Title: Associations between the neighbourhood characteristics and body mass index, waist circumference, and waist-to-hip ratio: findings from Alberta's Tomorrow Project

Abstract:

This study estimated the associations between neighbourhood characteristics and self-reported body mass index (BMI), waist circumference (WC), and waist-to-hip ratio (WHR) risk categories among Canadian men and women. Using data from the Alberta's Tomorrow Project (n=14,550), we estimated 3- and 4-way intersections, business destinations, population count, and normalized difference vegetation index (NDVI) within a 400m radius of participant's home. Intersections, business destinations, and population count (z-scores) were summed to create a walkability score. *Four-way intersections* and *walkability* were negatively associated with overweight and obesity. *Walkability* was negatively associated with obesity. *NDVI* was negatively associated with high-risk WHR and *population count* and *walkability* positively associated with high-risk WHR. Among men, *population count* and *walkability* were negatively associated with obesity, and *business destinations* and *walkability* were negatively associated with overweight and obesity. Among women, *NDVI* was negatively associated with overweight (including obesity), obesity, and high-risk WC. Interventions promoting healthy weight could incorporate strategies that take into consideration local built environment characteristics.

Keywords: neighbourhood, environment, walkability, obesity, waist circumference, weight.

Introduction:

In the past few decades, the prevalence rates of overweight and obesity have increased across the globe (1, 2). Two key lifestyle factors associated with overweight and obesity include excess energy intake and low physical activity (2, 3). Creating physical activity supportive environments is one population-level strategy for encouraging physical activity among the general population (4-6). Neighbourhood characteristics associated with increased physical activity include *residential density, land use mix, street connectivity, pedestrian infrastructure, traffic and crime safety, and aesthetics* (7, 8). Neighbourhood characteristics that are associated with physical activity, may also have beneficial effects on obesity (9, 10).

Many studies have found more supportive neighbourhood built characteristics to be associated with lower body mass index (BMI), waist circumference (WC), and waist-to-hip ratio (WHR) (10-20), however, others have found null or even positive associations (21, 22). Evidence suggests more *urban sprawl* and less land use mix are associated with higher risk of overweight or obesity (23). Furthermore, negative (supportive) associations between *intersection density*, *business destinations*, *population count*, and *neighbourhood greenness* and overweight or obesity have also been found (10, 17-19, 24). Higher neighbourhood walkability may also be associated with a lower risk of overweight or obesity (11, 13-15). Notably, associations between neighbourhood built characteristics and weight among men and women are mixed (25, 26).

Some noteworthy shortcomings of previous studies include sample selection bias in terms of recruitment of higher socioeconomic status individuals, or recruitment of individuals from small geographical areas impacting generalizability (9, 13, 16). Furthermore, few studies incorporate multiple weight measures (15, 16, 27). BMI is frequently investigated, yet it does not account for variation in body fat distribution including abdominal adiposity (28). Thus, weight measures other than BMI are required to accurately quantify obesity-related morbidities (28). Physical activity is negatively associated with WC, WHR, and BMI (29) therefore, given the relations between the built environment and physical activity (30) we expect some aspects of the built environment (protective elements) to also be negatively associated with these weight outcomes. Despite all being indicators of weight status, the built environment may not be associated with WC, WHR, and BMI to the same extent (16, 31).

Undertaking studies that include multiple weight measures with geographically and socially diverse samples is needed to provide more rigorous evidence to inform interventions that support healthy weight. In our study, we include neighbourhood characteristics *street intersection density, business destination density, population count*, and *neighbourhood greenness,* and *walkability* (aggregate of built characteristics) that are associated with physical activity and weight in a beneficial way. Specifically, we estimated associations between objectively-determined neighbourhood characteristics and self-reported BMI, WC, and WHR and tested the extent to which these associations were modified by sex.

Methods:

Study structure

This study involved a secondary analysis of data from the Alberta's Tomorrow Project (ATP), a longitudinal study conducted in Alberta (Canada). Briefly, from 2000 to 2008 urban and rural Albertans (n=63,486) were invited to complete a health and lifestyle questionnaire (HLQ) (32, 33).

The returned HLQs captured sociodemographic and health data from the 31,072 participants (32, 33). Later, in 2008, participants completed a follow-up survey aimed at updating data on previously collected sociodemographic and health factors, as well as collecting new data on perceived neighbourhood characteristics (32). We included data for urban participants who completed the follow-up survey in 2008 (n=15,342).

Anthropometric measures

During the follow-up ATP survey, participants self-reported or self-measured their weight, height, WC, and hip circumference (HC) (32). WC was measured one inch above the belly button (33). HC was measured at the largest portion of the buttocks (33). BMI was estimated from height and weight (33). We used the World Health Organization (WHO) recommended BMI cut-off value of 25 kg/m^2 to dichotomize participants as healthy weight versus overweight (including obese) and 30 kg/m^2 to dichotomize participants as obese versus not obese (34, 35). We applied WHO's sex-based classification of abdominal obesity to WC values (men: ≥94 cm and women: ≥80 cm) (36). To derive high-risk WHR, we divided WC by HC and dichotomized based on sex-based cut points (men: ≥0.90 and women: ≥0.85)(36).

Neighbourhood characteristics

Geographic Information System estimated neighbourhood characteristics within a 400m radius of each participant's household. A 400m buffer represents the approximate distance travelled after 5 minutes of walking (37, 38). Household location was estimated based on geo-locating participant's 6-digit residential postal code. 'Street network' and 'an enhanced point of interest' files were used to derive the street intersection and business destination counts, respectively. Derived from 76

Standard Industrial Classification codes, different types of business destinations were counted (e.g., hardware stores, departmental stores, grocery stores, restaurants, banks, libraries, laundry stores, stationary stores, liquor stores, jewellery stores, barbershops, museums, schools, colleges, and universities). We could not differentiate between different types of restaurants (fast food and non-fast food). Population count was calculated using Statistics Canada 2006 census dissemination block level data (39). Population counts were estimated based on the geometric overlap of the 400m buffers and dissemination blocks. The percentage of each buffer overlap was multiplied by the population count of the dissemination block and then summed to obtain a weighted count for the buffer.

Normalized difference vegetation index (NDVI) is an established, widely, used measure of vegetation (40) and is indicative of the amount of greenness on the surface of the earth (41). In alignment with previous studies (19, 42), we used NDVI as a measure of green space exposure. Landsat 5 satellite imagery obtained from the Canadian Urban Environmental Health Research Consortium (43) was used as a data source for determining NDVI. The NDVI values were calculated as pixel-based mean NDVI values by utilizing the satellite imagery for Alberta captured between May and August of 2008 at a spatial resolution of 30 m X 30 m. The satellite imagery represented the period of maximum greenness for Alberta. Cloud-free satellite images were used to estimate NDVI. Note that mean NDVI values were estimated by averaging NDVI values for land and water surfaces across growing season months (May to August). NDVI values for water surfaces were considered as null values and these null values included from calculation of mean NDVI values. We utilized Google Earth Engine® to generate NDVI (44). Using Google Earth Engine®, Landsat 5 imagery was compiled and processed using a custom-developed JavaScript

script to perform the spectral band math required for NDVI calculations. The NDVI imagery captured within Google Earth Engine® was representative of Alberta as a whole and individual postal code buffers needed to be extracted in post-processing. Post-processing was conducted using MATLAB® to extract mean NDVI values for each postal code buffer (45). In other words, the average NDVI of all pixels within each 400m buffer was estimated.

Similar to previous studies (9, 14, 27), we converted neighbourhood characteristics to z-scores and summed these z-scores to construct a walkability score. The NDVI was negatively correlated with other neighbourhood characteristics and was not included in the walkability score.

Statistical analysis

The cases with missing data were excluded (5%; n=792), leaving 14,550 complete cases for inclusion in the analysis. To prevent collinearity, neighbourhood characteristics were examined in separate regression models however, we included walkability in one model that represented the combined effect of all built characteristics. *Street intersections*, *business destinations*, and *population count* were rescaled to aid in the interpretation of the model estimates (*street intersections* and *business destinations* divided by 10, and *population count* divided by 100). Informed by previous studies (19, 42), *NDVI* was divided by the interquartile range. We performed independent t-tests and chi-square tests to compare sociodemographic, health-related, and neighbourhood characteristics between men and women. Covariate-adjusted binary logistic regression models estimated the associations between each neighbourhood characteristic and weight outcome (odds ratios (ORs) and 95% confidence intervals (CIs)). Interaction tests were conducted to explore sex as an effect modifier. We tested for effect modification by sex by including the interaction term within each regression model. If the p-value of the interaction term was less than 0.05 then the interaction term was considered to be statistically significant. Subsequently, separate parameter estimates were obtained for men and women. Models were adjusted for age, sex, general health status, current smoking status, current marital status, number of children in the household, highest education achieved, current employment status, and annual household income. Data were analyzed using Stata Version 15 (StataCorp LLC, Texas, and USA). The University of Calgary Conjoint Health Research Ethics Board approved this analysis (REB17-1466).

Results:

Sample and neighbourhood characteristics

The mean (standard deviation (SD)) age of the participants was 55.2 (9.1) years. Approximately 61% were female. The mean (SD) BMI was 27.4 (5.3) kg/m^2. Among participants, 65% were overweight (including obese) and 26% were obese. The mean (SD) WC was 93.2 (14.8) cm. Based on WC, 70% of participants were obese. The mean (SD) WHR was 0.9 (0.1). Based on WHR, 61% of the participants were at high risk of abdominal obesity (Table 1). Significant differences in sociodemographic and weight characteristics were found between men and women (Table 1). The neighbourhood density of business destinations also differed between men and women (Table 2).

Neighbourhood characteristics and weight (pooled analysis)

Adjusting for covariates, *4-way intersections* was associated with a decrease in overweight and obesity (OR 0.94; CI 0.89, 0.99). *Walkability* was independently associated with a decrease in overweight and obesity (OR 0.98; CI 0.96, 0.99) and obesity (OR 0.98; CI 0.96, 0.99).

Neighbourhood characteristics were not associated with high-risk WC. *NDVI* was associated with decrease in high-risk WHR (OR 0.93; CI 0.89, 0.96). However, *population count* (OR 1.01; CI 1.005, 1.012) and *walkability* (OR 1.02; CI 1.001, 1.04) were associated with increase in high-risk WHR. No other significant associations were found (Table 3).

Neighbourhood characteristics and weight (sex-specific analysis)

Adjusting for covariates, among men, *population count* (OR 0.998; CI 0.996, 0.999) and *walkability* (OR 0.991; CI 0.985, 0.996) were associated with reduced obesity, and *business destinations* (OR 0.971; CI 0.952, 0.990) and *walkability* (OR 0.991; CI 0.985, 0.996) were associated with reduced overweight and obesity. Among women, *NDVI* was associated with reduced obesity (OR 0.988; CI 0.978, 0.998) as well as reduced overweight and obesity (OR 0.984; CI 0.973, 0.995). Further, *NDVI* was associated with reduced high-risk WC (OR 0.984; CI 0.974, 0.994) (Table 4).

Discussion:

Brief summary of the main results of the study

Neighbourhood characteristics were associated with weight outcomes and some of these associations were pronounced for men or women. Our findings suggest that aspects of the built environment could support healthy weight among adults living in urban areas.

Comparison of study results with other studies

In support of previous studies (14, 27), we found that neighbourhood characteristics were associated with a decrease in overweight or obesity. For example, Müller-Riemenschneider et al.(14) found that walkability was associated with a lower likelihood of obesity. Carlson et al.(27) also found walkability to be inversely associated with obesity. Kowaleski-Jones et al.(13) showed that participants living in less walkable neighbourhoods were more likely to be obese compared with counterparts living in high walkable neighbourhoods. Different from previous studies (17, 18), we found that NDVI was not associated with generalized obesity (BMI), although we did find a negative association with WHR. Pereira et al.(18) found that participants living in the highest tertile of neighbourhood greenness (NDVI) were less likely to be overweight or obese than their counterparts living in the lowest tertile of neighbourhood greenness. Sarkar et al.(17) also found that neighbourhood greenness (NDVI) was associated with a lower risk of obesity. In general, our findings are supported by other studies, but not all, suggesting more supportive neighbourhood environments are associated with lower BMI (10-12, 17, 27). Notably, Ball et al.(21) found street connectivity was not associated with overweight or obesity. Sriram et al.(15) and McCormack et al.(16) also found no association between Walk Score® and BMI. The difference in findings between our study and previous studies could be due to methodological differences (e.g., study locations, definitions and estimation of neighbourhood characteristics and boundaries).

In contrast to our findings, other studies have found associations between a higher Walk Score® (15) and neighbourhood greenness (17) and lower WC. In a recent study, higher Walk Score® was associated with a lower odds of being classified as high risk for abdominal obesity based on WC (16). In our study, *population count* and *walkability* only were positively associated with high-risk WHR. Some characteristics of walkable neighbourhoods, such as increased availability of fast food restaurants, might increase obesity (46). Our analysis does not allow the unpacking of possible reasons as to why neighbourhood characteristics might increase WHR.

Contributing to previous studies (25, 26), we found effect modification by sex for association between neighbourhood characteristics and weight. Frank et al.(26) found *residential density*, *street connectivity*, and *land use mix* were associated with lower obesity among men while for women, *street connectivity* was associated with overweight and *residential density* was associated with obesity. Li et al.(25) found Walk Score® was inversely associated with BMI among middle-to-older aged men and neighbourhood greenness was inversely associated with BMI among middle-to-older aged women. Like Frank et al.(26), we found that residing in a neighbourhood with a higher *population density* was associated with a lower likelihood of obesity among men. Modifications to the built environment could reduce overweigh and obesity among the public, but some modifications may have a different impact on weight of men and women.

Strengths and limitations of this study

The strength of this study is a large sample size that increased estimate precision. Our sample size was notably higher than most previous studies investigating neighbourhood characteristics and weight (10, 11, 14-16, 18, 19, 21, 22, 24, 47). The novelty of our study is that we estimated association in a new cohort (ATP), we included multiple measures of weight, and used objectively-determined built environment variables representative of the local neighbourhood. Causality cannot be inferred from our cross-sectional analysis. Residual confounding due to factors cannot be entirely ruled out (e.g., diet, sleep, and physical activity). We selected covariates based on prior knowledge (48, 49) and availability of correlates of weight from the ATP dataset. The anthropometric measures were self-reported and under-reporting of outcomes may have occurred. Nevertheless, the estimated health risks are similar for self-reported or objectively measured weight outcomes (50). As computer algorithms for the creation of network-based buffers on a provincial scale for all urban postal codes within Alberta (approximately 80,000) are complex and resource intensive, we generated 400m Euclidian buffers only for household addresses. The estimated built environment variables were based on spatial data available for all urban areas across the province thus some characteristics related to weight were not included in our study (e.g., green space quality, recreational destinations, and fast food destinations).

Conclusions and future directions

Neighbourhood characteristics were associated BMI and WHR, but not with WC. Some of the neighbourhood environment-weight status associations are apparent in men, whilst other associations are apparent in women. Our findings are important for informing local urban planning policy and public health interventions for promoting healthy weight in Canada and elsewhere. Longitudinal studies (e.g., residential relocation studies) and natural experiments are needed to provide more rigorous evidence to establish a causal link between the built environment and weight outcomes. Moreover, the mediating roles of physical activity, social interactions, diet, sedentary behaviour, and sleep should be examined in future studies.

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Competing interests

All authors have no conflict of interest.

Table 1: Sociodemographic and health-related characteristics of the participants

Sociodemographic and health-related characteristics				
	Pooled sample (n=14,550) mean (SD) or %	**Men** (n=5,626) mean (SD) or %	**Women** (n=8,924) mean (SD) or %	**Test Statistic** (p-value) [#]
Age (years)	55.2 (9.1)	55.5 (9.0)	54.9 (9.2)	3.9 (0.0001)*
Body mass index (kg/m^2)	27.4 (5.3)	28.1 (4.4)	27.0 (5.7)	12.0 (0.0000)*
Waist circumference (cms)	93.2 (14.8)	100.7 (12.3)	88.5 (14.3)	52.8 (0.0000)*
Waist-to-hip ratio	0.9 (0.1)	0.9 (0.1)	0.8 (0.1)	103.6 (0.0000)*
Age (years) (categorical)				
35 to <45	14.7	13.6	15.4	
45 to <55	37.6	36.6	38.3	19.9 (0.000)*
55 to <65	30.3	32.1	29.2	
≥65	17.4	17.7	17.1	
Sex				
Men	38.7	100.0	-	-
Women	61.3	-	100.0	
Self-reported general health status				
Poor or fair	7.4	7.8	7.2	
Good	34.1	37.2	32.1	50.6 (0.000)*
Very good	41.2	39.5	42.3	
Excellent	17.3	15.5	18.4	

Current marital status				
Married or not married, but living with someone	77.2	83.4	73.4	308.9 (0.000)*
Separated or divorced	12.4	8.9	14.6	
Widowed	4.5	1.6	6.3	
Single, never married	5.9	6.1	5.7	
Number of children currently in the household				
0	73.1	71.6	74.1	19.0 (0.000)*
1	11.9	11.9	11.8	
2	11.0	11.8	10.6	
≥3	4.0	4.7	3.5	
Highest education level				
Some or entire high school	22.8	20.6	24.2	65.7 (0.000)*
Some or entire technical college training	38.3	38.1	38.5	
Some or entire university degree	26.0	25.9	26.1	
Some or entire university post-graduate degree	12.9	15.4	11.2	
Current employment status				
Working full-time	53.8	68.6	44.4	1300 (0.000)*
Working part-time	14.5	7.4	18.9	
Home maker	6.3	0.2	10.2	
Retired	20.7	19.9	21.3	
Other or not employed or student	4.7	3.9	5.2	

Annual household income (Canadian Dollars)				
\$0 to 49,999	18.7	13.9	21.8	277.5 (0.000)*
\$50,000 to 99,999	31.8	32.3	31.4	
\$100,000 to 149,999	23.0	26.1	21.1	
\$150,000 to 199,999	9.6	11.7	8.3	
\$200,000 to 249,999	4.0	4.6	3.6	
\$≥250,000	5.3	6.1	4.8	
Refused to answer	7.6	5.3	9.0	
Current smoking status				
Non-smokers	87.5	86.8	87.9	4.3 (0.04)*
Smokers	12.5	13.2	12.1	
Body mass index (binary)				
Healthy weight (<25 kg/m^2)	35.1	23.5	42.4	542.0 (0.000)*
Overweight and obesity (≥25 kg/m^2)	64.9	76.5	57.6	
Body mass index (binary)				
Non-obesity (<30 kg/m^2)	74.4	72.4	75.7	19.9 (0.000)*
Obesity (≥30 kg/m^2)	25.6	27.6	24.3	
Waist circumference (binary)				
Low risk category (<94 cm in men or <80 cm in women)	30.0	29.5	30.3	1.1 (0.29)
High risk category (≥94 cm in men or ≥80 cm in women)	70.0	70.5	69.7	
Waist-to-hip ratio (binary)				
Low risk category (<0.90 in men or <0.85 in women)	39.5	13.5	56.0	2600 (0.000)*

High risk category (≥0.90 in men or ≥0.85 in women)	60.5	86.5	44.0

Abbreviation: SD=standard deviation
=test statistic estimated by using chi-square tests (categorical variables) or t-tests (continuous variables)
*=p-value is significant

Table 2: Neighbourhood characteristics of the participants

	Neighbourhood characteristics			
	Pooled sample (n=14,550) mean (SD)	**Men** (n=5,626) mean (SD)	**Women** (n=8,924) mean (SD)	**Test Statistic**[#] (p-value)
3-way intersections (raw counts)	18.6 (11.0)	18.6 (10.9)	18.7 (11.1)	-0.7 (0.5)
4-way intersections (raw counts)	6.6 (6.3)	6.6 (6.4)	6.6 (6.2)	0.4 (0.7)
Business destinations (raw counts)	4.5 (5.7)	4.3 (5.6)	4.6 (5.8)	-3.0 (0.003)*
Population count (raw counts)	1085 (655)	1095 (661)	1079 (651)	1.5 (0.2)
Normalized difference vegetation index (raw values)	0.4 (0.1)	0.4 (0.1)	0.4 (0.1)	-0.3 (0.8)
Walkability[a]	-0.3 (2.1)	-0.3 (2.1)	-0.2 (2.1)	-0.9 (0.4)

Abbreviation: SD=standard deviation
a=walkability estimated by adding z scores. As normalized difference vegetation index was negatively correlated with other neighbourhood characteristics, it was not included in walkability (i.e., walkability=$z_{\text{3-way intersections}} + z_{\text{4-way intersections}} + z_{\text{business destinations}} + z_{\text{population counts}}$).
Neighbourhood defined as a 400m buffered area around each participant's household
#=test statistic estimated by using t-tests (continuous variables)
*=p-value is significant

Table 3: Binary logistic regression analysis for the associations between neighbourhood characteristics and BMI, WC, and WHR outcomes (pooled analysis)

	BMI (overweight (including obesity) [n=9,443] vs. healthy weight (reference) [n=5,107]) Adjusted ORs (95% CI)[a]	**BMI (obesity [n=3,723] vs. non-obesity (reference) [n=10,827])** Adjusted ORs (95% CI)[a]	**WC (high risk [n=10,186] vs. low risk (reference) [n=4,364])** Adjusted ORs (95% CI)[a]	**WHR (high risk [n=8,797] vs. low risk (reference) [n=5,753])** Adjusted ORs (95% CI)[a]
Neighbourhood characteristics[b]				
3-way intersections[c]	0.99 (0.96, 1.02)	0.98 (0.94, 1.01)	0.99 (0.96, 1.03)	1.01 (0.98, 1.04)
4-way intersections[c]	0.94 (0.89, 0.99)*	0.95 (0.90, 1.02)	0.95 (0.90, 1.01)	1.03 (0.98, 1.09)
Business destinations[c]	0.95 (0.89, 1.01)	0.96 (0.90, 1.03)	1.00 (0.94, 1.07)	1.04 (0.98, 1.11)
Population count[c]	0.99 (0.98, 1.00)	0.99 (0.98, 1.00)	1.00 (0.99, 1.01)	1.01 (1.005, 1.012)*
Normalized difference vegetation index[c]	0.96 (0.93, 1.00)	0.98 (0.94, 1.03)	0.96 (0.92, 1.00)	0.93 (0.89, 0.96)*
Walkability[d]	0.98 (0.96, 0.99)*	0.98 (0.96, 0.99)*	0.99 (0.98, 1.01)	1.02 (1.001, 1.04)*

Abbreviations: BMI=body mass index, WC=waist circumference, WHR=waist-to-hip ratio, OR=odds ratio, and CI=confidence interval

a=adjusted for age, sex, self-reported general health, current marital status, number of children in household, highest education level, current employment status, annual household income, and current smoking status

b=to prevent collinearity, neighbourhood characteristics were examined in separate regression models (that is, more than one neighbourhood characteristics not included in regression model at a time).

c=raw values were rescaled prior to regression analysis (street intersections and business destinations divided by 10, population count divided by 100, and normalized difference vegetation index divided by the interquartile range).

d=walkability estimated by adding z scores. As normalized difference vegetation index was negatively correlated with other neighbourhood characteristics, it was not included in walkability (i.e., walkability=$z_{\text{3-way intersections}} + z_{\text{4-way intersections}} + z_{\text{business destinations}} + z_{\text{population counts}}$)
Neighbourhood defined as a 400m buffered area around each participant's household
*=p-value <0.05

Table 4: Sex-specific analysis for the associations between neighbourhood characteristics and weight outcomes

Neighbourhood characteristics[a]	**Weight outcomes**	**Parameter estimate for men (n= 5,626) OR (95% CI)[b]**	**Parameter estimate for women (n=8,924) OR (95% CI)[b]**
Population count[c]	BMI (obesity vs. non-obesity)	0.998 (0.996, 0.999)*	0.999 (0.998, 1.001)
Normalized difference vegetation index[c]	BMI (obesity vs. non-obesity)	1.010 (0.998, 1.023)	0.988 (0.978, 0.998)*
Walkability[d]	BMI (obesity vs. non-obesity)	0.991 (0.985, 0.996)*	0.999 (0.996, 1.004)
Business destinations[c]	BMI (overweight and obesity vs. healthy weight)	0.971 (0.952, 0.990)*	1.001 (0.984, 1.020)

Normalized difference vegetation index[c]	BMI (overweight and obesity vs. healthy weight)	1.010 (0.996, 1.022)	0.984 (0.973, 0.995)*
Walkability[d]	BMI (overweight and obesity vs. healthy weight)	0.991 (0.985, 0.996)*	0.998 (0.993, 1.003)
Normalized difference vegetation index[c]	WC (high risk vs. low risk)	1.006 (0.993, 1.020)	0.984 (0.974, 0.994)*

Abbreviations: BMI=body mass index, WC=waist circumference, OR=odds ratio, and CI=confidence interval

a=to prevent collinearity, neighbourhood characteristics were examined in separate regression models (that is, more than one neighbourhood characteristics not included in regression model at a time).

b=the effect sizes represent marginal means for the associations between neighbourhood characteristics and weight outcomes. As some of the CIs are quite narrow, effect sizes are reported to three decimal places.

c=raw scores were rescaled prior to regression analysis (street intersections and business destinations divided by 10, population count divided by 100, and normalized difference vegetation index divided by the interquartile range).

d=walkability estimated by adding z scores. As normalized difference vegetation index was negatively correlated with other neighbourhood characteristics, it was not included in walkability (i.e., walkability=$z_{\text{3-way intersections}} + z_{\text{4-way intersections}} + z_{\text{business destinations}} + z_{\text{population counts}}$)

Neighbourhood defined as a 400m buffered area around each participant's household

*=p-value <0.05

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