likely to be nutritionally knowledgeable (Turrell, 1997), to perceive nutrition as important when food shopping (Turrell, 1997), and to engage in risk-reducing strategies (Mitchell and Boustani, 1993). Consequently, they may be less responsive to the normative dimension driven by the foodscape.

CMA-differences in the magnitude of foodscape–FVI associations were further found, with a significantly stronger association for men living in Montréal and Toronto compared to men living in Calgary, Ottawa and Vancouver. Given that Montréal and Toronto are less sprawled than Calgary, Ottawa and Vancouver (Ross et al., 2007), and therefore potentially more 'walkable' (Camagni et al., 2002; Ewing et al., 2003), one possible explanation could be that individuals' mobility moderates the foodscape–diet relationship at their place of residence (Longacre et al., 2012).

Further research is however needed to both pinpoint the underlying causes of those gender- and CMA-variations, and rule out potential Canadian context specificity.

Limitations

First, given the cross-sectional nature of our study, we cannot exclude that significant associations may be due to reverse causation (i.e. FVI influencing residential migration to specific neighborhoods). Second, our FVI variable was aggregated across four food items obtained from a non-quantitative FFQ. Some misspecification problems may be expected, if the relationship between the four food items taken separately and the control variables is not homogeneous. Furthermore, portion sizes were not accounted for and over-declaration of variables obtained via FFQ have been reported. However, there is no a priori suspicion that the possible level of over-reporting would be correlated to exposure while holding covariates constant, and then reason to think our estimates are badly inflated. Third, as our subsample may not be fully representative of the whole urban population in Canada, caution is required in generalizing those findings. Fourth, in order to rule out the large sample size as the primary cause of observed significant associations, the replication of our findings in other settings would be timely. Finally, foodscape exposure may have been underestimated, since our study focused solely on the residential neighborhood (Kestens et al., 2010; Burgoine and Monsivais, 2013). Accounting for individuals' daily mobility would help refine exposure assessment.

Conclusions

Our findings add to the evidence that relative exposures may be more appropriate than absolute exposures when exploring foodscape–diet associations. Policies sensitive to striking a better balance between healthy and unhealthy outlets may be more effective in encouraging fruit and vegetable consumption than policies seeking to alter access to either healthy or unhealthy outlets independently. More evidence, especially drawn from longitudinal studies, is needed, though. Overall, those findings encourage a more systematic use of relative measures when assessing foodscape influences on health. By highlighting gender and city differences in the foodscape–FVI relationship, they also underline the absence of one universal effect of the foodscape on diet, and position sub-group analysis as a promising avenue for research.

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.ypmed.2014.11.023.

Conflict of interest statement

The authors declare that there are no conflicts of interests.

Acknowledgment

This study was supported by the Canadian Institutes of Health Research (CIHR grant # MOP-106420). Christelle M. Clary was supported by three grants from the Research Centre, Centre Hospitalier de l'Université de Montréal (CRCHUM), the Quebec Inter-University Center for Social Statistics (QICSS), and the École de Santé Publique de l'Université de Montréal (ESPUM). Yan Kestens holds a CIHR Chair in Applied Public Health on Urban Interventions and Population Health.

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Table 3

Associations[a] between foodscape exposure and daily fruit and vegetable intake in gender- and CMA-stratified samples, Canada, 2007–2010.

	Women		Men		Men	
			Montreal, Toronto		Calgary, Ottawa, Vancouver	
	(n = 27,241)		(n = 13,268)		(n = 8894)	
	β[b]	95% CI	β[b]	95% CI	β[b]	95% CI
Foodscape exposure						
Percentage of healthy outlets	0.004	(0.000; 0.007)	0.012***	(0.006; 0.018)	0.008***	(0.004; 0.012)

[a] Model adjusted for age, education level, marital status, ethnic origin, household size adjusted income and neighborhood material and social deprivations.
[b] Unstandardized regression coefficient.
*** $P < 0.001$.

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