Relationships Between Neighborhoods, Physical Activity, and Obesity: A Multilevel Analysis of a Large Canadian City

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In Canada, there is limited research examining the associations between objectively measured neighborhood environments and physical activity (PA) and obesity. The purpose of this study was to determine the relationships between variables from built and social environments and PA and overweight/obesity across 86 Ottawa, Canada neighborhoods. Individual-level data including self-reported leisure-time PA (LTPA), height, and weight were examined in a sample of 4,727 adults from four combined cycles (years 2001/03/05/07) of the Canadian Community Health Survey (CCHS). Data on neighborhood characteristics were obtained from the Ottawa Neighbourhood Study (ONS); a large study of neighborhoods and health in Ottawa, Canada. Binomial multivariate multilevel models were used to examine the relationships between environmental and individual variables with LTPA and overweight/obesity using survey weights in men and women separately. Within the sample, ~75% of the adults were inactive (<3.0 kcal/kg/day) while half were overweight/obese. Results of the multilevel models suggested that for females greater park area was associated with increased odds of LTPA and overweight/obesity. Greater neighborhood density of convenience stores and fast food outlets were associated with increased odds of females being overweight/obese. Higher crime rates were associated with greater odds of LTPA in males, and lower odds of male and female overweight/obesity. Season was significantly associated with PA in men and women; the odds of LTPA in winter months were half that of summer months. Findings revealed that park area, crime rates, and neighborhood food outlets may have different roles with LTPA and overweight/obesity in men and women and future prospective studies are needed.

INTRODUCTION

Physical activity (PA) is known to be protective against several chronic diseases and premature mortality (1). In spite of its protective abilities, average PA levels continue to fall short of recommendations. Self-reported data from the 2009 Canadian Community Health Survey (CCHS) showed that 51% of women and 44% of men were inactive (<1.5 kcal/kg/day) in their leisure time (2). Furthermore, 59% of Canadian men and 44% of women were at increased health risk from being overweight or obese (3).

Canadian rates of physical inactivity and obesity have continued to rise dramatically over the past several decades and individual factors are unable to explain these large increases (4,5). It has been suggested that the social and built environments are potential contributors to the current trends (4). To date, most research has focused on perceived access to environments rather than objective measures of the environment (6). Objectively measured studies have mixed results, but have found positive associations between PA and availability of walking/bike paths, recreation/fitness facilities, and parks and green spaces (6–8). While results are mixed, studies suggest that overweight and obesity are generally related to limited access to environmental supports (9).

Social environmental factors can mediate the effects of the built environment and influence the adoption of healthy lifestyles. Studies using area-level socioeconomic status (SES) have reported associations between lower area SES and higher rates of inactivity (10,11) and obesity (12,13). Little is known as to the relationship between other neighborhood social factors like crime, civic participation and social cohesion, and individual PA

and body composition. In addition, most research investigating environmental influences on PA or obesity for adults has been conducted in the United States, Europe, and Australia with little on Canadian populations. Furthermore, sex-based analyses are often lacking (14,15). To address these research gaps, this study assesses built and social environmental factors and their relationships with self-reported leisure-time PA (LTPA) and overweight/obesity using sex-specific multilevel models while controlling for individual-level variables in a large sample of Canadian adults.

METHODS AND PROCEDURES
A multilevel framework was used to examine the association between individual- and neighborhood-level characteristics with LTPA and overweight/obesity in 86 neighborhoods in Ottawa, Canada. The study received ethical approval from the University of Ottawa's Health Science Research Ethics Board (#H10-08-11) and the City of Ottawa's Public Health Research Ethics Board (#128-09).

Data sources
CCHS. The CCHS targets Canadians ≥12 years that live in private dwellings in Canada. Four cycles of the CCHS (years 2000/01, 2003, 2005, 2007) were combined to create a dataset of respondents from Ottawa, Canada. The CCHS did not sample uniformly across Ottawa, but survey weights were applied. As the CCHS is a national probability sample with a typical overall sample response rate ranging from 70–80%, standard survey weights were provided by Statistics Canada's methodologists in order to adjust for regional nonresponse and unequal size of sampling units. Weights were derived based on the sampling frames used (16). These weights were further rescaled to the analytical sample size and incorporated in all analyses to achieve regional-level representativeness.

Ottawa Neighbourhood Study (ONS). Environment characteristics were collected by the ONS (http://www.neighbourhoodstudy.ca), a large study of neighborhoods and health outcomes in Ottawa. Neighborhoods were defined based on natural barriers, similarity in socioeconomics and demographics, Ottawa multiple listing services maps, and participatory mapping feedback from the steering group (17). Most neighborhoods contained ≥4,000 people. Objectively measured environmental data were collected from 2006 to 2008 using the following data and methods: (i) 2006 Canadian census household data; (ii) geographical information system data from DMTI Spatial, the City of Ottawa, Ottawa, Ontario, Canada and the National Capital Commission (NCC); (iii) telephone contact with businesses; (iv) web-based research (e.g., Canada 411, websites, Google maps); (v) team knowledge of local resources; and (vi) field research and validation (e.g., car, walking, bicycle). A further in-depth description of methods related to the ONS and its variables is available elsewhere (17). **Figure 1** provides a visual representation of the ONS neighborhood delineations in the City of Ottawa.

Neighborhood environments
Recreation environment. Recreational facilities were defined using the North American Industry Classification System (NAICS) Code 71 (18) and were only included if they provided activity for free or minimal cost. Neighborhood recreation measures included total bike and walking path length (km), counts per 1,000 people of indoor recreation facilities, winter outdoor facilities, summer outdoor facilities, park area (km^2), and green space area (km^2). Green space managed by the City or the NCC was included in the area of parkland variable, while nonmanaged areas were considered green space. Facility density (per 1,000 people) was used to capture demand on the facilities. Recreation data were added to the models as continuous variables.

Social environment. The socioeconomic environment was assessed using a neighborhood SES index that was developed using principal components analysis. It included percent of households below the low-income cut-off (19), average household income, percent of unemployed residents, percent of residents with less than a high school education, and percent of single-parent families. The SES index was *t*-scored to represent a mean of 50 with a s.d. of 10 for comparability across neighborhoods and was reverse coded with higher scores indicating lower SES. Social cohesion/participation was evaluated using councillor voting rates from the 2006 Ottawa municipal election and aggregated reporting of a strong sense of community belonging from the CCHS (cycles 1–4). Missing sense of belonging values were imputed using the mean values from the appropriate neighborhood SES quintiles. Neighborhood safety was evaluated using City of Ottawa Police 2006 crime incidence rates for each neighborhood aggregated to crimes against property and crimes against person following the Uniform Crime Reporting Survey version 2.2 (20). Social environment data were analysed as continuous variables.

Food environment. The food environment was included in the models as a neighborhood-level covariate to account for availability of food choices and as a proxy for density of neighborhood resources. Within the ONS, objective measures of the food environment were classified into five types of food retail outlets according to the NAICS (18). The food outlets were examined using density (number per 1,000 individuals) and included grocery stores, convenience stores, specialty food stores, fast food outlets, and full service restaurants. Food environment data were added to the models as continuous variables.

Individual-level data
LTPA. The CCHS captured LTPA using an interview-administered questionnaire. Respondents were asked to self-report participation, frequency and duration in LTPA (including walking for exercise, gardening/yard work, swimming, bicycling, popular/social dance, home exercises, ice hockey, ice skating, in-line skating/rollerblading, jogging/running, golfing, exercise class/aerobics, downhill skiing, bowling, baseball/softball, tennis, weight-training, fishing, volleyball, basketball, and up to three other categories) over the previous 3 months. Each activity was assigned a metabolic equivalent value for use in the derived PA index. The PA index is calculated as the sum of the average daily energy expenditures (kcal/kg/day) of all leisure time activities. Respondents were classified as follows: physically active (≥3.0 kcal/kg/day); moderately active (1.5–2.9 kcal/kg/day); and inactive (<1.5 kcal/kg/day). LTPA was analysed as a binomial outcome with inactive and moderately active respondents (inactive; <3.0 kcal/kg/day) compared to those who reported being physically active. This follows recommendations for distinguishing those at the population level who meet health recommendations (21).

Overweight and obesity. Height and weight were self-reported in the CCHS and used to calculate BMI as weight (kg) divided by height (m^2). BMI guidelines for adults (22) were used to group individuals into the following categories: underweight (<18.5 kg/m^2), normal weight (18.5–24.9 kg/m^2), overweight (25.0–29.9 kg/m^2), and obese (≤30 kg/m^2). BMI was analysed as a binomial outcome with under-/normal weight compared to overweight/obese.

Individual-level covariates
The models controlled for age category (18–24, 25–44, 45–64, and ≥65 years); education level (<high school, high school graduate, some post-secondary, post-secondary degree); household income (≤$29,999, ≥$30,000), smoking status (daily, occasional, former, never); and season of data collection (summer, fall, winter, spring). In addition, LTPA or BMI category was controlled for when not used as the outcome of interest.

Statistical analysis
All analyses were conducted in the year 2010. All descriptive and comparative analyses were conducted using SAS version 9.1 (SAS Institute, Cary, NC) incorporating appropriate survey weights and bootstraps provided by Statistics Canada. Means and s.d. of all exposure and
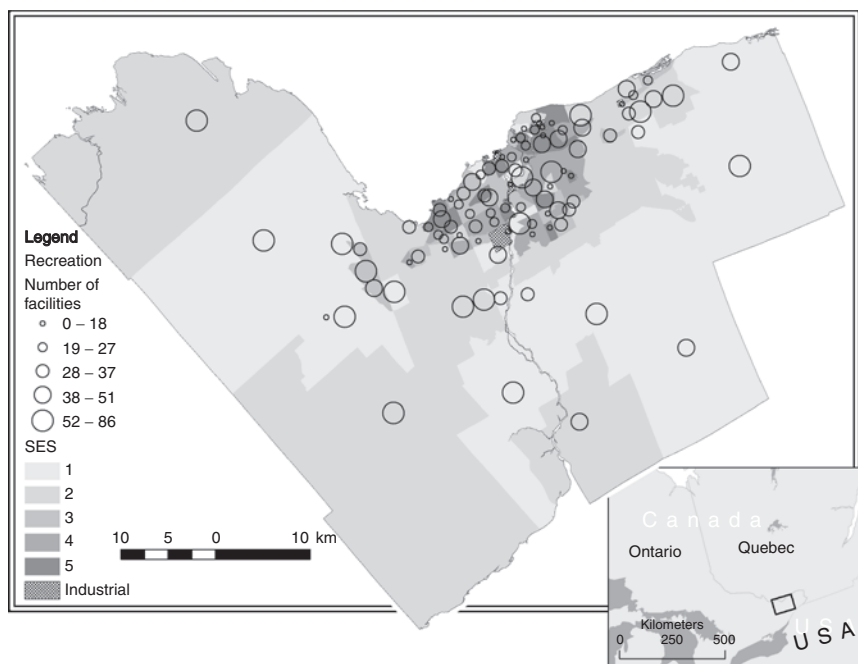
Figure 1 Ottawa Neighbourhood Study map including neighborhood delineations. SES, socioeconomic status.

outcome variables were calculated. *t*-tests and χ^2 tests were used to identify significant differences between males and females.

Sex-specific binary logistic regression models were used to assess the relationships of environmental and individual variables with the outcomes of LTPA and overweight/obesity. All of the neighborhood-level independent variables except for the already *t*-scored SES index were standardized ((independent variables − mean)/s.d.) to render them comparable. The models were built to distinguish between two levels: neighborhood and individual. A five-step modeling strategy was employed. The first step comprised identifying the null model or a description of the variance in the outcomes explained at the two levels as captured by the intraclass correlation coefficient. The second step involved the inclusion of all the built environment variables (recreation and food). Social environment variables were added in the third, season in the fourth and finally, all of the individual-level variables were added in the fifth step to produce final models. All regressions were estimated by the residual iterated generalized least squares and started with 1st order marginal quasi-likelihood then proceeded to 2nd order penalized quasi-likelihood methods using MLwiN (Version.2.21; Centre for Multilevel Modelling, University of Bristol, UK). Survey weights (standardized in MLwiN) generated from the CCHS were used at the individual level. Design weights were not available for the neighborhood level; therefore, level 2 weights were set to equal one. Standardized odds ratios (ORs) and their 95% confidence intervals (CIs) were estimated from regression coefficients and standard errors.

RESULTS
Sample characteristics
Upon combining the four cycles of CCHS data, a total of 6,564 respondents were identified from 89 neighborhoods. After excluding respondents who were <18 years (*n* = 628), pregnant (*n* = 58), had missing information on LTPA (*n* = 164), BMI (*n* = 381), education (*n* = 62), household income (*n* = 388) or smoking (*n* = 2), living outside the 89 predefined neighborhoods (*n* = 19), or residing in neighborhoods without voting rates (*n* = 137), the final unweighted sample used for analyses was 4,727

from 86 neighborhoods with a minimum of five respondents per neighborhood.

A sensitivity analysis revealed that those missing household income were more likely to be smokers, have a lower education, be classified in the youngest or oldest age categories, and less likely to be active and overweight/obese. As a result, the income data is not missing at random and study results should be interpreted in light of these potential biases.

Table 1 provides descriptive characteristics for the weighted sample. Half (51%) of the sample was female. Men were more likely to be classified as overweight/obese, highly active, report higher income, more post-secondary education, and be former smokers. Women were more likely to be seniors (65+ years), under-/normal weight, inactive, never smokers, and report lower income and education.

Neighborhood environments
Table 2 provides descriptive characteristics of the 86 neighborhoods. **Figure 1** displays the neighborhood SES index values and the density of recreation resources per neighborhood.

Multilevel analysis
Table 3 provides final multilevel multivariate model results.

PA models. Null models (not shown) revealed significant variability in LTPA levels across neighborhoods. The intraclass correlation coefficient of the null model was 10% for females and 15% for males indicating that a significant but limited level of the variation in LTPA could be explained by neighborhood-level characteristics. The intraclass correlation coefficients decreased with each block of variables indicating that a proportion of the

Table 1 Weighted sample characteristics

	Total (n = 494,800)	Men (n = 243,800)	Women (n = 251,000)
Age category, n (%)			
18–24 years	60,400 (12%)	30,500 (12%)	29,900 (12%)
25–44 years	215,500 (44%)	108,400 (44%)	107,100 (42%)
45–64 years	170,400 (34%)	83,700 (32%)	86,700 (35%)
65+ years	48,500 (10%)	21,100 (12%)*	27,400 (11%)*
BMI category, n (%)			
Underweight/ normal weight	257,100 (52%)	103,700 (43%)*	153,300 (61%)*
Overweight/ obese	237,800 (48%)	140,000 (57%)*	97,700 (39%)*
Level of physical activity, n (%)			
Inactive	363,000 (73%)	166,700 (68%)*	196,300 (78%)*
Active	131,900 (27%)	77,100 (32%)*	54,800 (22%)*
Education, n (%)			
Did not graduate from high school	43,800 (9%)	19,400 (9%)**	24,400 (10%)**
Graduated from high school	72,400 (14%)	32,500 (14%)**	39,900 (16%)**
Some post-high school education	47,500 (10%)	25,800 (10%)	21,700 (9%)
College/ university diploma/ degree	331,100 (67%)	166,100 (66%)	165,000 (64%)
Household income, n (%)			
≤$29,999	61,100 (12%)	24,900 (10%)*	36,200 (14%)*
≥$30,000	433,700 (88%)	218,800 (90%)*	214,900 (86%)*
Smoking status, n (%)			
Daily	74,400 (15%)	39,400 (18%)	35,000 (14%)
Occasional	26,800 (5%)	14,900 (6%)	11,900 (5%)
Former	226,000 (46%)	119,100 (47%)*	106,900 (42%)*
Never	167,600 (34%)	70,300 (30%)*	97,200 (39%)*
Season of data collection, n (%)			
Summer	118,900 (24%)	59,400 (27%)	59,500 (27%)
Fall	132,000 (27%)	68,000 (29%)	64,000 (27%)
Winter	119,400 (24%)	56,200 (17%)	63,200 (18%)
Spring	124,500 (25%)	60,200 (27%)	64,300 (28%)

Data are presented as frequencies and proportions unless otherwise stated. Proportions are significantly different between males and females at *$P < 0.001$, **$P < 0.05$.

Table 2 Neighborhood characteristics (N = 86)

	Mean ± s.d.	Range (min–max)
Recreation environment		
Indoor recreation facilities per 1,000 people	0.16 ± 0.16	0–0.64
Outdoor—winter per 1,000 people	0.29 ± 0.17	0–1.10
Outdoor—summer per 1,000 people	3.91 ± 2.02	0–13.98
Park area (km²) per 1,000 people	39.47 ± 44.76	2.09–329.42
Bike/walking path length (km)	11.44 ± 16.17	0–140.83
Green space (km²) per 1,000 people	0.62 ± 3.46	0.01–32.09
Food environment		
Grocery stores per 1,000 people	0.12 ± 0.15	0–0.87
Fast food outlets per 1,000 people	1.23 ± 2.19	0–17.94
Convenience stores per 1,000 people	0.53 ± 0.40	0–1.99
Restaurants per 1,000 people	0.96 ± 1.78	0–14.76
Specialty food stores per 1,000 people	0.38 ± 0.60	0–4.03
Social environment		
Socioeconomic index (t-score)	41.75, 48.69, 57.73[a]	36.00–77.69
Strong sense of belonging (%)	56.08, 60.87, 63.70[a]	36.70–77.90
Councillor voting rates (%)	46.55 ± 8.31	32.06–100.00
Founded offences of property and violent crime (counts in 2006)	451.15 ± 439.34	72.00–3,019.00

[a]Q1, median, Q3.

every 1 s.d. increase in the crime rate resulted in a 14% increase in the odds of being physically active. For men, the winter and spring months, and for women winter months, were associated with significantly lower levels of LTPA compared to summer months. In males, increasing age was associated with lower LTPA levels and having higher income (≥$30,000) resulted in a 65% greater likelihood of LTPA. In females, increasing age and being classified as overweight/obese were associated with lower odds of LTPA.

Overweight/obesity models. Null models (not shown) identified a significant variance in the likelihood of being overweight or obese across neighborhoods. The intraclass correlation coefficient of the null model was higher for males (27%) than females (20%).

None of the built environment variables were associated with male overweight/obesity. In females, the odds of being overweight/obese increased by 15% for every 1 s.d. increase in

variation of LTPA between neighborhoods was explained by the variables in the model.

There were no significant associations between LTPA and any of the built environment variables for men. In females, one standard deviation increase in the availability of park area (km²) resulted in 17% higher odds of being active. For males,

the amount of park area (km^2). In addition, increased density of convenience stores (OR = 1.17, 95% CI: 1.03–1.34) and fast food outlets (OR = 1.38, 95% CI: 1.11–1.72) were associated with greater odds of overweight/obesity. No significant associations between the food environment and male overweight/obesity were observed. For both males and females, every s.d. increase in the crime rate resulted in an 8–9% decrease in the odds of overweight/obesity. Final models showed that increasing age for both men and women was associated with greater odds of being overweight or obese. In addition, for women, higher education decreased the odds of being physically active and increased the odds of being overweight or obese. In men, higher income (≥$30,000) and being a former smoker increased their odds while being a college/university graduate decreased their odds of being overweight or obese.

DISCUSSION

This study is one of the first to examine multilevel influences of objectively measured recreation, food and social environments, and individual-level factors and season as they relate to rates of PA, and overweight/obesity in a large representative sample of Canadian adults. Furthermore, the study employed the use of neighborhoods that are relatively homogeneous in terms of socioeconomics, contrary to the use of census tracts usually seen in Canadian research on this topic.

The main objective of this research was to understand and identify potential built and social environment characteristics, seasonal and individual correlates of LTPA and overweight/obesity in Ottawa neighborhoods. The results showed different relationships for men and women. Surprisingly, LTPA was significantly associated with park area in females and crime rates in males. The likelihood of females being overweight/obese was positively related to park area, convenience store, and fast food outlet density and negatively influenced by crime rates. Males' odds of overweight/obesity were only negatively related to crime rates.

Findings of this analysis are similar to other Canadian studies in which significant area variation was reported for PA (23) and overweight and obesity (24). However, while the area-level variation in PA and overweight/obesity has generally been low in previous studies (23–25), our models revealed a considerable degree of variation at the neighborhood level possibly attributable to our more natural definition of neighborhoods.

Surprisingly in our study, the only recreation variable associated with LTPA and overweight/obesity was park area for females. Our LTPA findings are similar to investigations of spatial access to built and natural facilities and associations with meeting PA recommendations in a sample of Australian adults by Giles-Corti and Donovan (11). They found no significant associations between the environment and PA, but did find that individual determinants had stronger relationships with PA (11) and that access differed by neighborhood SES (26). By controlling for neighborhood SES factors, we may be controlling for this effect. Our PA findings also agree with those found by Panter and colleagues (27) who studied six English neighborhoods of varying SES. Their results showed

that those living in the closest tertile to a park or green space were twice as likely to meet PA guidelines (27). Interestingly, in addition to greater park area being associated with higher odds of female LTPA, it was also associated with higher odds of female overweight/obesity. Although these findings appear counterintuitive they do support the idea that park area may not necessarily be linearly related to BMI (28). However, caution should be exerted when interpreting the present findings as a number of issues related to the conception and analysis of the data require further investigation. The measure of park area in the current study included various types of "parks" including children's playgrounds and maintained green spaces which affects the specificity of their use. Female use of park area is likely affected by parity (i.e., number of children) which was unfortunately not available in the current data. Further, it was not possible to ascertain from the data information on park quality. Seasonality is also another issue of importance in this North American city where a colder climate can render parks not usable for up to 6 months of the year. Therefore, while a park may be present in a neighborhood it is not necessarily accessible. Finally, information on dog ownership was not available, but could provide important covariate information for park use and BMI. Previous research has shown that dog ownership is associated with lower BMIs (29) and an increased use of parks (30).

Interestingly, none of the facility variables had significant associations with LTPA. There is evidence to suggest that the relationship between PA and the built environment may be modified by whether facilities are free or pay-for-use with a greater density of pay-for-use facilities associated with being physically active vs. inactive (31). It is also possible that reverse causality could occur whereby pay-for-use facilities may locate to areas of higher SES with more potential clientele. Our study included facilities that were free or available at a minimal cost, however, the inclusion of both neighborhood and individual SES potentially captures the possibility that higher cost facilities are associated with higher levels of LTPA.

Similar to our investigation, Pouliou and colleagues examined associations of BMI from the 2003 CCHS with the density of food sources and recreation facilities within 1-km buffers of homes in two other Canadian cities; Toronto and Vancouver (32). They found that the density of fast food outlets, convenience stores, grocery stores, and recreation facilities were not significantly associated with BMI (32). It is possible that 1-km buffers are more meaningful from a walkability perspective, but these may not adequately capture an individual's exposure to food sources and recreational facilities which are dependent on the use of a car. In addition, several Canadian studies have identified that resource availability may be dependent on area-level SES (33) and area-level SES may mediate the uptake of PA (34,35) and access to food outlets (36). By controlling for neighborhood social factors in our analyses we are controlling for this effect and this is perhaps why the recreation and social environments did not have strong independent associations with LTPA or overweight/obesity.

Table 3 Final multivariate multilevel models for male and female physical activity and overweight/obesity status

Final models	Outcome: physically active		Outcome: overweight/obesity	
	Males, OR (95% CI)	Females, OR (95% CI)	Males, OR (95% CI)	Females, OR (95% CI)
Built environment				
Number of indoor recreation facilities per 1,000 people	0.99 (0.84, 1.15)	0.95 (0.84, 1.07)	1.03 (0.91, 1.17)	1.01 (0.92, 1.11)
Number of summer outdoor recreation facilities per 1,000 people	1.02 (0.83, 1.26)	1.07 (0.88, 1.31)	1.06 (086, 1.32)	0.84 (0.66, 1.07)
Number of winter outdoor recreation facilities per 1,000 people	0.97 (0.79, 1.19)	0.86 (0.72, 1.01)	0.98 (0.86, 1.11)	1.10 (0.91, 1.32)
Park area (km^2) per 1,000	0.91 (0.77, 1.06)	**1.17 (1.03, 1.33)**	0.97 (0.78, 1.20)	**1.15 (1.00, 1.32)**
Green space area (km^2) per 1,000 people	0.57 (0.27, 1.21)	0.94 (0.74, 1.21)	0.80 (0.63, 1.01)	0.86 (0.70, 1.05)
Bike and walking path length (km) (total)	0.88 (0.70, 1.10)	0.88 (0.68, 1.15)	1.09 (0.84, 1.41)	1.18 (0.95, 1.47)
Number of grocery stores per 1,000 people	1.05 (0.88, 1.24)	0.99 (0.87, 1.13)	1.07 (0.93, 1.23)	0.93 (0.79, 1.08)
Number of convenience stores per 1,000 people	0.90 (0.79, 1.04)	1.08 (0.91, 1.29)	0.92 (0.82, 1.04)	**1.17 (1.03, 1.34)**
Number of fast food outlets per 1,000 people	1.12 (0.72, 1.73)	0.95 (0.79, 1.15)	1.22 (0.97, 1.55)	**1.38 (1.11, 1.72)**
Number of restaurants per 1,000 people	0.87 (0.52, 1.44)	0.94 (0.72, 1.24)	0.78 (0.55, 1.11)	0.77 (0.57, 1.06)
Number of specialty stores per 1,000 people	1.00 (0.69, 1.43)	1.18 (0.96, 1.46)	1.04 (0.83, 1.30)	1.00 (0.84, 1.19)
Social environment				
SES index *t*-score	0.99 (0.98, 1.01)	0.99 (0.97, 1.00)	1.00 (0.99, 1.02)	1.00 (0.99, 1.02)
Strong sense of community belonging	0.93 (0.81, 1.07)	1.05 (0.94, 1.17)	0.95 (0.85, 1.07)	1.04 (0.92, 1.16)
Councillor voting rate	1.08 (0.97, 1.20)	0.97 (0.86, 1.10)	0.91 (0.82, 1.02)	0.99 (0.85, 1.14)
Crime rate	**1.14 (1.05, 1.23)**	0.97 (0.89, 1.06)	**0.92 (0.86, 0.99)**	**0.91 (0.85, 0.98)**
Contextual (season)				
Summer	1.00	1.00	1.00	1.00
Fall	1.01 (0.75, 1.36)	0.95 (0.74, 1.21)	0.99 (0.74, 1.33)	1.11 (0.87, 1.41)
Winter	**0.56 (0.39, 0.79)**	**0.54 (0.39, 0.77)**	1.07 (0.79, 1.45)	1.05 (0.76, 1.45)
Spring	**0.48 (0.36, 0.64)**	0.80 (0.58, 1.11)	1.12 (0.81, 1.55)	1.03 (0.76, 1.40)
Individual-level				
Age				
18–24 years	1.00	1.00	1.00	1.00
25–44 years	**0.54 (0.37, 0.79)**	**0.68 (0.46, 0.99)**	**2.85 (1.88, 4.33)**	**2.75 (1.80, 4.21)**
45–64 years	**0.36 (0.23, 0.54)**	0.71 (0.45, 1.14)	**4.28 (2.82, 6.52)**	**4.81 (3.14, 7.37)**
65+ years	**0.43 (0.25, 0.71)**	**0.59 (0.38, 0.91)**	**2.43 (1.52, 3.87)**	**3.94 (2.47, 6.28)**
Household income				
≤$29,999	1.00	1.00	1.00	1.00
≥$30,000	**1.65 (1.19, 2.29)**	1.00 (0.73, 1.36)	**1.39 (1.05, 1.84)**	0.96 (0.73, 1.26)
Education				
Did not graduate from high school	1.00	1.00	1.00	1.00
Graduated from high school	0.81 (0.51, 1.28)	1.13 (0.64, 1.98)	0.69 (0.47, 1.02)	0.67 (0.43, 1.03)
Some post-high school education	1.28 (0.72, 2.29)	1.01 (0.57, 1.81)	0.82 (0.51, 1.34)	0.93 (0.57, 1.51)
College/university diploma/degree	1.16 (0.74, 1.83)	1.52 (0.92, 2.52)	**0.56 (0.38, 0.84)**	**0.55 (0.37, 0.83)**
BMI category (for PA models), PA level (for BMI models)				
Under/normal weight or inactive	1.00	1.00	1.00	1.00

Table 3 Continued

Overweight/obese or active	1.09 (0.85, 1.39)	**0.62 (0.49, 0.79)**	1.09 (0.85, 1.40)	**0.63 (0.50, 0.79)**
Smoking status				
Daily	1.00	1.00	1.00	1.00
Occasional	1.59 (0.90, 2.79)	1.10 (0.55, 2.21)	1.29 (0.79, 2.10)	0.78 (0.42, 1.43)
Former	1.40 (0.97, 2.03)	1.45 (0.90, 2.33)	**1.63 (1.18, 2.24)**	1.17 (0.87, 1.58)
Never	1.26 (0.83, 1.92)	1.32 (0.84, 2.09)	1.25 (0.89, 1.75)	0.90 (0.65, 1.24)
	Coefficient (s.e.)	Coefficient (s.e.)	Coefficient (s.e.)	Coefficient (s.e.)
Individual-level variance	**−0.68 (0.26)**	**−1.17 (0.28)**	**−0.98 (0.30)**	**−1.08 (0.28)**
Area-level variance	0.05 (0.04)	0.06 (0.05)	0.05 (0.03)	0.02 (0.02)
Intraclass correlation coefficient	7.93%	5.41%	5.38%	1.89%

All neighborhood-level variables have been standardized ((independent variable − mean)/s.d.). Statistically significant findings are highlighted in bold.
CI, confidence interval; OR, odds ratio; PA, physical activity; SES, socioeconomic status.

Results of the present study also found that higher crime rates were associated with greater odds of LTPA in males and lower odds of overweight and obesity in both males and females. It is likely that crime correlates strongly with greater population density acting as a proxy measure for this environmental factor. Population density has been shown to be associated with higher levels of PA and lower BMIs (37).

The present study has limitations that should be recognized. First, the neighborhood-level indicators were collected between 2006 and 2008 while individual-level data were derived from four surveys spanning 2000–2007. We had confidence in using multiple years of survey data as Ottawa level estimates were relatively stable across this time period. Second, the individual-level variables were self-reported and evidence suggests that self-report measures of PA and height and weight differ significantly from their objective measures (38,39). In addition, PA was recalled from the previous 3 months which also adds to the possibility of recall bias. While it would have been preferable to use direct measures to examine these relationships, there is no known large dataset for the Ottawa area and collection of these measures on such a large scale would be very time and cost intensive. The self-report measures allowed us to capture data on a large scale and the use of a high PA cut-point (active vs. moderate/inactive) may have helped to identify individuals who were receiving health benefits. It is also important to realise that our PA outcome is based on LTPA and does not measure energy expenditures from activities of daily living. In addition, the use of BMI as a measure of overweight/obesity may misclassify individuals with a high muscle mass (40).

Another limitation of this study is its cross-sectional design; this prevents assessment of causality. Most previous research has relied on cross-sectional designs due to the costs associated with tracking a large group of individuals over time; however, prospective studies are needed to establish the direction of relationships. Finally, we were unable to assess perceptions of the neighborhoods including preferences and the likelihood that residents self-selected into their respective neighborhoods or that they crossed boundaries to access resources. It would have been ideal to determine whether the relationships differed between perceived awareness of resources and LTPA and

overweight/obesity. Unfortunately, the CCHS does not capture this information. Furthermore, it is possible that individuals who are more active select to live in neighborhoods that are supportive of their behaviors. While we did not assess preference and travel, we did control for clustering at the neighborhood level through hierarchical modeling.

Conclusions
Our results suggest that in this large Canadian city there is significant individual variation in PA and overweight/obesity that can be attributed to the neighborhood. Findings suggest that the recreation and social environment may play less of a role in LTPA and BMI status than the availability of neighborhood amenities and food outlets. In addition, neighborhood-level interventions to support PA and healthy weight may need to be gender and season tailored.

This study is the first of which we are aware that examines the multilevel associations between individual PA and overweight/obesity with neighborhood-level recreation, food and social environments and individual socio-demographics, and season in a large sample of urban-dwelling Canadians. Our findings provide support for the growing research demonstrating that physical inactivity and obesity may be partially explained by neighborhood-level exposures. Although there were few significant associations between the environment variables and LTPA and overweight/obesity, we are confident that our large sample size had adequate power to assess these relationships. Future research in this area is necessary to determine whether the findings could be replicated and whether the relationships would differ with the use of objectively measured PA and body composition, accounting for neighborhood preferences, parity and dog ownership and whether longitudinal associations exist.

DISCLOSURE

The authors declared no conflict of interest.

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