

The Local Food Environment and Obesity: Evidence from Three Cities

Blake Byron Walker¹, Aateka Shashank², Danijela Gasevic³, Nadine Schuurman², Paul Poirier⁴, Koon Teo⁵, Sumathy Rangarajan⁵, Salim Yusuf⁶, and Scott A. Lear^{6,7} 

Objective: This study aimed to identify the association between the food environment and obesity.

Methods: BMI and waist circumference (WC) were measured in 8,076 participants from three cities. The number of fast-food restaurants, full-service restaurants, bars/pubs, markets, and liquor stores within 500 m of each participant was documented. The association between the food environment (ratio of fast-food to full-service restaurants, ratio of bars/pubs to liquor stores, and presence of markets) with obesity (BMI ≥ 30 kg/m²) and abdominal obesity (WC ≥ 102 cm for males or WC ≥ 88 cm for females) was investigated, adjusted for age, sex, education level, neighborhood deprivation, neighborhood type, and total hours per week of walking and taking into account city-level clustering.

Results: The ratios of fast-food to full-service restaurants and of bars/pubs to liquor stores were positively associated with obesity (OR = 1.05 [CI: 1.02–1.09] and OR = 1.08 [CI: 1.04–1.13], respectively). The ratio of bars/pubs to liquor stores was positively associated with abdominal obesity (OR = 1.10 [CI: 1.05–1.14]). There was no association between markets and either obesity or abdominal obesity.

Conclusions: Features of the food environment have varying associations with obesity. These features have an additive effect, and future studies should not focus on only one feature in isolation.

Obesity (2020) 28, 40–45.

Introduction

The prevalence of obesity (BMI ≥ 30 kg/m²) has been rising drastically in recent decades, and it has been estimated that more than 650 million adults, or 13% of the global population, had obesity in 2016 (1). Given the rapid increase, it has been postulated the environment has a role in the causation of obesity. Factors such as neighborhood-scale features (referred to as the built environment) have been identified as influencing diet and physical activity (2). Of particular importance to this framework are features of the food environment (FE), constituting barriers and opportunities to food sources of varying nutritional quality and energy density (3).

The FE is defined as the physical presence of food that can influence a person's diet (4). Contributing to the FE is the proximity to food store locations such as restaurants (fast-food, full service, and bars and pubs) and retail outlets (food markets/grocery stores and liquor stores). Fast-food establishments usually have foods of lower nutritional quality and higher caloric density than home-prepared foods (3). Early studies have reported fast-food restaurants to be more common in neighborhoods with a higher prevalence of obesity (5,6). However, more recent studies have been mixed, with some showing no association (7) and an association in only the least educated (8). Conversely, it is presumed that full-service restaurants have healthier options (9), yet studies that have

Study Importance

What is already known?

- ▶ There are inconsistent findings on the association between features of the food environment and obesity.
- ▶ Previous studies have investigated features of the food environment in isolation.
- ▶ There is also limited knowledge on the role of other features of the food environment such as bars/pubs and liquor stores.

What does this study add?

- ▶ The ratio of fast-food to full-service restaurants and the ratio of bars/pubs to liquor stores are positively associated with obesity and abdominal obesity across a diverse range of communities and cities.
- ▶ The combination of food environment features may matter more than associations of the individual components and future studies should not focus on only one in isolation.

¹Institute of Geography, FA University of Erlangen-Nürnberg, Erlangen, Germany ²Department of Geography, Simon Fraser University, Burnaby, British Columbia, Canada ³School of Public Health and Preventive Medicine, Monash University, Melbourne, Victoria, Australia ⁴Institut de cardiologie et de pneumologie de Québec, Université Laval, Québec City, Québec, Canada ⁵Population Health Research Institute, Hamilton, Ontario, Canada ⁶Faculty of Health Sciences, Simon Fraser University, Burnaby, British Columbia, Canada. Correspondence: Scott A. Lear (slear@providencehealth.bc.ca) ⁷Division of Cardiology, Providence Health Care, Vancouver, British Columbia, Canada.

© 2019 The Authors. *Obesity* published by Wiley Periodicals, Inc. on behalf of The Obesity Society (TOS).

Received: 10 April 2019; Accepted: 10 July 2019; Published online 26 November 2019. doi:10.1002/oby.22614

This is an open access article under the terms of the Creative Commons Attribution-NonCommercial License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited and is not used for commercial purposes.

examined the relationship between these restaurants and obesity have been limited (7,10). Despite this, there has been some evidence that the relative proportion of fast-food to full-service restaurants may be a significant determinant of obesity (9,11).

On the retail aspect, markets and grocery stores (forthwith referred to as markets) are presumed to offer healthy food options (12). The presence of markets has been associated with healthier diets in surrounding neighborhoods (13) and a lower prevalence of obesity (14). However, not all studies have demonstrated an association between markets and obesity (15). Often not represented in studies are establishments focusing on the provision of alcoholic beverages. Bars and pubs are associated with increased volume and frequency of alcohol consumption and calorie-dense foods, both of which are known obesity risk factors (16). The role of liquor stores is unknown yet may also be important because they increase community exposure to alcohol.

The variability in findings from previous studies may be due to small sample sizes and limited geographical scope (i.e., in one city only). In addition, most studies have focused on only one or two features of the FE, which obscures the possible additive effects of having multiple features in one's community. The present study investigates the mutual associations between features of the FE and individual-level obesity, focusing on the effects of fast-food restaurants, full-service restaurants, markets/grocery stores, bars/pubs, and liquor stores within walking distance of a person's place of residence on the risk of obesity using a large number of individuals from 42 communities in three distinct cities.

Methods

This is a substudy of the Prospective Urban Rural Epidemiology (PURE) study. The PURE study is an ongoing investigation of the upstream causes of chronic diseases in 25 countries worldwide (17). Participants for the current investigation were recruited from 42 urban, suburban, and rural communities in Canada (Vancouver, British Columbia; Hamilton, Ontario; and Québec City, Québec), for whom we recorded full participant and local environmental data. Within each city, communities (three-digit postal code-Forward Sortation Area) were selected to reflect a range of household income levels based on Census data (high/medium/low) and geographic settings (urban/rural). All households in each community were invited by mail to participate and followed up by telephone. Residents aged 35 to 70 years at enrollment who provided informed consent were recruited, with a resulting participation rate of 69.5% of all contacted households. Participant questionnaires and measurements were completed from 2006 until 2009. This study was approved by all local research ethics boards, and all participants provided informed consent.

Participant assessment

Participants underwent a thorough assessment consisting of sociodemographics and physical measures. This included date of birth, sex, socioeconomic indicators, and postal code of the participants' primary place of residence. BMI was calculated from height (measured without shoes using a stadiometer; Invicta Plastics, Leicester, UK) and weight (measured without shoes and pockets emptied by electronic scale; AmCells, Vista, California). Waist circumference (WC) was taken as an average of two measures at the narrowest point over the skin using a flexible tape measure attached to a spring balance (OHAUS, Parsippany-Troy Hills, New Jersey)

held to a force of 750 g. Participants were classified as having obesity based on $BMI \geq 30$ (18) and abdominal obesity based on $WC \geq 102$ cm for males or ≥ 88 cm for females (19). Total hours per week of walking was assessed using the International Physical Activity Questionnaire (20). Methods were standardized across the three study sites, and research assistants underwent training prior to any participant assessments.

Environment assessment

In 2008, research assistants walked every street within participant communities to record the presence and GPS location of fast-food restaurants, full-service restaurants, bars/pubs, and food markets categorized using the North American Industry Classification System 2007 (Supporting Information Table S1) (21). Prior to the environmental assessment, research assistants received standardized training on conducting the assessment along with a protocol under the supervision of SAL (22). Weekly meetings and site visits were conducted to ensure proper adherence to the protocol.

Neighborhood socioeconomic data for the year 2006 were retrieved from Statistics Canada for every census dissemination area in participant communities; a dissemination area is the smallest area for which Census data are available. Using a previously validated Canadian classification method (23), we categorized participants as urban or rural residents. Census data were used to determine local population density. A socioeconomic deprivation score was calculated for each participant using the Vancouver Area Neighbourhood Deprivation Index (VANDIX) (24). The VANDIX is a multivariable weighted index that indicates socioeconomic deprivation based on income, educational attainment, employment status, housing tenure, and family structure. Higher VANDIX scores, which are indicative of higher deprivation have been associated with worse health outcomes (25,26).

For each participant, we mapped the area within a 500-m walking distance (following roads, sidewalks, paths, and trails) around the residential postal code area. As postal codes generally cover an area greater than the single residence, the centroid of the postal code was used to define the 500-m area. For rural postal codes where the 500-m buffer was often smaller than the postal code itself, the entire rural postal code was used. The number of each FE feature (fast-food restaurants, full-service restaurants, markets/grocery stores, bars/pubs, and liquor stores) within that walking region was computed. We selected a 500-m distance because 500 m represents a local area within walking distance for most adults. In preliminary sensitivity analyses, 500 m had the strongest effect size compared with distances of 1,000 m and 1,500 m in urban and suburban areas and up to 10 km in rural areas (data not shown). Because 500 m has been used in other studies (27-30), it enables us to make comparisons to other findings in the literature.

We calculated ratios of both fast-food to full-service restaurants and of pubs to liquor stores as variables of interest. For example, a ratio of 0.5 indicates twice as many liquor stores as pubs, and a ratio of 3.0 indicates three times as many pubs as liquor stores. If no numerator was present, a ratio value of 0 was assigned. If no denominator was present, the raw number of numerator features was assigned. The number of markets/grocery stores was retained as a raw count variable.

Statistical analyses

All statistical analyses were conducted using SPSS Statistics version 23 (IBM Corp., Armonk, New York) with a significance threshold

of $P=0.05$. The Bonferroni correction was applied where necessary. Between-city differences were assessed using Pearson χ^2 (Mantel-Haenszel correction applied); differences in mean socioeconomic deprivation scores were assessed using Student t test for independent samples.

We first ran unadjusted univariate binary logistic regression models to assess the association between each independent variable (e.g., fast-food) and control variable (e.g., age, sex, education) with obesity. In addition, we conducted univariate models using the ratios of fast-food to full-service restaurants and of bars/pubs to liquor stores. Given that the ratios had a stronger effect than the individual components, and following methods from previous studies using ratios, our subsequent models included the ratios (9,11). We then ran fully adjusted logistic regression models, which included all independent variables of interest in the same model (ratio of fast-food to full-service restaurants, ratio of bars/pubs to liquor stores, and markets). Separate models were conducted for obesity and abdominal obesity.

Models were adjusted for participant age, sex, educational attainment (modeled as a categorical covariate: none/primary school/high school and college/CÉGEP/university), neighborhood type (urban/rural), socioeconomic deprivation, and total hours per week of walking. The fully adjusted models were then run again with the inclusion of mixed effects (random intercepts) to control for city-level and community-level clustering (i.e., to account for city-level differences in obesity rates). As there was no significant clustering effect at the community level (data not shown), the final models considered only city-level clustering. Only complete records with valid values for all variables in this analysis were included in the modeling procedures. All control variables were highly significant ($P<0.01$) in the fully adjusted models. No significant statistical interactions between independent and control variables were found (data not shown).

Model fit was assessed using Hosmer-Lemeshow χ^2 with a threshold of $P=0.05$, and the predictive performance of BMI and WC models was separately compared using Nagelkerke/Cragg and Uhler's R^2 (31).

TABLE 1 Number of communities, participants, and food and alcohol environment features in the study area by city

	Vancouver	Hamilton	Québec	Total
Communities	25	32	11	42
Participants	2,701	3,411	1,964	8,076
Fast-food restaurants	829	572	137	1,538
Full-service restaurants	834	366	156	1,356
Markets/groceries	112	67	38	217
Liquor stores	64	45	9	118
Bars/pubs	73	100	32	205
Total number of food environment features	1,912	1,150	372	3,434

TABLE 2 Study population characteristics by city

	All study areas ($n=8,076$)	Vancouver ($n=2,701$)	Hamilton ($n=3,411$)	Québec ($n=1,964$)
Participants (%)	8,076	2,701 (33)	3,411 (42)	1,964 (24)
Females (%)	4359 (54)	1,438 (53)	1,858 (54)	1,063 (54)
Median age (IQR)	54 (15)	52 (15)	54 (15)	54 (14)
Education				
Primary/none (%)	310 (4)	45 (2)	175 (5)*	90 (5)
Secondary (%)	2,230 (28)	542 (22)	1,160 (34)*	492 (25)
Postsecondary (%)	5,507 (68)	2,050 (77)	2,075 (61)	1,382 (70)
Residence				
Urban (%)	1,546 (19)	594 (22)	521 (15)	431 (22)
Urban (%)	6,749 (84)	2,384 (88)	2,675 (78)	1,533 (78)
Rural (%)	1,327 (16)	317 (12)	736 (22)	274 (14)
Mean BMI (SE)	27.6 (0.2)	26.5 (0.2)	29.0 (0.2)	26.6 (0.2)
Obesity (%)	2,072 (26)	485 (18)	1,195 (36)*	392 (20)
Mean WC (SE)	90.1 (0.2)	84.8 (0.6)	95.2 (0.6)	88.7 (0.6)
Abdominal obesity (%)	2,652 (33)	506 (19)	1,571 (46)*	575 (29)
Mean deprivation score (SE) ^a	-0.46 (0.01)	-0.75 (0.02)	-0.07 (0.01)	-0.75 (0.02)

^aLow deprivation scores (unitless index) correspond to higher socioeconomic status.

*Highly significant mean differences between cities ($P<0.001$).

Obesity, BMI ≥ 30 ; abdominal obesity, waist circumference ≥ 102 cm for males and ≥ 88 cm for females.

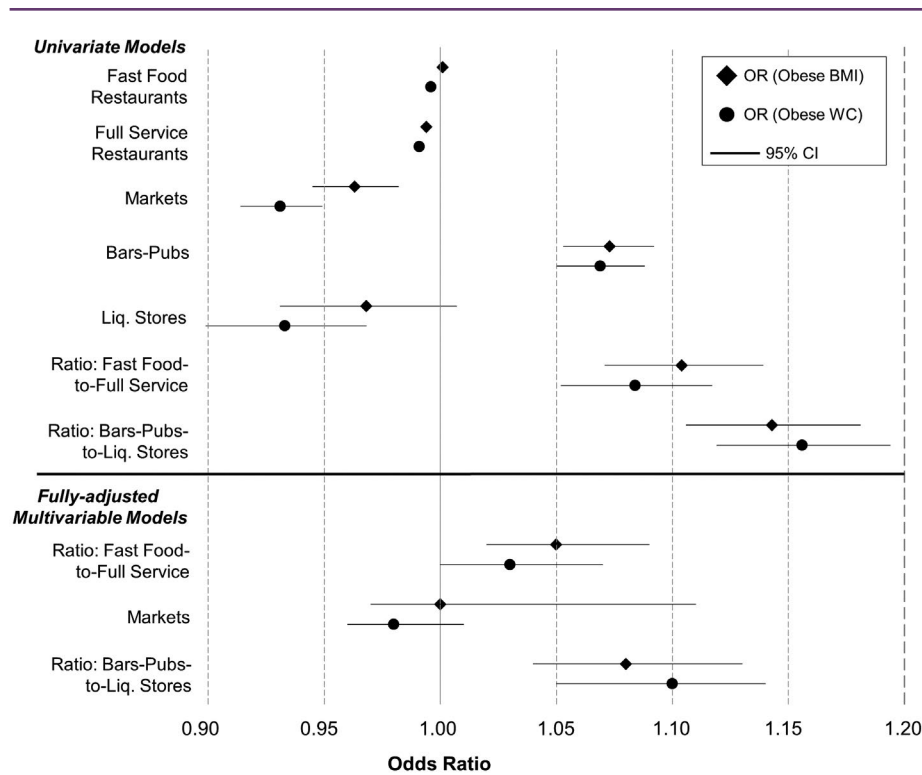


Figure 1 Forest plot of odds ratios of obesity and abdominal obesity associated with features of the built environment, derived from univariate models (top) and fully adjusted models (bottom). Fully adjusted models adjusted for age, sex, education, socioeconomic deprivation score, neighborhood type (urban/rural), and total hours walked per week with the inclusion of mixed effects (random intercepts) to control for city-level clustering. Obesity, BMI ≥ 30 ; abdominal obesity, waist circumference ≥ 102 cm for males and ≥ 88 cm for females.

Results

Across all 42 communities (consisting of 8,076 participants), a total of 3,434 food features were mapped with variation across all three cities (Table 1). Food features were more common in urban areas than suburban and rural areas (Supporting Information Table S2).

Both generalized and abdominal obesity proportions in Hamilton were higher than in Vancouver and Québec ($P < 0.001$; Table 2). Participants in Hamilton had lower educational attainment ($P < 0.001$) and a higher average socioeconomic deprivation score ($P < 0.001$) than both Vancouver and Québec. Alternate Healthy Eating Index scores were higher in Vancouver than in Hamilton and Québec ($P < 0.001$).

In univariate models, the presence of full-service restaurants, markets, and liquor stores was each negatively associated with obesity, while the presence of bars/pubs was positively associated with obesity (Figure 1 and Table 3). There was no association between fast-food outlets and obesity. The presence of fast-food restaurants, full-service restaurants, markets, and liquor stores was each negatively associated with abdominal obesity, while the presence of bars/pubs was positively associated with abdominal obesity. The ratios of fast-food to full service and bars/pubs to liquor stores were both positively associated with obesity and abdominal obesity. Adjusted for age, sex, education, socioeconomic deprivation score, neighborhood type (urban/rural) and total hours walked per week, the ratios of fast-food to full-service restaurants and bars/pubs to liquor stores were positively associated with obesity (1.09

TABLE 3 Univariate association of food environment features with obesity and abdominal obesity presented as odds ratio and 95% CI

	Obesity	Abdominal obesity
Fast-food restaurant	1.00 (1.00-1.00)	1.00 (1.00-1.00)*
Full-service restaurant	1.00 (0.99-1.00)***	0.99 (0.99-0.99)***
Market/grocery	0.96 (0.95-0.98)***	0.93 (0.91-0.95)***
Bar/pub	1.07 (1.05-1.09)***	1.07 (1.05-1.08)***
Liquor store	0.97 (0.93-1.01)	0.93 (0.90-0.97)***
Ratio: fast-food to full service	1.10 (1.07-1.14)***	1.08 (1.05-1.12)***
Ratio: bar to liquor store	1.14 (1.11-1.12)***	1.16 (1.12-1.19)***

* $P < 0.05$.

*** $P < 0.001$.

Obesity, BMI ≥ 30 ; abdominal obesity, waist circumference ≥ 102 cm for males and ≥ 88 cm for females.

[1.06-1.14] and 1.10 [1.07-1.15], respectively), while the presence of markets was negatively associated with obesity BMI (0.97 [0.95-0.99]). Similarly, the ratios of fast-food to full-service restaurants (1.07 [1.04-1.11]) and bars/pubs to liquor stores (1.15 [1.10-1.20]) were positively associated with abdominal obesity, while the presence of

markets was negatively associated with abdominal obesity (0.93 [0.91–0.95]). Accounting for city-level clustering, the relationship between fast-food to full-service restaurants with abdominal obesity was not significant (Figure 1; Supporting Information Table S3). In addition, there was no association between markets and either obesity or abdominal obesity. All other associations remained significant.

Discussion

In this study of more than 8,000 people from 42 communities across three cities, we found living in communities with a greater ratio of fast-food restaurants to full-service restaurants as well as a greater ratio of bars/pubs to liquor stores was associated with a greater risk for obesity. At the same time, a greater number of markets was associated with a lower risk for obesity, although these associations were not significant when taking into account city-level clustering. These findings were independent of key sociodemographic and lifestyle factors.

The majority of studies have focused on the role of fast-food restaurants, with some studies demonstrating positive associations between the FE and obesity (32), while others reported either no significant association (7,33) or a lower prevalence of obesity (34). However, these studies have looked at fast-food restaurants in isolation. In our study, we found the ratio of fast-food to full-service restaurants to be positively associated with obesity, indicating that the presence of full-service restaurants may mitigate the role of fast-food restaurants. This is consistent with the limited number of studies to have considered this ratio (9,11), both of which found the ratio of fast-food to full-service restaurants to have a stronger association with obesity than each type alone. The larger effect of the ratios and our mutual adjustment of the FE features suggests it is important to take into account context of the entire FE instead of just one single feature. The potential protective effect observed for full-service restaurants may be due to the availability of relatively healthier food options in full-service restaurants and higher socioeconomic status among full-service restaurant clientele compared with fast-food customers. Previous studies have identified differential effects on obesity risk, in which diners at full-service restaurants consumed less calories compared with fast-food (35).

A novel finding of our study is the association of bars/pubs to liquor stores with increased risk of obesity. Bars and pubs predominantly serve high-calorie food and drinks, and both the geographical proximity to bars and pubs and the consumption of alcohol have been associated with obesity risk in previous studies (36,37). Few studies have investigated the role of liquor stores. However, Zenk et al. (38) reported BMI to be nonsignificantly lower as the number of liquor stores in their study area increased. In Canada, the allocation of liquor stores is highly regulated and tends to be in areas with a higher mixture of land use, which is inherently more walkable and associated with a lower prevalence of obesity (39,40). Therefore, the presence of liquor stores in our study may actually serve as a marker for areas of high walkability. However, we did adjust for total hours walked per week, which is a downstream outcome of neighborhoods with high walkability (41).

While our results indicate associations between the local FE and the risk for obesity, the direction of causation is unclear. Restaurants, markets, liquor stores, and bars/pubs are not randomly distributed; rather, their locations are carefully selected based on many variables, including the demographic composition of the local populace. Fast-food restaurants, for example, are more likely to be found in neighborhoods of low socioeconomic status (42). In addition, neighborhoods with low

socioeconomic status have been found to have higher rates of obesity (32), which may be linked to the greater prevalence of outlets with high-calorie and cheap fast-food. However, in our models, we adjusted for a robust measure of deprivation and still these associations were apparent. Disentangling this relationship will require a longitudinal study with serial data both for the FE and participants over an extended time period.

The small effect sizes observed may be due to several factors. First, unlike many studies, we mutually adjusted for a range of FE features, which had opposing effects. However, this allowed us to robustly assess the independent associations of the FE. Second, while these food features were in close proximity to participants' residences, we do not know whether participants actually shopped at these places and how often. It is possible that participants purchased food and frequented restaurants outside of the geographical area studied. In a survey of costumers shopping at five different supermarkets, we found that more than half of the customers traveled more than 1,000 m to get to the store even though smaller markets were in closer proximity to their residence (43). Lastly, even if participants frequented these food features, we do not know what exactly was purchased. While fast-food restaurants are generally categorized as unhealthy, in recent years, several fast-food chains have made efforts to offer more nutrient-rich and less calorie-dense meal options. Likewise, markets, while offering fresh foods, also offer foods that may be considered less healthy choices. Despite these possibilities, the presence of twice as many fast-food to full-service restaurants was associated with a 5% to 8% increased risk for obesity.

This study had some limitations. For our study, we used postal code for place of residence, as we were unable to obtain full residential addresses in all locations. In urban areas, a single postal code comprises a small area (half a city block) unlikely to make a difference in the location of the 500-m buffer. However, we acknowledge that in rural areas, postal codes represent a much larger area and thus limit precision. Our selection of a 500-m radius was chosen, as it approximates the actual distance a person may travel by foot to access their FE. As acknowledged above, people may travel much further; however, a 500-m radius had a greater effect than larger distances of 1,000 m and 1,500 m. In addition, very few of our food features were present within this distance in rural areas, and we conducted additional analyses in these areas with distances up to 10 km along rural roads with no change in effect (data not shown). There was also no apparent interaction between any of our FE variables with place of residence (urban, rural). The inclusion of the rural communities in these analyses acted as a "quasi-control" group given they had little, or none, of the food features. Further exploratory geographical analysis may reveal more nuanced threshold distances, as these may vary by age, socioeconomic status, automobile ownership, and local walkability. As our investigation was limited to an external audit of FE features, all FE features within the same category (for example, markets) were viewed equally. It is possible that within the same category, the types of food available (healthy and unhealthy) may vary from outlet to outlet, which could affect what foods were purchased and thus part of the participants' diets. This variation within category and the effects on diet could not be accounted for in our analysis. Lastly, the cross-sectional design does not allow for causal inferences, and additional unmeasured variables may be accounting for the observed associations.

Conclusion

We found that different aspects of the FE have a different relationship with obesity. In particular, we found the ratios of fast-food restaurants to full-service restaurants and of bars/pubs to liquor stores to be

positively associated with obesity. The role of the ratios and our mutual adjustment of all the FE features indicate that the entire FE needs to be taken into context rather than investigating one type in isolation. Strengths of our study include the large sample size across a diverse range of communities from three geographically distinct cities as well as direct participant and environmental feature assessments. Given our findings, business licensing and urban planning policies may provide opportunities to enact policies that foster a healthier FE. **O**

Acknowledgments

We wish to thank all of the study participants for their interest and time participating. We acknowledge the project team members who collected participant data, the data management team at the Population Health Research Institute, the built environment data collection teams, PURE study collaborators for their significant feedback throughout the study, editors, editorial staff, and reviewers for their significant contributions to the improvement of the manuscript, and the PURE study participants. BBW wishes to acknowledge the German Federal Ministry of Education and Research (BMBF) for their support. SY holds the Heart and Stroke Foundation of Ontario/Marion W. Burke Chair in Cardiovascular Disease. SAL holds the Pfizer/Heart and Stroke Foundation Chair in Cardiovascular Prevention Research at St. Paul's Hospital, Vancouver, Canada.

Funding agencies: The Prospective Urban Rural Epidemiology (PURE) Study is an investigator-initiated study funded by the Population Health Research Institute, the Canadian Institutes of Health Research (CIHR), Heart and Stroke Foundation of Ontario; support from CIHR's Strategy for Patient Oriented Research (SPOR) through the Ontario SPOR Support Unit and the Ontario Ministry of Health and Long-Term Care; and through unrestricted grants from several pharmaceutical companies (with major contributions from AstraZeneca [Canada], Sanofi-Aventis [France and Canada], Boehringer Ingelheim [Germany and Canada], Servier, and GSK) and additional contributions from Novartis and King Pharma.

Disclosure: The authors declared no conflict of interest.

Supporting information: Additional Supporting Information may be found in the online version of this article.

References

- World Health Organization. Obesity and overweight. <https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight>. Published February 16, 2018. Accessed April 6, 2019.
- MacMillan F, George ES, Feng X, et al. Do natural experiments of changes in neighborhood built environment impact physical activity and diet? A systematic review. *Int J Environ Res Public Health* 2018;15:217. doi:10.3390/ijerph15020217
- Tiwari A, Aggarwal A, Tang W, Drewnowski A. Cooking at home: a strategy to comply with U.S. dietary guidelines at no extra cost. *Am J Prev Med* 2017;52:616-624.
- Centers for Disease Control and Prevention. General food environment resources. <https://www.cdc.gov/healthypplaces/healthtopics/healthyfood/general.htm>. Updated March 6, 2014. Accessed May 21, 2019.
- Inagami S, Cohen DA, Brown AF, Asch SM. Body mass index, neighborhood fast food and restaurant concentration, and car ownership. *J Urban Health* 2009;86:683-695.
- Li F, Harmer P, Cardinal BJ, Bosworth M, Johnson-Shelton D. Obesity and the built environment: does the density of neighborhood fast-food outlets matter? *Am J Health Promot* 2009;23:203-209.
- Mazidi M, Speakman JR. Higher densities of fast-food and full-service restaurants are not associated with obesity prevalence. *Am J Clin Nutr* 2017;106:603-613.
- Burgoine T, Forouhi NG, Griffin SJ, Brage S, Wareham NJ, Monsivais P. Does neighborhood fast-food outlet exposure amplify inequalities in diet and obesity? A cross-sectional study. *Am J Clin Nutr* 2016;103:1540-1547.
- Mehta NK, Chang VW. Weight status and restaurant availability a multilevel analysis. *Am J Prev Med* 2008;34:127-133.
- Cobb LK, Appel LJ, Franco M, Jones-Smith JC, Nur A, Anderson CA. The relationship of the local food environment with obesity: a systematic review of methods, study quality, and results. *Obesity (Silver Spring)* 2015;23:1331-1344.
- Polsky JY, Moineddin R, Dunn JR, Glazier RH, Booth GL. Absolute and relative densities of fast-food versus other restaurants in relation to weight status: does restaurant mix matter? *Prev Med* 2016;82:28-34.
- Farley TA, Rice J, Bodor JN, Cohen DA, Bluthenthal RN, Rose D. Measuring the food environment: shelf space of fruits, vegetables, and snack foods in stores. *J Urban Health* 2009;86:672-682.

- Mackenbach JD, Burgoine T, Lakerveld J, et al. Accessibility and affordability of supermarkets: associations with the DASH diet. *Am J Prev Med* 2017;53:55-62.
- Drewnowski A, Aggarwal A, Hurvitz PM, Monsivais P, Moudon AV. Obesity and supermarket access: proximity or price? *Am J Public Health* 2012;102:e74-e80.
- Dubowitz T, Ghosh-Dastidar M, Cohen DA, et al. Diet and perceptions change with supermarket introduction in a food desert, but not because of supermarket use. *Health Aff* 2015;34:1858-1868.
- Traversy G, Chaput JP. Alcohol consumption and obesity: an update. *Curr Obes Rep* 2015;4:122-130.
- Teo K, Chow CK, Vaz M, Rangarajan S, Yusuf S. The Prospective Urban Rural Epidemiology (PURE) study: examining the impact of societal influences on chronic noncommunicable diseases in low-, middle-, and high-income countries. *Am Heart J* 2009;158:1-7.e1.
- World Health Organization. Obesity. <https://www.who.int/topics/obesity/en/>. Accessed April 4, 2019.
- Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults. Executive Summary of The Third Report of The National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III). *JAMA* 2001;285:2486-2497.
- Craig CL, Marshall AL, Sjoström M, et al. International Physical Activity Questionnaire: 12-country reliability and validity. *Med Sci Sports Exerc* 2003;35:1381-1395.
- Statistics Canada. North American Industry Classification System (NAICS) 2007. <http://www23.statcan.gc.ca/imdb/p3VD.pl?Function=getVD&TV=44547>. Accessed April 4, 2019.
- Gasevic D, Vukmirovich I, Yusuf S, et al. A direct assessment of "obesogenic" built environments: challenges and recommendations. *J Environ Public Health* 2011;2011:161574. doi:10.1155/2011/161574
- Gordon DLA, Janzen M. Suburban nation? Estimating the size of Canada's suburban population. *J Archit Plann Res* 2013;30:197-220.
- Bell N, Schuurman N, Oliver L, Hayes MV. Towards the construction of place-specific measures of deprivation: a case study from the Vancouver metropolitan area. *Can Geogr* 2007;51:444-461.
- Auluck A, Walker BB, Hislop G, Lear SA, Schuurman N, Rosin M. Population-based incidence trends of oropharyngeal and oral cavity cancers by sex among the poorest and underprivileged populations. *BMC Cancer* 2014;14:316. doi:10.1186/1471-2407-14-316
- Walker BB, Schuurman N, Hameed SM. A GIS-based spatiotemporal analysis of violent trauma hotspots in Vancouver, Canada: identification, contextualisation and intervention. *BMJ Open* 2014;4:e003642. doi:10.1136/bmjopen-2013-003642
- Berke EM, Koepsell TD, Moudon AV, Hoskins RE, Larson EB. Association of the built environment with physical activity and obesity in older persons. *Am J Public Health* 2007;97:486-492.
- Coffee NT, Howard N, Paquet C, Hugo G, Daniel M. Is walkability associated with a lower cardiometabolic risk? *Health Place* 2013;21:163-169.
- de Sa E, Ardem CI. Neighbourhood walkability, leisure-time and transport-related physical activity in a mixed urban-rural area. *PeerJ* 2014;2:e440. doi:10.7717/peerj.440
- Harris JK, Lecy J, Hipp JA, Brownson RC, Parra DC. Mapping the development of research on physical activity and the built environment. *Prev Med* 2013;57:533-540.
- Smith TJ, McKenna CM. A comparison of logistic regression pseudo R2 indices. *Mult Linear Regres Viewpoints* 2013;39:17-26.
- Burgoine T, Sarkar C, Webster CJ, Monsivais P. Examining the interaction of fast-food outlet exposure and income on diet and obesity: evidence from 51,361 UK Biobank participants. *Int J Behav Nutr Phys Act* 2018;15:71. doi:10.1186/s12966-018-0699-8
- Simmons D, McKenzie A, Eaton S, et al. Choice and availability of takeaway and restaurant food is not related to the prevalence of adult obesity in rural communities in Australia. *Int J Obes (Lond)* 2005;29:703-710.
- Black JL, Macinko J, Dixon LB, Fryer GE Jr. Neighborhoods and obesity in New York City. *Health Place* 2010;16:489-499.
- An R. Fast-food and full-service restaurant consumption and daily energy and nutrient intakes in US adults. *Eur J Clin Nutr* 2016;70:97-103.
- Campbell CA, Hahn RA, Elder R, et al. The effectiveness of limiting alcohol outlet density as a means of reducing excessive alcohol consumption and alcohol-related harms. *Am J Prev Med* 2009;37:556-569.
- Weitzman ER, Folkman A, Folkman MP, Wechsler H. The relationship of alcohol outlet density to heavy and frequent drinking and drinking-related problems among college students at eight universities. *Health Place* 2003;9:1-6.
- Zenk SN, Mentz G, Schulz AJ, Johnson-Lawrence V, Gaines CR. Longitudinal associations between observed and perceived neighborhood food availability and body mass index in a multiethnic urban sample. *Health Educ Behav* 2017;44:41-51.
- Creatore MI, Glazier RH, Moineddin R, et al. Association of neighborhood walkability with change in overweight, obesity, and diabetes. *JAMA* 2016;315:2211-2220.
- Hirsch JA, Diez Roux AV, Moore KA, Evenson KR, Rodriguez DA. Change in walking and body mass index following residential relocation: the multi-ethnic study of atherosclerosis. *Am J Public Health* 2014;104:e49-e56.
- Wasfi R, Steinmetz-Wood M, Kestens Y. Place matters: a longitudinal analysis measuring the association between neighbourhood walkability and walking by age group and population center size in Canada. *PLoS One* 2017;12:e0189472. doi:10.1371/journal.pone.0189472
- Fleischhacker SE, Evenson KR, Rodriguez DA, Ammerman AS. A systematic review of fast food access studies. *Obes Rev* 2011;12:e460-e471.
- Lear SA, Gasevic D, Schuurman N. Association of supermarket characteristics with the body mass index of their shoppers. *Nutr J* 2013;12:117. doi:10.1186/1475-2891-12-117