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ORIGINAL ARTICLE

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Built environment influences on healthy eating and active living: The NEWPATH study

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Abstract

Objective: The Neighbourhood Environments in Waterloo: Patterns of Active Transportation and Health (NEWPATH) study examined built environment influences on travel, physical activity, food consumption, and health. This collaboration between researchers and practitioners in health and transportation planning is the first, to our knowledge, to integrate food purchasing, diet, travel, and objectively measured physical activity into a trip-destination protocol. This study simultaneously examines diet and physical activity relationships with BMI and waist circumference (WC).

Methods: Individual diet and travel diary data were linked to objective built-environment measures of walkability and retail food environments. BMI and WC were self-reported ($n = 1,160$). Some respondents wore accelerometers to objectively measure physical activity ($n = 549$). Pathways from the built environment through behavior (walking and eating) to BMI and WC were assessed using path analysis.

Results: Walkability was associated with lower BMI and WC through physical activity and active travel. Healthy retail food environments were associated with healthy eating and lower BMI and WC, whereas walkability and healthy retail food environments were insignificant ($p < 0.05$). Walkable neighborhoods had less healthy food environments, but active travel was not associated with healthy eating or caloric intake.

Conclusions: Findings highlight the importance of neighborhood walkability and food environments in shaping physical activity, diet, and obesity.

INTRODUCTION

Physical activity levels and dietary patterns are major predictors of chronic disease risk, including cardiovascular diseases, hypertension, some cancers, and type 2 diabetes, in part through obesity (1-3). Recent evidence has suggested that obesity or having a chronic disease increases the risk of COVID-19-related mortality (4). Increased time spent at home has resulted in a heightened awareness of how our home environment impacts our health. Physical activity and diet are a function of individual preferences and personality (5,6), psychosocial factors that include enablement and support from others (7,8), and the built environment (9-11). Growing evidence has suggested that multicomponent environmental interventions focused on improving physical activity and diet, as opposed to a single intervention, could lead to better health outcomes (12,13). By the end of the last millennium, both researchers and practitioners began to more seriously consider the role of the built environment, which dictates presence, quality, and convenience of choices to be active (9) and eat healthy food (14).

Despite growing interest in the role of the built environment's influence on obesity and chronic disease, existing research lacks a holistic understanding of how the built environment influences

This paper is in memory and honor of Kathleen McSpurren from the University of Waterloo, who keenly oversaw the data collection process for this project on which this paper is based and whose untimely death from cancer occurred as this project was being completed.

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physical activity and dietary behaviors. Kremers et al. (15) proposed a dual-process model separating conscious and unconscious environmental influences on physical activity and diet. They asserted that developing a model that incorporates diet, activity, and whether a behavior is a direct, subconscious reaction to environment or an indirect cognitive choice results in a deeper understanding of human response to environmental influence. Through two case studies, Popkins et al. (16) showed positive associations between neighborhood resources and health-related behaviors, demonstrating the importance of the environmental influence on physical activity and healthy diet. A 2018 study using large-scale UK data (17) showed that high densities of physical activity facilities were associated with smaller waist circumference (WC) and lower BMI and body fat percentage; however, the adiposity measures were weakly associated with proximity to fast food. This is further evidenced by two studies that have shown complex patterns of physical activity and food environments in relation to adiposity measures (18,19), which call for a more systematic understanding of the concept of the integration of built environments, food access, and walkability.

Little empirical research to date has simultaneously assessed environmental influences on BMI and WC via both diet and physical activity in an integrated path modeling framework (17,20). Studies that examined built environment influences on healthy body weight have focused on physical activity or diet or lacked behavioral data to connect environments with health outcomes. A comprehensive study that includes both energy intake and energy expenditure in an integrated framework with detailed built environment and behavior measures for food and physical activity is still lacking. Furthermore, WC has seldom been included as an outcome, pedestrian infrastructure has rarely been used to estimate built environment metrics, and food purchasing has rarely been captured within the context of a household travel diary. The Neighbourhood Environments in Waterloo: Patterns of Active Transportation and Health (NEWPATH) study integrates dietary, travel, and physical activity data into a trip-destination protocol and determines access and walkability measures based on the sidewalk network.

Study Importance

What is already known?

- Physical activity levels, dietary patterns, and obesity are major predictors of chronic disease risk, including cardiovascular diseases, hypertension, some cancers, and type 2 diabetes.
- Growing evidence has suggested that multicomponent environmental interventions focused on improving physical activity and diet, as opposed to a single intervention, could lead to less obesity and reduced risk of chronic disease.

What does this study add?

- Objectively measured walkability and retail food environments were linked with objective physical activity and reported diet to predict obesity and waist circumference (WC) in an integrated framework.
- Walkability and healthy retail food environments were associated with lower BMI, smaller WC, and healthier eating patterns.
- Walkable neighborhoods were found to have less healthy food options but higher levels of active travel.

How might these results change the direction of research or the focus of clinical practice?

- Results support the need for the integrated assessment of neighborhood walkability and food environments to gauge collective impacts of physical activity and diet on obesity.
- Objective walkability, food environment, and physical activity data, along with WC data, are needed to simulate the causal pathway linking environments where we live with obesity.

METHODS

Conceptual model

This study is premised on an ecological framework in which individual behavior is influenced by the environments in which participants are situated (21). Recognizing that weight status is influenced by both diet and physical activity, this study follows an integrated approach to assessing built environment influences on weight status by simultaneously assessing causal pathways corresponding to both of these behaviors. The conceptual model for this paper is presented in Figure 1. It should be acknowledged that this is a highly simplified model for a complex, dynamic process. This reflects our intent to contribute evidence informing the relative importance of food and physical activity environments in supporting healthy weight status.

Sample

Data collection occurred from May 2009 to May 2010. Recruitment of participants from across the Region of Waterloo in Ontario, Canada, was stratified by three levels of walkability and income into a nine-cell matrix with an effort to achieve representativeness across household size compared with 2006 census totals. Telephone listings with postal codes were used for recruitment and were matched a priori to a regional walkability surface. A stratified sampling frame captured variation across walkability by income. This resulted in an "oversampling" in higher levels of walkability. Variation is required to test relationships between walkability and travel, physical activity, and dietary patterns. Random sampling would not yield sufficient variation across walkability to

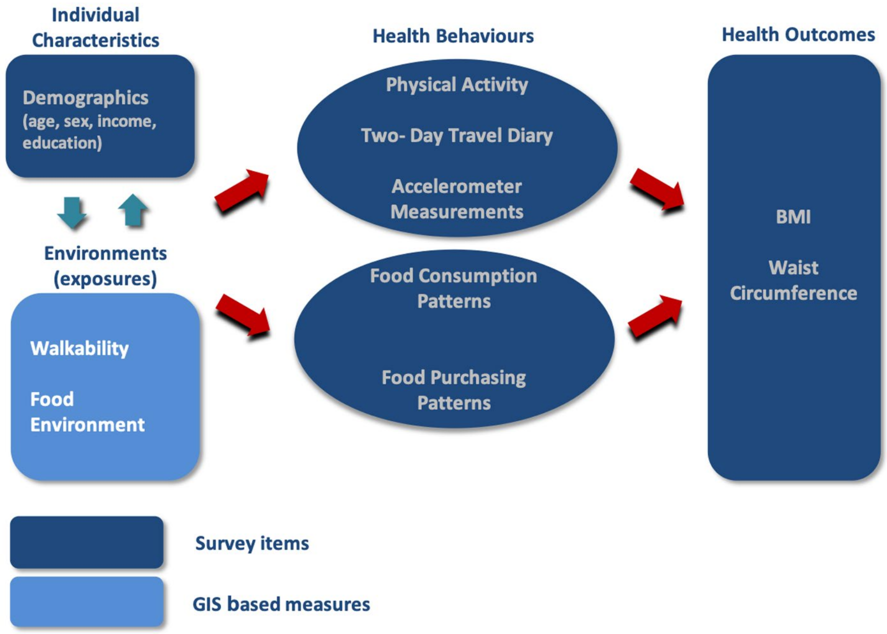

FIGURE 1 NEWPATH model. NEWPATH, Neighbourhood Environments in Waterloo: Patterns of Active Transportation and Health [Color figure can be viewed at wileyonlinelibrary.com]

detect these relationships because the Waterloo region is mostly unwalkable and car dependent (22).

Participating households were given a "simple" (n = 1,400) or "complex" (n = 1,000) survey package. The simple version had an adult head of household answer a telephone recruitment survey and it was then followed up with a mailed-out paper questionnaire on neighborhood preferences and food shopping. Every member of the household aged 11 or older self-reported waist and height measurements and completed a 2-day paper travel diary. The address of each location visited during the 2-day survey period was recorded with mode, vehicle occupancy, trip purpose, arrival time, and activity at destination. Households were recruited in "day-pairs" (pairs of consecutive days) across all days of the week. The complex survey version further included food purchase information and diet records within the travel diary, and one adult (aged ≥18 years) in the household wore an accelerometer. Three models of Actigraph accelerometers were used: the 7164, GT1M, and GT3X. Incentives were initially $15 for simple and $25 for complex and later increased to $30 for the complex version in larger households.

Total sample sizes achieved were 4,902 individuals for the simple survey and 1,359 individuals for the complex survey, of which 747 provided complete accelerometer data. Although the sample was stratified, the full sample was still somewhat representative of regional characteristics. One exception was that median household income for the Region of Waterloo is Canadian dollar [Can]$74,070 (23), whereas, in the simple sample, 47% of participants lived in households with an income over $85,000. Approximately 47% of the simple sample was male, and the median age was 42 years, compared with the regional median age of 36 years (23). For the following analysis, the sample was restricted to the subset of individuals with all relevant diet and physical activity data. The study was approved by the Behavioural Research Ethics Board of the University of British Columbia (H08-00189).

Measures

Outcomes

Two outcome measures were used, both obtained from self-reported items recorded on the travel diary: BMI and WC. BMI (weight in kilograms divided by height in meters squared) is the most common proxy for body composition and it has been used to link obesity and chronic illness (24,25). WC has been shown to be less crude than BMI based on evidence that abdominal fat, or central adiposity, is a better predictor of body fat percentage and morbidity than BMI (26-28). Obtaining WC data is rare to nonexistent within built environment and health studies and especially within the context of a household travel survey.

Behaviors

One representative behavioral variable was selected for each of the diet and physical activity pathways. For physical activity, average daily minutes of walking or cycling was taken from the travel diary data. For diet, the Healthy Eating Index for Canada (HEI) (29) was calculated based on food records recorded over both days of travel diary data collection. Food records were completed by every participant over the age of 10 years who participated in the complex survey. Briefly, participants recorded a detailed description of what they ate at every location, including the amount or serving size.

These records were entered into an ESHA, Inc., food processor to analyze the micro- and macronutrient composition of the diet over the 2-day period, and the Canadian Nutrient File (2007) was used to assess the food groups based on Canada's Food Guide to Healthy Eating. These data were used to derive the HEI, which is a comprehensive diet quality indicator based on dietary adequacy (e.g., number of servings of vegetables and fruit, number of servings of whole grains, number of grams of unsaturated fats) and moderation (e.g., proportion of energy intake from saturated fats, sodium intake). This index reflects Canadian food intake recommendations based on participants' age and sex and it is a normalized, comprehensive measure of diet from 0 to 100, in which scores less than 50 represent a poor diet, scores between 50 and 80 represent a diet in need of improvement, and scores above 80 represent a good-quality diet (30). Alternative behavioral variables were also tested by substituting daily minutes of moderate to vigorous physical activity (MVPA) from the accelerometer data for physical activity and average caloric intake per day (kilocalories) from the eating survey data for diet.

Environments

All data were linked to built environment measures of physical activity supports and the quality of the food environment. Built environment supports for physical activity were gauged by a "Walkability Index" (22), whereas those for the food environment were represented by a "Retail Food Environment Index" (RFEI) (31). Geographic information system-based walkability was calculated as the sum of *z* scores of the following four component measures: intersection density, land use mix, net residential density, and floor area ratio (FAR; a measure of commercial density), using a methodology similar to that developed previously by Frank et al. (22). These four measures are shown in greater detail in Figure 2.

The four walkability components shown in Figure 2 were calculated within a geographic area defined around participants' homes based on a 1-km pedestrian network distance. Density and land use mix collectively determine proximity, whereas intersection density determines connectivity or route directness. Proximity and connectivity collectively determine the presence and ability to access opportunities. Commercial FAR captures the degree to which the pedestrian environment is designed to support walking or driving. High FAR occurs where buildings and stores are near the sidewalk's edge rather than behind a sea of parking.

Nearly all previous studies have used the road network to create area or "buffer" in which these measures were calculated. The pedestrian network was created from three components: the local street network (excluding expressways, highways, and ramps), cul-de-sac connectors, and multiuse trails. This network was created by the Region of Waterloo and was used to create street-based network buffers, which represent the area accessible to participants within 1 km of their homes. Higher values of the walkability index correspond to neighborhoods that are more dense and well connected and that contain a greater mix of land uses. The walkability index was calculated for the area within a 1-km sidewalk-based network buffer distance from the centroid of every postal code in the Region of Waterloo. The resulting "walkability surface" is illustrated in Figure 3.

The food environment was assessed using the RFEI, calculated for a 1-km euclidean radial buffer around the homes of study participants. The RFEI is calculated as the ratio of the number of fast-food restaurants and convenience stores to the number of grocery and specialty food stores around respondent homes, with higher ratios corresponding to less healthy food environments (31,32).

Statistical methods

Figure 4 provides a conceptual model for this analysis and builds off the linkages presented in Figure 1. Two pathways of influence (diet and physical activity) with multiple mediators were established to simultaneously evaluate relationships between environment features and health-related outcomes. Several factors mediate these relationships, including activity patterns, body weight, and biological mechanisms. We chose to use a structural equation approach or "path analysis," which enabled us to calculate model coefficients for each of the paths indicated, simultaneously, in a single model. The specified models are estimated in R statistical software (The R Foundation), using the "lavaan" package (33), with Huber-White robust maximum likelihood estimation.

Four variables were used as sociodemographic controls: age (in years, as a continuous variable), sex (as a binary variable, with male as reference level), household income (as a three-level factor variable split at Can$35,000 and $85,000, with the middle level as the

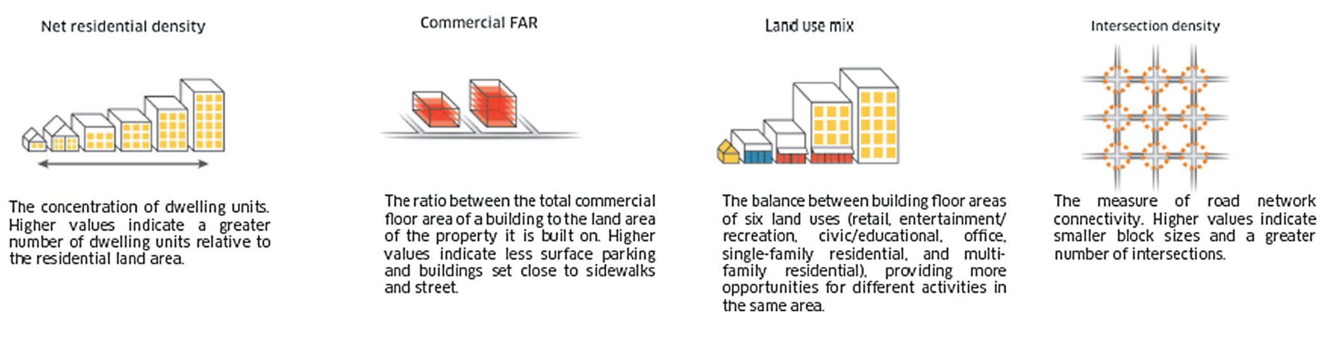

FIGURE 2 Walkability components. FAR, floor area ratio [Color figure can be viewed at wileyonlinelibrary.com]

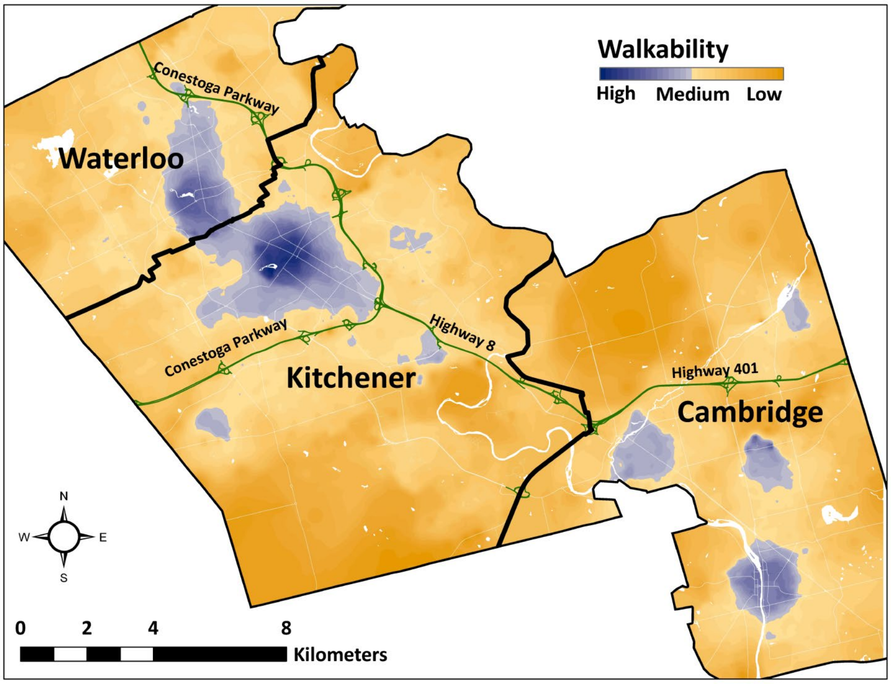

FIGURE 3 Walkability surface for the Region of Waterloo, Ontario, Canada [Color figure can be viewed at wileyonlinelibrary.com]

reference), and education (a binary variable for having a graduate degree, with false as the reference level). These controls are included as independent effects on the outcome, physical activity, and diet variables.

In deriving the statistical model, the major simplification from our conceptual model is that the analyses do not account for environmental influences on neighborhood preferences or individual influences on the environment (e.g., via self-selection). A variable for walkable neighborhood preference was included in the survey but was only available with complete data for all other variables for fewer than 200 respondents; therefore, it could not be used in the path analysis. Neighborhood preference correlated with both neighborhood walkability and sociodemographic variables, as expected. The control variables in the model can account for some self-selection, but the reliance on these cross-sectional data limits causal inference, as discussed later in this paper.

RESULTS

The final sample with complete data (BMI or WC, minutes of walking or cycling, HEI, walkability, RFEI, and age, sex, income, and education controls) consists of 1,160 participants. Descriptive statistics for the sample are summarized in Table 1. The sample consists of similar proportions of individuals who were classified as having normal weight (BMI = 18.5-25) at 37%, having overweight (BMI = 25-30) at 33%, and having obesity (BMI > 30) at 27%, with a small proportion (3%) who were underweight. The average walkability of 0.06 represents a slightly higher walkability than the regional mean (0). The mean RFEI value of about 4.9 means that individuals in the sample lived in neighborhoods with approximately five times as many convenience stores and fast-food outlets as grocery stores. According to the United States Department of Agriculture (USDA) classification for the HEI, the mean HEI of 53 corresponds to a diet that needs improvement (HEI between 50 and 80).

Only a subset of participants wore accelerometers. Therefore, objectively assessed MVPA was measured only for 549 of the 1,160 participants who otherwise had complete data. On average, individuals obtained approximately 31 min/d of MVPA, with 43% obtaining at least 30 min/d of MVPA. The subsample with MVPA data was not substantially different from the full sample across these variables (Table 1), with the exception of fewer male participants.

Model estimation results

Results of the path analysis are shown in Table 2, and the key pathways are summarized in Figure 5. Model fit indices indicate acceptable fit: high comparative fit index and low root mean square error of approximation. The R^2 for the outcome variables was 0.092 for BMI and 0.194 for WC, indicating a closer statistical fit for the WC model. R^2 for the behavior variables (walk/bike time and HEI) was 0.06 to 0.11 in both models. Slightly more complete observations were available for WC (1,105) than for BMI (1,031). The full standardized effect of walkability on BMI and WC (both direct and indirect through walk/bike time) was −0.081 ($p = 0.002$) and −0.050 ($p = 0.060$), respectively. The full effect of RFEI on BMI and WC (both direct and indirect through HEI) was −0.013 ($p = 0.649$) and 0.029 ($p = 0.330$), respectively.

Results indicate that, after controlling for sociodemographic variables, walkability was associated with greater walking and

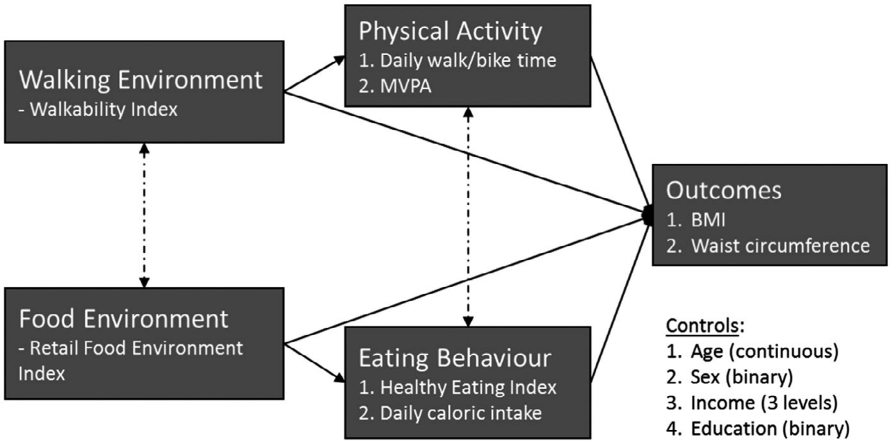

FIGURE 4 Diagram of model tested using path analysis. MVPA, moderate to vigorous physical activity

TABLE 1 Sample characteristics

	Full sample (n = 1,160)	Subsample with MVPA data (n = 549)
Outcomes		
BMI (kg/m^2)	27.12 (5.80)	27.86 (5.82)
WC (cm)	89.60 (16.65)	90.68 (16.11)
Physical activity pathway		
Standardized walkability *z* score index value	0.06 (3.53)	0.49 (3.71)
Walking or biking time (min/d)	13.66 (28.41)	13.59 (28.70)
MVPA (min/d)[a]	31.15 (24.36)	31.15 (24.36)
Diet pathway		
RFEI	4.85 (4.55)	5.24 (5.42)
HEI	53.36 (9.81)	53.82 (9.75)
Caloric intake (kcal/d)	1,847 (984)	1,804 (913)
Controls		
Age (y)	42.21 (17.27)	46.93 (14.3)
Sex	45.60% male	32.06% male
Household income		
Low (<Can$35,000)	17.59%	17.30%
Middle	41.81%	42.08%
High (>Can$85,000)	40.60%	40.62%
Education (graduate degree)	41.03%	44.44%

Note: Data given as mean (SD) or percentage.

Abbreviations: Can, Canadian dollar; HEI, Healthy Eating Index; MVPA, moderate to vigorous physical activity; RFEI, Retail Food Environment Index; WC, waist circumference.

[a]52.7% missing data in full sample.

cycling time and lower BMI and WC. RFEI was associated with lower HEI (less healthy eating), which, in turn, was associated with higher BMI and WC, although the combined effect was not significant at $p < 0.05$. In both models, more walkable neighborhoods had less healthy food environments (higher RFEI), but higher levels of active travel (greater walking and cycling time) were not significantly associated with healthy eating at $p < 0.05$.

Regarding the control variables, increased age was associated with less walk and bike time and higher BMI and WC. Female participants had higher diet quality scores and had significantly lower WC at $p < 0.01$ (although not lower BMI). There were no significant effects of income on behavior or either outcome at $p < 0.10$ in either model. Having a graduate degree was associated with healthier eating, but not physical activity; it also was moderately associated with lower BMI (at $p = 0.066$), but not WC. Age also significantly ($p < 0.01$) covaried with education; no other covariance among control variables was significant at $p < 0.10$.

TABLE 2 Path analysis model estimated standardized parameters

	BMI outcome		WC outcome	
	β	p value	β	p value
Physical activity pathway				
Walkability walk/bike time	0.244	<0.001	0.255	<0.001
Walk/bike time outcome	−0.072	0.042	−0.044	0.055
Walkability outcome	−0.063	0.023	−0.038	0.153
Diet pathway				
RFEI HEI	−0.057	0.020	−0.074	0.001
HEI outcome	−0.055	0.075	−0.084	0.003
RFEI outcome	−0.016	0.572	0.023	0.451
Covariance				
Walkability RFEI	0.174	<0.001	0.145	<0.001
Walk/bike time HEI	0.036	0.245	0.019	0.516
Controls				
Age				
Walk/bike time	−0.179	<0.001	−0.195	<0.001
HEI	0.043	0.155	0.003	0.906
Outcome	0.253	<0.001	0.330	<0.001
Sex (female)				
Walk/bike time	−0.008	0.794	−0.007	0.811
HEI	0.200	<0.001	0.186	<0.001
Outcome	−0.042	0.167	−0.244	<0.001
Income (low)				
Walk/bike time	−0.037	0.213	−0.020	0.491
HEI	−0.025	0.427	−0.018	0.566
Outcome	0.044	0.195	0.021	0.512
Income (high)				
Walk/bike time	0.019	0.571	0.028	0.370
HEI	−0.052	0.116	−0.047	0.143
Outcome	−0.033	0.295	−0.044	0.117
Education (graduate degree)				
Walk/bike time	0.024	0.414	0.007	0.813
HEI	0.122	<0.001	0.124	<0.001
Outcome	−0.055	0.066	−0.032	0.247
Goodness of fit				
CFI	0.959		0.968	
RMSEA	0.030		0.031	
R^2 (outcome)	0.092		0.194	
Number of observations	1,031		1,105	

Abbreviations: CFI, comparative fit index; HEI, Healthy Eating Index; RFEI, Retail Food Environment Index; RMSEA, root mean square error of approximation; WC, waist circumference.

Alternative specifications

Additional model specifications were tested using alternate variables for physical activity (MVPA) and eating behaviors (daily caloric intake). Daily caloric intake (in kilocalories) was log-transformed to account for positive skew. The key results of these model estimates are given in Table 3. An important difference among the models is the sample size (roughly half as large for the models using accelerometer-based physical activity data [MVPA]). The walkability-to-obesity pathway was significant at $p < 0.05$ in all the models, either as a direct effect or indirect effect through physical activity (or both). Conversely, only RFEI was a significant predictor in one model (A4) at $p < 0.05$ on the diet pathway.

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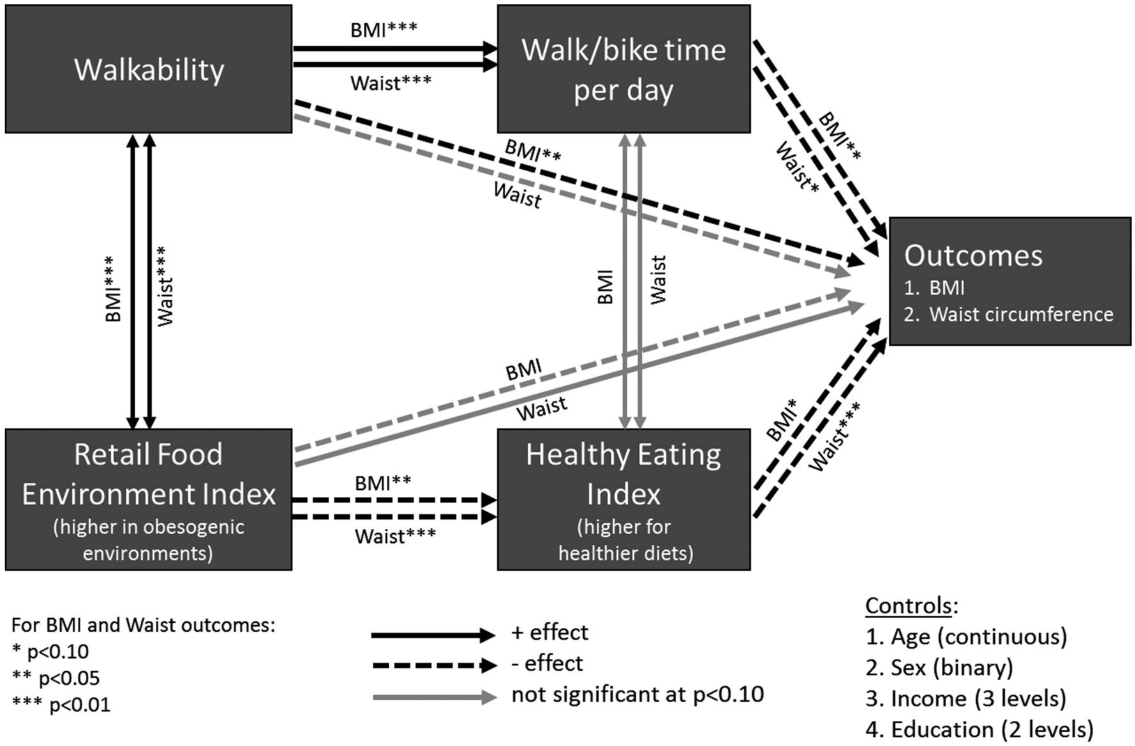

FIGURE 5 Summary of key effects in estimated path analysis model

TABLE 3 Alternative model specifications[a]

	Model A1	Model A2	Model A3	Model A4	Model A5	Model A6
Outcome variable	BMI	BMI	BMI	WC	WC	WC
Physical activity variable	MVPA	Walk/bike time	MVPA	MVPA	Walk/bike time	MVPA
Eating behavior variable	HEI	Caloric intake	Caloric intake	HEI	Caloric intake	Caloric intake
Physical activity pathway						
Walkability physical activity	0.076*	0.243***	0.074*	0.079*	0.255***	0.078*
Physical activity outcome	−0.057	−0.074**	−0.058	−0.012	−0.045**	−0.020
Walkability outcome	−0.125***	−0.063**	−0.124***	−0.086**	−0.041	−0.089**
Diet pathway						
RFEI eating behavior	−0.048	0.004	−0.004	−0.077**	−0.009	−0.012
Eating behavior outcome	−0.006	0.007	−0.003	−0.064	0.028	0.023
RFEI outcome	−0.005	−0.013	−0.005	0.017	0.029	0.022
Correlations						
Walkability RFEI	0.170***	0.174***	0.170***	0.143***	0.146***	0.143***
Physical activity eating	0.131***	0.012	0.059	0.116***	−0.004	0.037
Goodness of fit						
CFI	1.000	0.927	1.000	0.980	0.934	0.932
RMSEA	0.001	0.040	0.001	0.021	0.047	0.038
R^2 (outcome)	0.044	0.089	0.044	0.135	0.186	0.133
Number of observations	512	1,029	511	550	1,104	550

Abbreviations: CFI, comparative fit index; HEI, Healthy Eating Index; MVPA, moderate to vigorous physical activity; RFEI, Retail Food Environment Index; RMSEA, root mean square error of approximation; WC, waist circumference.

[a]Standardized parameters.

*$p < 0.10$; **$p < 0.05$; ***$p < 0.01$.

Based on the estimated parameters in Table 2 and Table 3, physical activity in the model was a stronger connection between walkability and obesity when represented as active travel (walk/bike time) than general physical activity (MVPA). Similarly, diet was a stronger connection between food environment and obesity when represented by the HEI than general caloric intake. The covariance between the two behaviors was only significant, at $p < 0.05$, for MVPA and HEI.

Additional models were estimated using further alternatives for physical activity, including metabolic equivalent (MET)-minutes/day, based on the accelerometer data and MET threshold assumptions from Gillis et al. (34), and energy expenditure per day in kilocalories, based on a combined measure of accelerometer data and resting metabolic rate (RMR) assumptions drawn from McMurray et al. (35). The models reflected the patterns shown earlier but with a poorer goodness of fit, possibly because of the additional measurement uncertainty involved. Also, daily energy expenditure in kilocalories was related to body weight (through RMR), which introduces potential endogeneity into the statistical model for BMI.

Another analysis combined daily energy expenditure and caloric intake (both in kilocalories) to calculate the daily energy balance (net caloric flux in, in kilocalories). Net caloric intake had a mean value of just 2 kcal and a median of −45 kcal, suggesting an overall balance in the data set but high variability among participants with a SD of 915 kcal and interquartile range of −606 to 466 kcal. Net caloric intake was negatively correlated with BMI (−0.26, $p < 0.01$) and WC (−0.24, $p < 0.01$), which could be an artifact of the role of body mass in estimating energy expenditure (through RMR). At a given MET level, higher body mass leads to higher estimated RMR and caloric energy expenditure, and therefore lower calculated net caloric intake. Net caloric intake was also positively correlated with walk/bike time, MVPA, HEI, and walkability (although not at $p < 0.05$), suggesting it was higher for respondents in healthier environments and those with healthier habits.

DISCUSSION

Significant associations were found between neighborhood walkability and physical activity, BMI, and WC. As expected, based on a previous study (36), unhealthy food environments were also associated with higher BMI and WC, indirectly and through less healthy eating behavior (lower HEI). Interestingly, the significant relationship between walkability and unhealthy food environments had contrasting impacts on obesity. Although quickly changing, at the time of this data collection, household income was inversely related with walkability in the Region of Waterloo (correlation of −0.23, $p < 0.01$), a dominant pattern until recently.

Evaluating relationships between diet and physical activity is rare within the context of a built environment study of this nature. Healthy eating (HEI) was significantly associated with objectively measured physical activity (MVPA) after controlling for the environment and sociodemographic variables, but not active travel (walk/bike time). Caloric intake was not significantly associated with either definition of physical activity, indicating that respondents did not necessarily adjust daily caloric intake with energy expenditure. This is not surprising given the excess caloric consumption across North America (37). A modern sedentary lifestyle tends to encourage the consumption of energy but discourage energy expenditure, causing energy imbalance (38). An implication of this finding is that it may not be appropriate to include the caloric requirements of active travel in studies of travel energy consumption (39,40) because the marginal change in caloric consumption with increased walking and cycling may be insignificant. Even outside of the analysis framework (i.e., not controlling for environments and sociodemographic variables), the correlation between caloric consumption and walk/bike time was only 0.05 ($p = 0.06$) and, with MVPA, was 0.07 ($p = 0.08$).

The major limitation of this study is that it relies on cross-sectional data and is therefore unable to demonstrate causal effects. It also does not control for self-selection because of sample-size reductions negating the ability to include attitudinal predisposition. Another limitation is the simplified conceptual approach to approximate "energy balance." Although explained variance is on par with or greater than other studies in this area, considerable unexplained variance likely reflects lack of environmental variability in the sample, which, in turn, is likely due to a lack of environmental variation in the region. Recruitment was stratified by walkability to maximize the environmental variation achieved. The range of walkability encompassed by sample participants represents 82% of the range of walkability in the region. The Region of Waterloo is typical of many small or midsized cities in that it is characterized by relatively little environmental variation. The region has a "dispersed" spatial structure, characterized by low densities and little mixing of land uses. At the time of the study, 58% of the region was developed to residential densities of 10 units per acre or less, whereas 97% was developed at 20 units per acre or less (based on densities calculated for all postal code centroids in the region as part of the walkability surface). Consistent with the characteristic urban form of the region, the predominant mode of transportation is private automobile (either driver or passenger), at 88% of all trips, with relatively low proportions of walking (5.6%), transit (3.3%), and cycling (0.6%). As the study includes data from only one region, the transferability of the findings to other contexts is unknown. Another limitation in the analysis is that the walkability and food environment measures were calculated based on the home neighborhood only, whereas physical activity and dietary behavior is expected to be substantially influenced by environments surrounding the workplace and route between home and work (41,42).

Additional research is under way to investigate these relationships using a more complex definition of individual food environments that extends beyond the home location and includes work and other areas. The study contains food purchasing data linked with destinations and can help inform the spatial definition of food environments. The results in this paper can help to determine how to define and evaluate the environments and behaviors. As shown earlier, walk/bike time and HEI appear to be the strongest behavioral connections between walkability and food environments and obesity-related health outcomes. Although this study is based on data collected a decade ago, underlying structural relationships between walkability, food environments, and obesity are stable. Changes to the built environment are slow to manifest, and decisions to change it may take a decade or more to manifest. Results are applicable not only to obesity-related chronic disease considerations but also to the known links between chronic and infectious disease.

CONCLUSION

The NEWPATH study was a collaboration between researchers and practitioners whose goal was to expand existing methods to evaluate the health impacts of community design. This study includes several advancements in research design and highlights the need to incorporate an integrated framework to understand the complex and dynamic relationships between diet, physical activity, and health. Study findings highlight the importance of neighborhood walkability in shaping physical activity, BMI, and WC, as well as the importance of neighborhood food environments in shaping healthy eating behavior, which, in turn, predicts BMI and WC. Findings from this study are relevant. This adds new information while confirming the findings of similar studies conducted primarily in larger city contexts and extends these to the context of midsized cities. Findings from this effort have helped to inform plans and policies set forth by the Region of Waterloo and helped to document the critical population health impacts of walkability and neighborhood food environment in shaping healthy body weight.O

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CONFLICT OF INTEREST

The authors declared no conflict of interest.

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