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Original Research Article

Neighborhood urban form and individual-level correlates of leisure-based sedentary activity in Canadian adults

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What is already known on this subject?

Evidence regarding the potential determinants of sedentary behavior is rapidly accumulating however, little is known about the extent to which the neighborhood built environment encourages or discourages leisure-based screen time activities including watching television and using computers. The neighbourhood environment appears to be associated with sedentary behavior, although studies to date often include either objectively-assessed or self-reported measures of the built environment, but not both.

What this study adds?

The objectively-assessed, but not self-reported, neighborhood built environment was associated with participation in leisure-based screen time activity even after adjusting for physical activity and sociodemographic correlates. Improving neighborhood walkability has the potential to not only increase physical activity but also decrease sedentary behavior.

ABSTRACT

Background: Independent of physical activity levels, regular participation in sedentary activity is associated with negative health consequences. Despite evidence for an association between the built environment and physical activity, less evidence exists regarding relations between the built environment and sedentary behavior. This study investigated the extent to which objectively-assessed and self-reported neighborhood walkability, in addition to individual-level characteristics, were associated with leisure-based screen time activity in adults.

Method: A random cross-section of Canadian adults provided complete telephone-interview and postal survey data (n=1967). Captured information included leisure-based screen time, moderate and vigorous-intensity physical activity, perceived neighborhood walkability, sociodemographic characteristics, self-reported health status, and self-reported height and weight. Based on objectively-assessed built characteristics, participant's neighborhoods were identified as being low, medium, or high walkable. Using multiple linear regression, leisure-based screen time was regressed on self-reported and objectively-assessed walkability adjusting for sociodemographic and health-related covariates.

Results: Compared to others, residing in a objectively-assessed high walkable neighborhood, women, having a college education, at least one child at home, a household income ≥$120,000/year, and a registered motor vehicle at home, reporting very good-to-excellent health and healthy weight, and achieving 60-min/wk of vigorous-intensity physical activity were associated ($p<.05$) with less screen time. Marital status, dog-ownership, season, self-reported walkability, and achieving 210-minutes of moderate-intensity physical activity were not significantly associated with leisure-based screen-time.

Conclusion: Improving neighborhood walkability could decrease leisure-based television and computer screen time, while also increasing physical activity. Programs aimed at reducing sedentary behaviour may want to consider an individual's sociodemographic characteristics, physical activity level, health status, and weight status, in addition to the walkability of their neighbourhood as these factors were found to be important independent correlates of leisure-based screen-time activity.

Key words: sedentary, physical activity, walkability

ARTICLE SUMMARY

Strengths and limitations of this study

- A novel aspect of this study was the investigation of both objectively-assessed and self-reported built environmental characteristics in relation to leisure-time screen-based sedentary activity in adults.

- Participant recruitment involved simple random sampling from the population.

- Statistical models, with leisure-time screen-based activity as an outcome, adjusted for potential confounders including participation in moderate-intensity and vigorous-intensity physical activity and sociodemographic characteristics.

- Despite the known limitations of using self-report measures, this approach allowed us to assess the relationship between the built environment and a specific and popular type of sedentary activity – i.e., leisure-based screen-time.

BACKGROUND

Evidence regarding the negative health consequences of sedentary lifestyles is accumulating [1]. Sedentary behavior includes activities that primarily involve sitting and that require undertaking minimal energy expenditure (e.g., watching television, using computers, driving motor vehicles) [2]. Sedentary behavior is a modifiable risk factor for type 2 diabetes, cardiovascular disease, overweight and obesity, and early mortality[3-6]. Moreover, the negative health consequences of sedentary behavior may not offset the positive health benefits derived from being sufficiently physically active – that is, the effect of sedentary behavior on health appears to be independent of physical activity [7].

Several popular sedentary activities have been investigated in relation to health, including screen time (e.g., television viewing, computer use, and video games), reading, sitting in motorized vehicles, and occupational sitting[8]. Similar to physical activity, the socioecological model provides a useful framework for understanding the determinants of sedentary behavior. Intrapersonal, interpersonal, physical environmental, and policy related factors have been elucidated as potentially important determinants of sedentary behavior[2]. Evidence to date from this rapidly growing research area suggests that gender, age, education, income, employment status, weight status, those living with children at home, attitude towards sedentary behavior, participation in moderate-to-vigorous intensity physical activity, and the built environment are associated with sedentary behavior [9 10]. Further, the correlates of sedentary behavior appear to be context and behavior-specific (e.g., home versus workplace) and therefore different types of sedentary behavior likely have distinct correlates[2 10 11]. For instance, despite having similarly low energy expenditure (i.e., <2 metabolic equivalents;[12]) driving motorized vehicles and television viewing have some shared, but also different determinants[10]. Understanding the correlates of specific types of sedentary behavior could result in an increased focus on these specific determinants for interventions.

There is growing public health interest in the association between the neighborhood urban form and sedentary behavior. Findings so far between the objectively-assessed built environment and sedentary behavior are promising. For instance, Australian women who resided in low walkable neighborhoods spent more time viewing television compared with their counterparts residing in high walkable neighborhoods[13]. Similarly, Kozo et al.[11] found more television viewing time associated with lower neighborhood walkability in US adults. In contrast, Belgian adults residing in high walkable neighborhoods had higher accelerometer-measured and self-reported sitting time than those residing in less walkable neighborhoods [14]. Studies have also found associations between self-reported environment characteristics and sedentary behavior. Van Dyke et al.[15] reported finding significant associations between individual self-reported individual (i.e., land use mix, aesthetics, and safety) and composite environment characteristics and self-reported sitting. Moreover, Wallmann-Sperlich et al.[16] found that among several self-reported measures of the built environment (e.g., access to transit, recreation areas, and destinations, presence of trees, and safety) perception of traffic safety only, was associated with sitting time among German women. There are few studies of sedentary behavior however, that incorporate both self-reported and objectively-assessed built environment correlates within the same analysis. For instance, Ding et al.[17] found that objectively-assessed, but not self-reported, walkability characteristics to be associated with longitudinal changes in television viewing time. Given the limited and sometimes mixed findings regarding the associations between self-reported and objectively-assessed built environment characteristics and sedentary behavior suggests that further investigation is warranted.

Current levels of participation in sedentary activity among adults is concerning. Up to 38% of non-communicable diseases in Canada are attributed to sedentary lifestyles[18]. This is concerning given that at least two thirds of Canadian adults' waking hours are spent sedentary[19] and approximately of 29% of adults are watching television at least 15 hours per week and 15% are using computers for at least 11 hours per week[20]. Scientific understanding of the correlates of sedentary behavior in adults is rapidly emerging[11] but our understanding of the built environment correlates is rudimentary[10]. Thus, this study investigated the extent to which the objectively-assessed and self-reported neighborhood walkability, controlling for other sociodemographic, behavioral, and health-related characteristics, were associated with television and computer determined leisure-based screen time in adults.

METHODS

Study design and sample recruitment

The study design and recruitment have been fully described elsewhere[21 22]. The study location was Calgary Alberta, Canada. A random sample of adults (≥ 18 years of age) was recruited during telephone-interviews from August-October 2007 (n=2199, response rate=33.6%) and January-April 2008 (n=2223, response rate=36.7%). Telephone-interviews captured information about physical activity, psychosocial, and sociodemographic characteristics. A sub-sample of participants (n=1967; 44.5%) also completed and returned a follow-up postal survey. The postal survey captured information about perceived neighborhood characteristics, health and weight status, physical activity, sedentary behavior, and additional sociodemographic characteristics. The University of Calgary Conjoint Health Research Ethics Board approved this study and all participants provided informed consented.

Measures

Screen time: Participants were asked, "*On average, how many hours per week do you spend watching television or using a computer outside of your workplace? (e.g., videogames, computer games, DVD/movies, internet, email etc.)*". Time spent on television-viewing and computer use can be self-reported reliably[8]. We converted screen time hours per week to hours per day to assist in interpretation of results.

Moderate-intensity physical activity (MPA): Participants reported time spent in a usual week undertaking transportation and recreational walking, and other moderate-intensity physical activity for recreation, health or fitness, inside and outside of their neighborhood[23 24]. Responses were summed and dichotomized to reflect achievement of 30-minutes of daily MPA recommended for health benefits (i.e., <210 min/wk vs ≥210 min/wk).

Vigorous-intensity physical activity (VPA): Participants reported time spent in a usual week undertaking vigorous-intensity physical activity for recreation, health, or fitness, inside and outside of their neighborhood[23 24]. Responses were dichotomized to reflect achievement of at least 60-minutes of VPA per week – a level that has been reported to provide health benefits[25].

Health-related characteristics: Participants rated their overall level of health on a five-point scale. Responses were collapsed into three categories: poor/fair, good, and very good/excellent. This item had acceptable test-retest reliability (Spearman rank correlation=0.86). Participants' body mass index (BMI; weight/height^2) was estimated from their self-reported height and weight which incorporated a correction factor to account for sex-related reporting bias[26]. BMI was dichotomized into healthy weight (<25 kg/m^2) and overweight (≥25 kg/m^2).

Sociodemographic characteristics: Sociodemographic characteristics included gender, highest education level achieved (high school or less, college, or university), gross annual household income (≤$60,000/year, $60,000-119,000/year, ≥$120,000/year, or don't know/refused), dog ownership (non-owner vs. owner), marital status (married/living together vs. other), the number of dependents <18 years old living in the residence (none vs. at least one), and number of registered motor vehicles (0, 1, 2, or ≥3 vehicles). The season in which the telephone-interview was conducted was recorded.

Self-reported neighborhood walkability: Neighborhood walkability was captured using items (n=25) from the Neighborhood Environment Walkability Scale (NEWS-A)[27]. Item responses were captured on a balanced 4-point scale from strongly agree to strongly disagree. Item responses were averaged and then tertiled into low, medium, and high walkability categories. Items had adequate internal consistency (Cronbach's alpha=0.71).

Objectively-assessed neighborhood walkability: Procedures for determining the neighborhood built environment have been described elsewhere[21]. Briefly, participants' household postal codes were geocoded and a 1.6 km line-based network walkshed estimated. Using Geographical Information Systems (GIS) we assessed the built characteristics associated with physical activity within the walkshed. The derived built environment variables included: walkshed area (km^2), total population/km^2, proportion of neighborhood green space, path/cycleway (meters)/km^2, number of businesses/km^2, number of bus stops/km^2, length of sidewalk (meters)/km^2, mix of park types/km^2, and mix of recreational facilities/km^2. The built characteristics were entered into a two-staged cluster analysis which identified three neighborhood types: low (LW), medium (MW), and high walkable (HW) neighborhoods[21]. LW neighborhoods have smaller walkshed area, lower population density, sidewalk availability, and recreational destination mix, fewer business destinations and bus stops, and highest proportion of green space compared with the other neighborhood types. HW neighborhoods have higher population density, walkshed area, path/cycleway availability, and recreational destination mix, and more business destinations and bus stops compared with LW and MW neighborhoods (Table 1).

Statistical analysis

Means (±standard deviations) were estimated for all correlates. One-way Analysis of Variance was used for univariate comparisons of screen time (hours/day) between self-reported and objectively-assessed walkability, and sociodemographic, behavioral and health variables. Zero-order (unadjusted) and partial (adjusted) correlations were undertaken between screen, MPA, and VPA time. Fully-adjusted multiple linear regression models were used to regress screen time on the sociodemographic (sex, age, income, dependents <18 years at home, marital status, dog ownership, count of registered motor vehicles), behavioral (recommended MPA and VPA), health (self-reported health and BMI), self-reported and objectively-assessed walkability variables, and season. Linear regression estimates for all categorical variables were reported as marginal means (with 95% confidence intervals (CIs)). Analysis was undertaken using SPSS version 20.

RESULTS

Sample characteristics

Complete data from n=1906 were included in the analysis. The sample had higher representation from women, Caucasians, and those university educated, without children <18 years, married or living with another, without a dog, with at least two registered vehicles at home, and in good to excellent health (Table 2). Approximately half of the sample resided in LW (56.3%) neighborhoods, followed by MW (36.4%), and HW (7.3%) neighborhoods. Over half of all participants achieved recommended MPA (63.0%) and VPA (53.7%). On average, adults participated in 1.78±1.52 hours/day of screen time, with 39.5% undertaking ≥2 hours/day. Zero-ordered and partial correlations (adjusting for MPA) showed a significant association between screen time and VPA (r=-0.100 and r=-0.098, p<.05, respectively). Zero-ordered and partial correlations between screen time and MPA were not statistically significant (r=-0.019 and r=-0.004, respectively), however, time spent in MPA and VPA was positively correlated (zero-ordered r=0.233, p<.05).

Correlates of participating in screen time

After adjusting for all correlates, screen time was significantly higher (p<.05) among men versus women, no child versus at least one child at home, owning none versus owning two or at least three registered motor vehicles, and owning one versus two registered motor vehicles, those reporting good versus very good/excellent health, those participating in ≥60 min/wk versus <60 min/wk, and residents of objectively-assessed LW versus HW neighborhoods (Table 3). No other correlates were statistically significantly associated with screen time. The inclusion of all correlates in the linear regression model explained 7.6% of the explainable variance in screen time.

DISCUSSION

In support of prior evidence[11 13], we found that objectively-assessed, but not self-reported, neighborhood walkability was independently associated with leisure-based screen time. We also found that gender, education, household income, having a children at home, having a registered motor vehicle, VPA, self-reported health, and self-reported weight status were significant correlates, supporting previous studies showing the importance of sociodemographic and health-related factors in relation to sedentary behavior[10]. The findings between access to registered motor vehicles and screen time in particular is a novel finding of this study. Marital status, dog-ownership, season, self-reported walkability, or MPA were not associated with leisure-based screen time.

A unique finding of our study was that objectively-assessed, but not self-reported, walkability was associated with screen time. Similar to others[11 13], we found that adults residing in objectively-assessed low walkable neighborhoods participated in more screen time than those in high walkable neighborhoods. Higher sedentary time has been found among men and women residing in regional centres versus the city centre, which to some extent might reflect the difference in urban form and physical activity opportunities in these two environments[28]. Others have found relationships between objectively-assessed walkability and television viewing time after considering effect modification by other characteristics such as working status[17] and gender[13]. Similar to our study findings, Ding et al.[17] found no significant association between perceived walkability characteristics in models that included objectively-assessed walkability, as well as other sociodemographic characteristics. Residing in a high walkable neighborhood was associated with less screen time than residing in a low walkable neighborhood. Our finding is encouraging given the importance of the neighborhood environment for supporting physical activity[29 30]. Nevertheless, urban planner and health practitioners need more evidence about which neighborhood environmental characteristics individually or in combination might best explain differences in sedentary behavior.

A little less than half our sample participated in 2 hours of screen time per day – similar levels have been reported in Canada and elsewhere[17 28 31]. In support of evidence elsewhere[13 31 32], we found that adults of healthy weight reported less screen time than their overweight counterparts. Speculatively, the home environment might have contributed to the association between weight status and sedentary behavior in our study. Overweight adults have been found to own a higher count of televisions and to be more likely to have a television in the bedroom compared with healthy weight adults[32]. The count of televisions and computers in the home[31 32] and television size[31] might be positively associated with screen-based activity in adults. Despite including measures of the physical environment (urban form and season) we did not include measures of the home-based environment (i.e., where the majority of leisure-based sedentary activity occurs), which has been found to be important with regard to television viewing[33]. Home-based interventions that modify the physical environment could discourage television-viewing[34]. The estimated association between weight status and screen time might also be confounded by unhealthy diet, which is associated with compromised weight status and sedentary behavior[35]. Related to this was our finding that participants reporting better health also reported lower screen time than those who reported worse health. Self-reported poor health among those watching more television has been found elsewhere[36]. While there appears to be an association, we are unable to infer the causal pathway between self-reported health and screen time based on our cross-sectional data. Longitudinal and quasi-experimental studies that examine changes in sedentary behavior, physical activity, and diet in response to modifications to the neighborhood and home physical environments are needed to provide stronger evidence for assessing temporality.

Noteworthy, was that the number of registered motor vehicles at home was negatively associated with screen time. A recent study found an increase in the likelihood of watching television ≥2 hours/day among older Japanese women who reported being non-drivers[37]. Not having a registered motor vehicle (or being a non-driver) could decrease an individual's ability to access physical activity opportunities outside the home and therefore result in more time spent in the home where television viewing is a convenient activity option. Despite adjusting for income and education, it is possible that the association between registered motor vehicles at home and screen time could to some extent reflect other dimensions of socioeconomic status[38]. Others have found associations between socioeconomic status and leisure-time sedentary activity[11 13 14]. Higher education, in particular, is consistently associated with less television-viewing time and computer use[11 13 14 17 28 31 36]. We found that adults with high school or less education had significantly higher screen time than those with a college education. The negative relationship between household income and screen time found in our study, while not always statistically significant, showed a consistent pattern. Other studies also report higher television viewing in those with lower incomes[13]. This finding might reflect the financial barrier to participating in recreational activities outside of the home among low-income households, thus television and computer use are alternative and less expensive leisure pursuits. Interventions for decreasing sedentary behavior should equally target adults across the education and income spectra.

In general, weak correlations between physical activity and sedentary activity have been found[39].

An Australian study found similar estimates of television viewing time between those who achieved sufficient (i.e., ≥150 min/wk) versus insufficient moderate-to-vigorous intensity physical activity[28]. Conversely, others have found lower television viewing time among women participating in high (≥2 hrs/wk) versus low levels of leisure-time physical activity[13]. We did not find a significant difference in screen time between those achieving and not achieving recommended MPA (i.e., ≥210 min/wk) however, participants achieving recommended VPA (i.e., ≥60 min/wk) reported less screen time than those not achieving this level. This finding is similar to those found among Australian adults whereby participating in ≥90 min/wk of vigorous-intensity physical activity was associated with a lower likelihood of watching television ≥10 hrs/wk[40]. Encouraging adults to participate in more VPA might lead to reductions in screen time as well as provide additional health benefits. Our finding that achieving recommended MPA was not associated with screen time suggest that separate public health strategies might be needed for decreasing sedentary behavior in addition to increasing MPA among adults.

Several limitations should be considered when interpreting these findings. Self-reported sedentary behavior, physical activity, and other variables are subject to measurement error and recall bias. While less useful for identifying specific sedentary activities compared with self-reports, motion monitors may more accurately estimate total sedentary time. Despite these limitations the direction of associations found between the correlates and screen time in our study appeared to correspond with the associations found in other populations[10].

The findings of our study suggest that neighborhood urban form is associated with time spent participating in screen time, independent of other correlates including sociodemographic, health, and physical activity related characteristics. This finding is important, as most research to date support the potential role of the neighborhood urban form in supporting and discouraging physical activity. Creating walkable neighborhoods could increase physical activity but have the additional benefit of also decreasing leisure-based screen time among adults, which in turn could have significant implications for improving population health. Other potentially important correlates of screen time in adults include gender, education, household income, having a child at home, having a registered motor vehicle VPA, self-reported health, and weight status. Our findings suggest that practitioners should also consider neighborhood urban form when designing and implementing public health programs aimed at reducing sedentary behavior. Interventions that not only encourage physical activity but also discourage sedentary activity might be necessary for net gains in population health[2 39].

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CONFLICTS OF INTEREST

The authors declare there is no conflict of interest.

AUTHOR CONTRIBUTIONS

All authors contributed to the study design, data analysis, and interpretation of the findings. All authors contributed to the drafting of the manuscript.

DATA SHARING

No additional data available.

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Table 1. Descriptive comparison of the built characteristics between objectively-determined low, medium, and high walkable neighborhoods*

	Neighborhood walkability		
Built characteristics	**Low**	**Medium**	**High**
Walkshed area (km^2)	3rd	2nd	1st
Number of businesses (stores and services)/km^2	3rd	2nd	1st
Number of bus stops/km^2	3rd	2nd	1st
Mix of park types/km^2	1st	3rd	2nd
Mix of recreation destinations/km^2	3rd	1st	2nd
Sidewalk length (m/km^2)	3rd	1st	2nd
Total population/km^2	2nd	3rd	1st
Percent of neighborhood area as green space	1st	2nd	3rd
Pathway/cycleway length (m/km^2)	2nd	3rd	1st

*Ranks are based on the neighborhood types average level of built characteristic relative to the two other neighborhood types. Statistical details associated with these neighborhood type comparisons are fully described elsewhere (21)

Table 2. Descriptive statistics for sociodemographic, behavioral, and physical environmental characteristics for sample (n=1906)

	Estimate
Gender (%)	
Men	37.8
Women	62.2
Participant age	
<30 years	8.4
30-44 years	27.6
45 to 64 years	42.8
≥65 years	21.1
Education level achieved (%)	
High school or less	30.1
College	25.4
University	44.4
Annual gross household income (%)	
<$60,000/year	29.8
$60,000-119,999/year	32.2
≥$120,000/year	29.3
Don't know/refused	8.7
Children at home <18 years of age (%)	
No child	66.6
At least one child	33.4
Marital status (%)	
Married/living together	69.3
Single/divorced/separated	30.7
Ethnicity (%)	
Caucasian	90.5
Non-Caucasian	9.5
Dog ownership (%)	
Non-owner	73.4
Owner	26.6
Registered motorized vehicles at home (%)	
No motor vehicle	3.5
One motor vehicles	31.5
Two motor vehicles	46.3
At least three vehicles	18.7
Moderate-intensity physical activity (%)	
<210 min/week	37.1
≥210 min/week	62.9
Vigorous-intensity physical activity (%)	
<60 min/week	46.1
≥60 min/week	53.9
Self-rated health (%)	
Poor/fair	15.1
Good	41.0
Very good/excellent	43.9
Body Mass Index (%)	
Healthy weight	37.4
Overweight	62.6
Leisure-time screen-based activity (median/mean±SD)	1.43/1.77±1.52
Season survey completed (%)	
Summer	13.7
Fall	37.8
Winter	24.8
Spring	23.7
Objectively-assessed neighborhood walkability (%)	
Low walkability	56.5
Medium walkability	36.4
High walkability	7.2
Self-reported neighborhood walkability (%)	

Low walkability	33.4
Medium walkability	35.0
High walkability	31.6

Table 3. Adjusted linear regression estimates and 95% confidence intervals (CI) for the association between sociodemographic, behavioral, and physical environmental characteristics and leisure-based screen-time activity (hours per day; n=1906)

	Unadjusted Mean±SD (hours/day)	Estimated marginal mean (hours/day)	95%CI	Statistically significant differences (p<.05) after covariate adjustment
Gender[Ψ]				
Men	1.88±1.53	1.86	1.68, 2.04	
Women	1.71±1.52	1.71	1.55, 1.86	vs. men
Participant age[Ψ]				
<30 years	1.60±1.37	1.66	1.39, 1.92	
30-44 years	1.58±1.37	1.84	1.65, 2.03	
45-64 years	1.78±1.48	1.81	1.63, 1.98	
≥65 years	2.11±1.78	1.84	1.61, 2.05	
Education level achieved[Ψ]				
High school or less	2.00±1.81	1.89	1.71, 2.07	
College	1.75±1.46	1.69	1.50, 1.88	vs. high school or less
University	1.64±1.32	1.77	1.60, 1.95	
Annual gross household income[Ψ]				
<$60,000/year	2.11±1.81	1.95	1.77, 2.13	
$60,000-119,999/year	1.72±1.35	1.81	1.63, 2.00	
≥$120,000/year	1.55±1.36	1.75	1.55, 1.94	vs. <$60,000/year
Don't know/refused	1.63±1.38	1.63	1.37, 1.89	vs. <$60,000/year
Children at home <18 years of age[Ψ]				
No child	1.95±1.62	1.96	1.81, 2.11	
At least one child	1.45±1.23	1.61	1.41, 1.80	vs. no child
Marital status[Ψ]				
Married/living together	1.67±1.39	1.76	1.59, 1.93	
Single/divorced/separated	2.02±1.76	1.81	1.63, 1.99	
Dog ownership				
Non-owner	1.79±1.54	1.75	1.60, 1.90	
Owner	1.74±1.48	1.82	1.63, 2.01	
Registered motorized vehicles at home[Ψ]				
No motor vehicle	2.50±1.87	2.19	1.81, 2.57	
One motor vehicles	2.01±1.79	1.79	1.61, 1.96	vs. no/two motor vehicle
Two motor vehicles	1.60±1.30	1.55	1.38, 1.72	vs. no/one motor vehicle
At least three vehicles	1.68±1.38	1.61	1.41, 1.82	vs. no motor vehicle
Moderate-intensity physical activity[Ψ]				
<210 min/wk	1.89±1.61	1.84	1.66, 2.02	
≥210 min/wk	1.71±1.46	1.73	1.57, 1.89	
Vigorous-intensity physical activity[Ψ]				
<60 min/wk	2.02±1.71	1.92	1.75, 2.09	
≥60 min/wk	1.58±1.31	1.65	1.48, 1.82	vs. <60 min/wk
Self-rated health[Ψ]				
Poor/fair	1.96±1.58	1.80	1.58, 2.02	
Good	1.93±1.67	1.88	1.72, 2.04	vs. very good/excellent health
Very good/excellent	1.58±1.32	1.68	1.50, 1.85	
Body Mass Index[Ψ]				
Healthy weight	1.59±1.38	1.70	1.53, 1.88	
Overweight	1.89±1.59	1.87	1.70, 2.03	vs. healthy weight
Season survey completed				
Summer	1.90±1.50	1.86	1.63, 2.08	
Fall	1.75±1.52	1.76	1.58, 1.93	
Winter	1.82±1.58	1.80	1.61, 1.99	
Spring	1.72±1.47	1.72	1.53, 1.92	
Objectively-assessed neighborhood walkability				
Low walkability	1.74±1.44	1.88	1.72, 2.04	
Medium walkability	1.85±1.65	1.86	1.69, 2.03	
High walkability	1.75±1.44	1.61	1.34, 1.89	vs. low walkability
Self-reported neighborhood walkability				
Low walkability	1.84±1.67	1.80	1.63, 1.98	
Medium walkability	1.73±1.43	1.74	1.56, 1.92	

High walkability	1.77±1.46	1.81	1.62, 1.99
Variance explained (R^2)		*7.6%*	

Estimated marginal means for categorical correlates are adjusted for all covariates. $^{\Psi}$Statistically significant univariate test (ANOVA or t-test; p<0.05)

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported
Objectives	3	State specific objectives, including any prespecified hypotheses
Methods		
Study design	4	Present key elements of study design early in the paper
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group
Bias	9	Describe any efforts to address potential sources of bias
Study size	10	Explain how the study size was arrived at
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding
		(*b*) Describe any methods used to examine subgroups and interactions [Not undertaken]
		(*c*) Explain how missing data were addressed
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy
		(*e*) Describe any sensitivity analyses (Not applicable for this study)

Continued on next page

Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed
		(b) Give reasons for non-participation at each stage
		(c) Consider use of a flow diagram (not needed due to simple description)
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders
		(b) Indicate number of participants with missing data for each variable of interest (analysis was based on complete data)
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time
		Case-control study—Report numbers in each exposure category, or summary measures of exposure
		Cross-sectional study—Report numbers of outcome events or summary measures
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included
		(*b*) Report category boundaries when continuous variables were categorized
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period (not applicable)
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses (not applicable)
Discussion		
Key results	18	Summarise key results with reference to study objectives
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence
Generalisability	21	Discuss the generalisability (external validity) of the study results
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Original Research Article

Neighborhood urban form and individual-level correlates of leisure-based screen time in Canadian adults

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Table count: 3

What is already known on this subject?

Evidence regarding the potential determinants of sedentary behavior is rapidly accumulating however, little is known about the extent to which the neighborhood built environment encourages or discourages leisure-based screen time activities including watching television and using computers. The neighborhood environment appears to be associated with sedentary behavior, although studies to date often include either objectively-assessed or self-reported measures of the built environment, but not both.

What this study adds?

The objectively-assessed, but not self-reported, neighborhood built environment was associated with participation in leisure-based screen time even after adjusting for physical activity and sociodemographic correlates. Improving neighborhood walkability has the potential to not only increase physical activity but also decrease sedentary behavior.

ABSTRACT

Objectives: Despite evidence for an association between the built environment and physical activity, less evidence exists regarding relations between the built environment and sedentary behavior. This study investigated the extent to which objectively-assessed and self-reported neighborhood walkability, in addition to individual-level characteristics, were associated with leisure-based screen time in adults. We hypothesized that leisure-based screen time would be lower among adults residing in objectively-assessed and self-reported 'high walkable' versus 'low walkable' neighborhoods.

Setting: The study was undertaken in Calgary, Alberta, Canada in 2007/2008

Participants: Included a random cross-section of adults who provided complete telephone-interview and postal survey data (n=1906). Captured information included leisure-based screen time, moderate and vigorous-intensity physical activity, perceived neighborhood walkability, sociodemographic characteristics, self-reported health status, and self-reported height and weight. Based on objectively-assessed built characteristics, participant's neighborhoods were identified as being low, medium, or high walkable.

Primary and secondary outcome measures: Using multiple linear regression, hours of leisure-based screen time per day was regressed on self-reported and objectively-assessed walkability adjusting for sociodemographic and health-related covariates.

Results: Compared to others, residing in a objectively-assessed high walkable neighborhood, women, having a college education, at least one child at home, a household income ≥$120,000/year, and a registered motor vehicle at home, reporting very good-to-excellent health and healthy weight, and achieving 60-min/wk of vigorous-intensity physical activity were associated ($p<.05$) with less leisure-based screen time. Marital status, dog-ownership, season, self-reported walkability, and achieving 210-minutes of moderate-intensity physical activity were not significantly associated with leisure-based screen time.

Conclusion: Improving neighborhood walkability could decrease leisure-based television and computer screen time. Programs aimed at reducing sedentary behavior may want to consider an individual's sociodemographic characteristics, physical activity level, health status, and weight status, in addition to the walkability of their neighborhood as these factors were found to be important independent correlates of leisure-based screen time.

Key words: sedentary, physical activity, walkability

ARTICLE SUMMARY

Strengths and limitations of this study

- A novel aspect of this study was the investigation of both objectively-assessed and self-reported built environmental characteristics in relation to leisure-based screen time in adults.
- Participant recruitment involved simple random sampling from the population.

- Statistical models, with leisure-based screen time as an outcome, adjusted for potential confounders including participation in moderate-intensity and vigorous-intensity physical activity and sociodemographic characteristics.

- Despite the known limitations of using self-report measures, this approach allowed us to assess the relationship between the built environment and a specific and popular sedentary behavior – i.e., leisure-based screen time.

BACKGROUND

Evidence regarding the negative health consequences of sedentary lifestyles is accumulating [1]. Sedentary behavior includes activities that primarily involve sitting and that require undertaking minimal energy expenditure (e.g., watching television, using computers, driving motor vehicles) [2]. Sedentary behavior is a modifiable risk factor for type 2 diabetes, cardiovascular disease, overweight and obesity, and early mortality[3-6]. Moreover, the negative health consequences of sedentary behavior may offset the positive health benefits derived from being sufficiently physically active – that is, the effect of sedentary behavior on health is present even after controlling for moderate-to-vigorous leisure-time physical activity[7].

Several popular sedentary activities have been investigated in relation to health, including screen time (e.g., television viewing, computer use, and video games), reading, sitting in motorized vehicles, and occupational sitting[8]. Second to time spent sitting, the majority of time spent sedentary involves screen-based activities (i.e., television and computer use), followed by travelling in motor vehicles[9]. Among Canadian adults, at least two thirds of waking hours are spent sedentary[10], and approximately 29% watch television at least 15 hours per week and approximately 15% use computers for at least 11 hours per week[11]. Similar to physical activity, the socioecological model provides a useful framework for understanding the determinants of sedentary behavior. Intrapersonal, interpersonal, physical environmental, and policy related factors have been elucidated as potentially important determinants of sedentary behavior[2]. Evidence to date from this rapidly growing research area suggests that gender, age, education, income, employment status, weight status, those living with children at home, attitude towards sedentary behavior, participation in moderate-to-vigorous intensity physical activity, and the built environment are associated with sedentary behavior [12 13]. Further, the correlates of sedentary behavior appear to be context and behavior-specific (e.g., home versus workplace) and therefore different types of sedentary behavior likely have distinct correlates[2 9 13]. For instance, despite having similarly low energy expenditure (i.e., <2 metabolic equivalents[14]) driving motorized vehicles and television viewing have some shared, but also different determinants[13]. Understanding the correlates of specific types of sedentary behavior could result in an increased focus on these specific determinants for interventions.

There is growing public health interest in the association between the neighborhood urban form and sedentary behavior. Increasing neighborhood walkability has the potential to decrease sedentary behavior among many adults, which in turn could improve population health. However, findings from a recent review suggest that the evidence for an association between built environment characteristics and sedentary behavior, including screen time, are equivocal with less than one-third of associations found in the expected direction[15]. For instance, Australian women who resided in low walkable neighborhoods spent more time viewing television compared with their counterparts residing in high walkable neighborhoods[16]. Similarly, Kozo et al.[9] found more television viewing time associated with lower neighborhood walkability in US adults. In contrast, Belgian adults residing in high walkable neighborhoods had higher accelerometer-measured and self-reported sitting time than those residing in less walkable neighborhoods [17]. Studies have also found associations between self-reported environment characteristics and sedentary behavior. Van Dyke et al.[18] reported finding significant associations between individual self-reported individual (i.e., land use mix, aesthetics, and safety) and composite environment characteristics and self-reported sitting. Moreover, Wallmann-Sperlich et al.[19] found that among several self-reported measures of the built environment (e.g., access to transit, recreation areas, and destinations, presence of trees, and safety) perception of traffic safety only, was associated with sitting time among German women. There are few studies of sedentary behavior however, that incorporate both self-reported and objectively-assessed built environment correlates within the same analysis. For instance, Ding et al.[20] found that objectively-assessed, but not self-reported, walkability characteristics to be associated with longitudinal changes in television viewing time. Given the mixed findings regarding the associations between self-reported and objectively-assessed built environment characteristics and sedentary behavior suggests that further investigation is warranted.

Scientific understanding of the correlates of sedentary behavior in adults is rapidly emerging[9] but our understanding of the built environment correlates is rudimentary[13]. Thus, this study investigated the extent to which the objectively-assessed and self-reported neighborhood walkability, controlling for other sociodemographic, behavioral, and health-related characteristics, were associated with leisure-based television and computer screen time in adults. Based on previous evidence, we hypothesize that leisure-based screen time will be lower among adults residing in objectively-assessed and self-reported 'high walkable' versus 'low walkable' neighborhoods.

METHODS

Study design and sample recruitment

The study design and recruitment have been fully described elsewhere[21 22]. The study location was Calgary Alberta, Canada. A random sample of adults (≥ 18 years of age) was recruited during telephone-interviews from August-October 2007 (n=2199, response rate=33.6%) and January-April 2008 (n=2223, response rate=36.7%). Telephone-interviews captured information about physical activity, psychosocial, and sociodemographic characteristics. A sub-sample of participants (n=1967; 44.5%) also completed and returned a follow-up postal survey. The postal survey captured information about perceived neighborhood characteristics, health and weight status, physical activity, sedentary behavior, and additional sociodemographic characteristics. The University of Calgary Conjoint Health Research Ethics Board approved this study and all participants provided informed consented.

Measures

Leisure-based screen time: Participants were asked, "*On average, how many hours per week do you spend watching television or using a computer outside of your workplace? (e.g., videogames, computer games, DVD/movies, internet, email etc.)*". Time spent on television-viewing and computer use can be self-reported reliably[8]. We converted screen time hours per week to hours per day to assist in interpretation of results.

Moderate-intensity physical activity (MPA): Participants reported time spent in a usual week undertaking transportation and recreational walking, and other moderate-intensity physical activity for recreation, health or fitness, inside and outside of their neighborhood (within a 15-minute walk of home)[23 24]. Responses were summed and dichotomized to reflect achievement of 30-minutes of daily MPA recommended for health benefits (i.e., <210 min/wk vs ≥210 min/wk).

Vigorous-intensity physical activity (VPA): Participants reported time spent in a usual week undertaking vigorous-intensity physical activity for recreation, health, or fitness, inside and outside of their neighborhood (within a 15-minute walk of home)[23 24]. Responses were dichotomized to reflect achievement of at least 60-minutes of VPA per week – a level that has been reported to provide health benefits[25].

Health-related characteristics: Participants rated their overall level of health on a five-point scale. Responses were collapsed into three categories: poor/fair, good, and very good/excellent. This item had acceptable test-retest reliability (Spearman rank correlation=0.86). Participants' body mass index (BMI; weight/height^2) was estimated from their self-reported height and weight which incorporated a correction factor to account for sex-related reporting bias[26]. BMI was dichotomized into healthy weight (<25 kg/m^2) and overweight (≥25 kg/m^2).

Sociodemographic characteristics: Sociodemographic characteristics included gender, highest education level achieved (high school or less, college, or university), gross annual household income (≤$60,000/year, $60,000-119,000/year, ≥$120,000/year, or don't know/refused), dog ownership (non-owner vs. owner), marital status (married/living together vs. other), the number of dependents <18 years old living in the residence (none vs. at least one), and number of registered motor vehicles (0, 1, 2, or ≥3 vehicles). The season in which the telephone-interview was conducted was recorded.

Self-reported neighborhood walkability: Characteristics related to neighborhood walkability including access to services, personal and traffic safety, neighborhood aesthetics, and pedestrian infrastructure were captured using items (n=25) from the Neighborhood Environment Walkability Scale (NEWS-A)[27]. Item responses were captured on a balanced 4-point scale from strongly agree to strongly disagree. Item responses were averaged and then tertiled into low, medium, and high walkability categories. Items had adequate internal consistency (Cronbach's alpha=0.71) and moderate-to-high two-week test-retest reliability (r=0.50-0.88)[28].

Objectively-assessed neighborhood walkability: Procedures for determining the neighborhood built environment have been described elsewhere[21]. Briefly, participants' household postal codes were geocoded and a 1.6 km line-based network walkshed estimated. Using Geographical Information Systems (GIS) we assessed the built characteristics associated with physical activity within the walkshed. The derived built environment variables included: walkshed area (km^2), total population/km^2, proportion of neighborhood green space, path/cycleway (meters)/km^2, number of businesses/km^2, number of bus stops/km^2, length of sidewalk (meters)/km^2, mix of park types/km^2, and mix of recreational facilities/km^2. The built characteristics were entered into a two-staged cluster analysis which identified three neighborhood types: low (LW), medium (MW), and high walkable (HW) neighborhoods[21]. LW neighborhoods have smaller walkshed area, lower population density, sidewalk availability, and recreational destination mix, fewer business destinations and bus stops, and highest proportion of green space compared with the other neighborhood types. HW neighborhoods have higher population density, walkshed area, path/cycleway availability, and recreational destination mix, and more business destinations and bus stops compared with LW and MW neighborhoods (Table 1).

Statistical analysis

Means (±standard deviations) were estimated for all correlates. One-way Analysis of Variance was used for univariate comparisons of screen time (hours/day) between self-reported and objectively-assessed walkability, and sociodemographic, behavioral and health variables. Zero-order (unadjusted) and partial (adjusted) correlations were undertaken between screen, MPA, and VPA time. Fully-adjusted multiple linear regression models were used to regress screen time on the sociodemographic (sex, age, income, dependents <18 years at home, marital status, dog ownership, count of registered motor vehicles), behavioral (recommended MPA and VPA), health (self-reported health and BMI), self-reported and objectively-assessed walkability variables, and season. Linear regression estimates for all categorical variables were reported as marginal means (with 95% confidence intervals (CIs)). Analysis was undertaken using SPSS version 20.

RESULTS

Sample characteristics

Complete data from n=1906 were included in the analysis. The sample had higher representation from women, Caucasians, and those university educated, without children <18 years, married or living with another, without a dog, with at least two registered vehicles at home, and in good to excellent health (Table 2). Approximately half of the sample resided in LW (56.3%) neighborhoods, followed by MW (36.4%), and HW (7.3%) neighborhoods. Over half of all participants achieved recommended MPA (63.0%) and VPA (53.7%). On average, adults participated in 1.78±1.52 hours/day of screen time, with 39.5% undertaking ≥2 hours/day. Zero-ordered and partial correlations (adjusting for MPA) showed a significant association between screen time and VPA (r=-0.100 and r=-0.098, p<.05, respectively). Zero-ordered and partial correlations between screen time and MPA were not statistically significant (r=-0.019 and r=-0.004, respectively), however, time spent in MPA and VPA was positively correlated (zero-ordered r=0.233, p<.05).

Correlates of participating in leisure-based screen time

After adjusting for all correlates, screen time was significantly higher (p<.05) among men versus women, no child versus at least one child at home, owning none versus owning two or at least three registered motor vehicles, and owning one versus two registered motor vehicles, those reporting good versus very good/excellent health, those participating in ≥60 min/wk versus <60 min/wk, and residents of objectively-assessed LW versus HW neighborhoods (Table 3). No other correlates were statistically significantly associated with screen time. The inclusion of all correlates in the linear regression model explained 7.6% of the explainable variance in screen time.

DISCUSSION

Our study findings contribute to the mixed evidence regarding the influence of the built environment on sedentary behavior[15]. In support of prior evidence[9 16], we found that objectively-assessed, but not self-reported, neighborhood walkability was independently associated with leisure-based screen time. We also found that gender, education, household income, having a children at home, having a registered motor vehicle, VPA, self-reported health, and self-reported weight status were significant correlates, supporting previous studies showing the importance of sociodemographic and health-related factors in relation to sedentary behavior[13]. The findings between access to registered motor vehicles and screen time in particular is a novel. Marital status, dog-ownership, season, self-reported walkability, or MPA were not associated with leisure-based screen time.

Similar to others[9 16 20], we found that adults residing in objectively-assessed low walkable neighborhoods participated in more leisure-based screen time than those in high walkable neighborhoods. Higher sedentary time has been found among men and women residing in regional centres versus the city centre, which to some extent might reflect the difference in urban form and physical activity opportunities in these two environments[29]. Others have found relationships between objectively-assessed walkability and television viewing time after considering effect modification by other characteristics such as working status[20] and gender[16]. Similar to our findings, Ding et al.[20] found no significant association between perceived walkability characteristics in models that included objectively-assessed walkability, as well as other sociodemographic characteristics. Together, these findings might suggest that the walkability of the neighborhood in which adults live is more important than their perception of walkability for determining leisure-based television and computer use. This finding is not surprising given that there is often discordance between objective and self-report measures of the same built environment characteristics[30], as well as differences in their associations with physical activity[22].

Residing in a high walkable neighborhood was associated with less leisure-based screen time than residing in a low walkable neighborhood. Our finding is encouraging given the importance of the neighborhood environment for supporting physical activity[31 32]. Notably, the operational definition of neighborhood walkability in our study differed from previous studies investigating correlates of screen time. We estimated neighborhood walkability using cluster-analysis which incorporated nine built environment characteristics[21]. Furthermore, our walkability variable reflected a range of characteristics hypothesized to support transportation and recreational physical activity. Objectively-assessed walkability in other studies incorporate three or four built characteristics (e.g., land use mix, residential density, street connectivity, and retail floor area) that are commonly associated with transportation walking[9 16 20]. The fact that slightly different approaches for estimating neighborhood walkability are associated with screen time is encouraging yet some individual built characteristics may be more strongly associated screen time than others[15]. Urban planners and health practitioners need more evidence about which objectively-assessed and self-reported neighborhood environmental characteristics individually or in combination best explain differences in leisure-based screen time as well as other sedentary behaviors[15].

A little less than half our sample participated in 2 hours of screen time per day – similar levels have been reported in Canada and elsewhere[20 29 33]. In support of evidence elsewhere[16 33 34], we found that adults of healthy weight reported less screen time than their overweight counterparts. Speculatively, the home environment might have contributed to the association between weight status and leisure-based screen time in our study. Overweight adults have been found to own a higher count of televisions and to be more likely to have a television in the bedroom compared with healthy weight adults[34]. The count of televisions and computers in the home[33 34] and television size[33] might be positively associated with screen-based activity in adults. Despite including measures of the physical environment (urban form and season) we did not include measures of the home-based environment (i.e., where the majority of leisure-based screen time occurs), which has been found to be important with regard to television viewing[35]. Home-based interventions that modify the physical environment could discourage television-viewing[36]. The estimated association between weight status and screen time might also be confounded by unhealthy diet, which is associated with compromised weight status and sedentary behavior[37]. Related to this was our finding that participants reporting better health also reported lower screen time than those who reported worse health. Self-reported poor health among those watching more television has been found elsewhere[38]. While there appears to be an association, we are unable to infer the causal pathway between self-reported health and screen time based on our cross-sectional data. Longitudinal and quasi-experimental studies that examine changes in sedentary behavior, physical activity, and diet in response to modifications to the neighborhood and home physical environments are needed to provide stronger temporal evidence.

Noteworthy, was that the number of registered motor vehicles at home was negatively associated with screen time. A recent study found an increase in the likelihood of watching television ≥2 hours/day among older Japanese women who reported being non-drivers[39]. Not having a registered motor vehicle (or being a non-driver) could decrease an individual's ability to access physical activity opportunities outside the home and therefore result in more time spent in the home where television viewing is a convenient activity option. Despite adjusting for income and education, it is possible that the association between registered motor vehicles at home and screen time could to some extent reflect other dimensions of socioeconomic status[40]. Others have found associations between socioeconomic status and leisure based sedentary behavior[9 16 17]. Higher education, in particular, is consistently associated with less television-viewing time and computer use[9 16 17 20 29 33 38]. We found that adults with high school or less education had significantly higher screen time than those with a college education. The negative relationship between household income and screen time found in our study, while not always statistically significant, showed a consistent pattern. Other studies also report higher television viewing in those with lower incomes[16]. This finding might reflect the financial barrier to participating in recreational activities outside of the home among low-income households, thus television and computer use are alternative and less expensive leisure pursuits. Interventions for decreasing sedentary behavior should target adults across the education and income spectra.

In general, weak correlations between physical activity and screen time have been found[41]. An Australian study found similar estimates of television viewing time between those who achieved sufficient (i.e., ≥150 min/wk) versus insufficient moderate-to-vigorous intensity physical activity[29]. Conversely, others have found lower television viewing time among women participating in high (≥2 hrs/wk) versus low levels of leisure-time physical activity[16]. We did not find a significant difference in screen time between those achieving and not achieving recommended MPA (i.e., ≥210 min/wk) however, participants achieving recommended VPA (i.e., ≥60 min/wk) reported less screen time than those not achieving this level. This finding is similar to those found among Australian adults whereby participating in ≥90 min/wk of VPA was associated with a lower likelihood of watching television ≥10 hrs/wk[42]. Encouraging adults to participate in more VPA might lead to reductions in screen time as well as provide additional health benefits. Our finding that achieving recommended MPA was not associated with screen time suggest that separate public health strategies might be needed for decreasing sedentary behavior in addition to increasing MPA among adults.

Several limitations should be considered when interpreting these findings. Self-reported screen time, physical activity, and other variables are subject to measurement error and recall bias. While less useful for identifying specific sedentary activities compared with self-reports, motion monitors may more accurately estimate total sedentary time. Our study captured leisure-based screen time only, yet other sedentary behaviors are associated with the built environment[15]. Simple random sampling from the Calgary population resulted in a lower proportion of participants from high walkable neighborhoods. While we were still able to detect a significant difference in screen time between low and high walkable neighborhoods, the small sample size in the high walkable neighborhoods restricted our analysis to testing main effects only. It is possible that neighborhood walkability has differential effects on screen time for different sociodemographic groups[16 20]. The sample characteristics (adults from one Canadian city), the low response and follow-up participation rates, and the elapsed time since data collection may limit the generalizability of our findings. Compared with participants who completed the telephone-interview, those who also completed the postal survey included a higher proportion women, those with no child dependents, and those with postsecondary education[43].

Despite these limitations, the direction of associations found between the correlates and screen time in our study appeared to correspond with the associations found in other populations[13]. However, less than 8% of the explainable variance in screen time was accounted for by the fully-adjusted model, suggesting that other factors not examined in this study could be important for determining leisure-based screen time[12 13]. While the magnitude of the differences in screen time by neighborhood walkability found in this study and eslewhere[9 16 20] appear small, the reduction of screen time accumulated overtime and across many people could have a significant population health impact. Our study is just one of only a few studies to show a potential association between the built environment and leisure-based screen time[15]. More studies are required to identify other environmental and non-environmental correlates of screen time.

The findings of our study suggest that neighborhood urban form is associated with leisure-based screen time, independent of other correlates including sociodemographic, health, neighborhood perceptions, and physical activity related characteristics. This finding is important, as most research to date support the potential role of neighborhood urban form in supporting and discouraging physical activity. Creating walkable neighborhoods could increase physical activity but have the additional benefit of also decreasing leisure-based screen time among adults. Other potentially important correlates of screen time in adults include gender, education, household income, having a child at home, having a registered motor vehicle VPA, self-reported health, and weight status. Mutli-level interventions that not only encourage physical activity but also discourage leisure-based screen time might be necessary for improving population health[2 41].

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CONFLICTS OF INTEREST

The authors declare there is no conflict of interest.

AUTHOR CONTRIBUTIONS

All authors made substantial contributions to conception and design, acquisition of data, or analysis and interpretation of data; contributed to drafting the article or revising it critically for important intellectual content; and provided final approval of the published manuscript.

DATA SHARING

No additional data available.

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Table 1. Descriptive comparison of the built characteristics between objectively-determined low, medium, and high walkable neighborhoods*

	Neighborhood walkability		
Built characteristics	**Low**	**Medium**	**High**
Walkshed area (km^2)	3rd	2nd	1st
Number of businesses (stores and services)/km^2	3rd	2nd	1st
Number of bus stops/km^2	3rd	2nd	1st
Mix of park types/km^2	1st	3rd	2nd
Mix of recreation destinations/km^2	3rd	1st	2nd
Sidewalk length (m/km^2)	3rd	1st	2nd
Total population/km^2	2nd	3rd	1st
Percent of neighborhood area as green space	1st	2nd	3rd
Pathway/cycleway length (m/km^2)	2nd	3rd	1st

*Ranks are based on the neighborhood types average level of built characteristic relative to the two other neighborhood types. Statistical details associated with these neighborhood type comparisons are fully described elsewhere[21]

Table 2. Descriptive statistics for sociodemographic, behavioral, and physical environmental characteristics for sample (n=1906)

	Estimate
Gender (%)	
Men	37.8
Women	62.2
Participant age	
<30 years	8.4
30-44 years	27.6
45 to 64 years	42.8
≥65 years	21.1
Education level achieved (%)	
High school or less	30.1
College	25.4
University	44.4
Annual gross household income (%)	
<$60,000/year	29.8
$60,000-119,999/year	32.2
≥$120,000/year	29.3
Don't know/refused	8.7
Children at home <18 years of age (%)	
No child	66.6
At least one child	33.4
Marital status (%)	
Married/living together	69.3
Single/divorced/separated	30.7
Ethnicity (%)	
Caucasian	90.5
Non-Caucasian	9.5
Dog ownership (%)	
Non-owner	73.4
Owner	26.6
Registered motorized vehicles at home (%)	
No motor vehicle	3.5
One motor vehicles	31.5
Two motor vehicles	46.3
At least three vehicles	18.7
Moderate-intensity physical activity (%)	
<210 min/week	37.1
≥210 min/week	62.9
Vigorous-intensity physical activity (%)	
<60 min/week	46.1
≥60 min/week	53.9
Self-rated health (%)	
Poor/fair	15.1
Good	41.0
Very good/excellent	43.9
Body Mass Index (%)	
Healthy weight	37.4
Overweight	62.6
Leisure-based screen time/day (median/mean±SD)	1.43/1.77±1.52
Season survey completed (%)	
Summer	13.7
Fall	37.8
Winter	24.8
Spring	23.7
Objectively-assessed neighborhood walkability (%)	
Low walkability	56.5
Medium walkability	36.4
High walkability	7.2
Self-reported neighborhood walkability (%)	

Low walkability	33.4
Medium walkability	35.0
High walkability	31.6

Table 3. Adjusted linear regression estimates and 95% confidence intervals (CI) for the association between sociodemographic, behavioral, and physical environmental characteristics and leisure-based screen time (hours per day; n=1906)

	Unadjusted Mean±SD (hrs/day)	Estimated marginal mean (hrs/day)	95%CI	Statistically significant differences (p<.05) after covariate adjustment
Gender[Ψ]				
Men	1.88±1.53	1.86	1.68, 2.04	
Women	1.71±1.52	1.71	1.55, 1.86	vs. men
Participant age[Ψ]				
<30 years	1.60±1.37[a]	1.66	1.39, 1.92	
30-44 years	1.58±1.37[b,c,]	1.84	1.65, 2.03	
45-64 years	1.78±1.48[b,d]	1.81	1.63, 1.98	
≥65 years	2.11±1.78[a,c,d]	1.84	1.61, 2.05	
Education level achieved[Ψ]				
High school or less	2.00±1.81[a,b]	1.89	1.71, 2.07	
College	1.75±1.46[a]	1.69	1.50, 1.88	vs. high school or less
University	1.64±1.32[b]	1.77	1.60, 1.95	
Annual gross household income[Ψ]				
<$60,000/year	2.11±1.81[a,b,c]	1.95	1.77, 2.13	
$60,000-119,999/year	1.72±1.35[a]	1.81	1.63, 2.00	
≥$120,000/year	1.55±1.36[b]	1.75	1.55, 1.94	vs. <$60,000/year
Don't know/refused	1.63±1.38[c]	1.63	1.37, 1.89	vs. <$60,000/year
Children at home <18 years of age[Ψ]				
No child	1.95±1.62	1.96	1.81, 2.11	
At least one child	1.45±1.23	1.61	1.41, 1.80	vs. no child
Marital status[Ψ]				
Married/living together	1.67±1.39	1.76	1.59, 1.93	
Single/divorced/separated	2.02±1.76	1.81	1.63, 1.99	
Dog ownership				
Non-owner	1.79±1.54	1.75	1.60, 1.90	
Owner	1.74±1.48	1.82	1.63, 2.01	
Registered motorized vehicles at home[Ψ]				
No motor vehicle	2.50±1.87[a,b,c]	2.19	1.81, 2.57	
One motor vehicles	2.01±1.79[a,d]	1.79	1.61, 1.96	vs. no/two motor vehicle
Two motor vehicles	1.60±1.30[b]	1.55	1.38, 1.72	vs. no/one motor vehicle
At least three vehicles	1.68±1.38[c,d]	1.61	1.41, 1.82	vs. no motor vehicle
Moderate-intensity physical activity[Ψ]				
<210 min/wk	1.89±1.61	1.84	1.66, 2.02	
≥210 min/wk	1.71±1.46	1.73	1.57, 1.89	
Vigorous-intensity physical activity[Ψ]				
<60 min/wk	2.02±1.71	1.92	1.75, 2.09	
≥60 min/wk	1.58±1.31	1.65	1.48, 1.82	vs. <60 min/wk
Self-rated health[Ψ]				
Poor/fair	1.96±1.58[a]	1.80	1.58, 2.02	
Good	1.93±1.67[b]	1.88	1.72, 2.04	vs. very good/excellent health
Very good/excellent	1.58±1.32[a,b]	1.68	1.50, 1.85	
Body Mass Index[Ψ]				
Healthy weight	1.59±1.38	1.70	1.53, 1.88	
Overweight	1.89±1.59	1.87	1.70, 2.03	vs. healthy weight
Season survey completed				
Summer	1.90±1.50	1.86	1.63, 2.08	
Fall	1.75±1.52	1.76	1.58, 1.93	
Winter	1.82±1.58	1.80	1.61, 1.99	
Spring	1.72±1.47	1.72	1.53, 1.92	
Objectively-assessed neighborhood walkability				
Low walkability	1.74±1.44	1.88	1.72, 2.04	
Medium walkability	1.85±1.65	1.86	1.69, 2.03	
High walkability	1.75±1.44	1.61	1.34, 1.89	vs. low walkability
Self-reported neighborhood walkability				
Low walkability	1.84±1.67	1.80	1.63, 1.98	
Medium walkability	1.73±1.43	1.74	1.56, 1.92	

High walkability	1.77±1.46	1.81	1.62, 1.99
Variance explained (R^2)		*7.6%*	

[Ψ]Statistically significant univariate test (ANOVA or t-test; $p<0.05$). For unadjusted results with significant ANOVA, categories within variables with same superscript are significantly different ($p<0.05$) based on Tukey's Least Significance Tests. Estimated marginal means for categorical correlates are adjusted for all covariates.

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported
Objectives	3	State specific objectives, including any prespecified hypotheses
Methods		
Study design	4	Present key elements of study design early in the paper
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group
Bias	9	Describe any efforts to address potential sources of bias
Study size	10	Explain how the study size was arrived at
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding
		(*b*) Describe any methods used to examine subgroups and interactions [Not undertaken]
		(*c*) Explain how missing data were addressed
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy
		(*e*) Describe any sensitivity analyses (Not applicable for this study)

Continued on next page

Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed
		(b) Give reasons for non-participation at each stage
		(c) Consider use of a flow diagram (not needed due to simple description)
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders
		(b) Indicate number of participants with missing data for each variable of interest (analysis was based on complete data)
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time
		Case-control study—Report numbers in each exposure category, or summary measures of exposure
		Cross-sectional study—Report numbers of outcome events or summary measures
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included
		(*b*) Report category boundaries when continuous variables were categorized
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period (not applicable)
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses (not applicable)
Discussion		
Key results	18	Summarise key results with reference to study objectives
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence
Generalisability	21	Discuss the generalisability (external validity) of the study results
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.