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Abstract

The potential of the neighbourhood built environment for reducing sedentary behaviour has been highlighted in the recent research building on the socio-ecological models. Nevertheless, few studies have investigated the associations between objectively-measured environmental attributes and domain-specific sedentary behaviours in different geographical locations. Notably, high-quality environmental measures that are less data-dependent and are replicable in and comparable across different contexts are needed to expand the evidence on urban design and public health. We examined associations of environmental attributes and Space Syntax Walkability (SSW) with leisure screen time and car driving in a sample of Canadian adults. A total of 2006 Calgarian adults completed a survey that captured their leisure screen time and car driving. Environmental attributes were population density, intersection density, availability of sidewalks, availability of destinations, and SSW using geographic information systems. Adjusting for covariates, a one standard deviation increase in SSW was associated with 0.43 (95% CI −0.85, −0.02) hours/week decrease in leisure screen time. No other environmental attributes were significantly associated with leisure screen time. All environmental attributes (except the availability of sidewalks) were negatively associated with car driving. The strongest association was observed between SSW with car driving—a one standard deviation increase in SSW was associated with 0.77 (95% CI −0.85, −0.02) hours/week decrease in the car driving. Those who lived in highly populated and more connected areas with a variety of destinations nearby spent less time driving their cars. Further, our findings highlight that the composite measure of SSW is associated with both leisure screen time and car driving. Focusing on a novel environmental aspect (SSW) and an emerging health risk factor (sedentary behaviour) among a relatively large sample of Canadian adults, our study provides unique insights into environmental health research.

1. Introduction

Evidence demonstrating the negative health consequences of sedentary behaviour, after adjusting for physical activity is accumulating (Chastin *et al* 2015). Sedentary behaviour has been defined as 'any waking behaviour characterized by an energy expenditure ⩽1.5METs while in a sitting or reclining posture' (Sedentary Behaviour

Research 2012). Sitting for many individuals is a habitual behaviour which is undertaken in large doses daily (e.g., television and computer use, car driving). For example, Canadian adults spend at least two-thirds of their waking time in sedentary behaviours (Colley *et al* 2011). Screen time (television and computer use) and car driving are two types of common sedentary behaviours (Kozo *et al* 2012). To reduce such sedentary behaviours, interventions that incorporate individual, social, and built environment level factors are needed (Owen *et al* 2011). In particular, built environment attributes are barriers or facilitators for physical activities and may be relevant to sedentary behaviours. Nevertheless, a systematic review reported only mixed evidence on the associations between built environment attributes and adults' sedentary behaviours—less than 30% of associations were in the expected direction (Koohsari *et al* 2015). Furthermore, few studies have examined associations between built environment attributes (especially objectively-measured attributes) and sedentary behaviours in different geographical locations. Only 17 papers were included in the systematic review on the built environment attributes and adults' sedentary behaviours, none of which were from Canada (Koohsari *et al* 2015). In a recent systematic review on correlates of adults' sedentary behaviour, less than 20% of 257 eligible studies examined built environment attributes, which included only two Canadian studies (Prince *et al* 2017). Thus, more evidence on the associations between the built environment and sedentary behaviour in different geographical locations is needed to inform local urban design policy and public health interventions.

Furthermore, it is important that objective measures of the built environment have practical interpretation, can be estimated for different contexts, and can be constructed using readily available data. It is of interest to examine a newly-developed built environment index, space syntax walkability (SSW), in relation with sedentary behaviours. The details of SSW have been fully described elsewhere (Koohsari *et al* 2016). Briefly, SSW includes two measures of neighbourhood population density and street integration. While SSW employs readily-available spatial geographical data, compared with the conventional neighbourhood walkability index (Frank *et al* 2010); both indices were found to be equally associated with walking for transport (Koohsari *et al* 2016). Few studies have examined the associations between space syntax metrics and health behaviours and outcomes (Baran *et al* 2008, Koohsari *et al* 2017a, Koohsari *et al* 2018), and notably, none have explored the associations between SSW and sedentary behaviours.

Therefore, the aim of this study was to examine the associations of objectively-measured built environment attributes and a composite measure of SSW with two common sedentary behaviours (i.e., leisure screen time and car driving) in a sample of Canadian adults.

2. Methods

2.1. Data source and participants

Detailed methods of study design and recruitment have been documented elsewhere (McCormack *et al* 2010). Briefly, a random sample of adults (⩾18 years of age) was recruited for telephone-interviews during August-October 2007 (n = 2199, response rate = 33.6%) and January-April 2008 (n = 2223, response rate = 36.7%). Telephone-interviews captured information about sociodemographic characteristics and physical activity. Of participants who completed the telephone-interview, 2006 participants completed and returned a follow-up postal survey. Sedentary behaviour and additional sociodemographic characteristics were obtained by the postal survey. The University of Calgary Conjoint Health Research Ethics Board approved this study (REB# 20798).

2.2. Measures

2.2.1. Outcome variable

The outcome variables were self-report leisure screen time and car driving and have been fully-described previously (Swanson and McCormack 2012, McCormack and Mardinger 2015). The former was measured by the following question: '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)'. Participants also reported the total time on a typical weekday and weekend day spent as a driver or passenger travelling in a car. Total weekly driving time was calculated by summing weekday (multiplied by 5) and weekend (multiplied by 2) driving time.

2.2.2. Built environment attributes

Participant addresses were geocoded using their 6-digit residential postal codes. Using geographic information systems, population density, intersection density, availability of sidewalks, and availability of destinations were objectively calculated within a 1.6 km network buffer around each participant's geocoded point. The choice of 1.6 km buffer was similar to previous studies examining associations between built environment and health behaviours (Christian *et al* 2011). All businesses in the City of Calgary were coded according to their primary type of service (restaurants, bakeries, convenience stores, cinemas, drugstores, supermarkets, etc). These

addresses were geocoded, and the total number of businesses within each participants' buffer was calculated. Informed by a previous study (Koohsari *et al* 2016), the SSW index was calculated as a composite measure, including population density and street integration. Street integration was calculated for each street segment considering all the other street segments within a 1.6 km distance from its centre using Axwomen and Depthmap software (Turner 2004, Jiang 2012). SSW was calculated using the following formula (Koohsari *et al* 2016):

$$\mathrm{SSW} = \mathrm{z}[\mathrm{z}(\text{population density}) + 2 \times \mathrm{z}(\text{integration})].$$

2.2.3. Sociodemographic variables

Participants were reported their age, gender (female, male), education (high school or less, college, university), annual gross household income (<$60 000/year, $60 000–119 999/year, ⩾$120 000/year, don't know/refused), marital status (married/living together, single/divorced/separated), number of children <18 years of age at home (no child, at least one child), and self-rated health (poor/fair, good, very good, excellent).

2.2.4. Statistical analysis

Descriptive statistics (mean ± standard deviation; frequencies) were estimated for the sample. Generalized linear models (gamma distribution with identity link function) were used to estimate the associations between the built environment attributes and SSW with leisure screen and driving time, adjusting for the sociodemographic variables. Additionally, the same results hold when we controlled for seasonality. Each built environment attribute was examined separately in each model (not mutually adjusted) to examine their total effects. A complete-case analysis was chosen (n = 1,904) because the proportion of missing data was low (5% missing; n = 102). Analyses were conducted using Stata 15.0 (Stata Corp, College Station, Texas), and the level of significance was set at $p < 0.05$.

3. Results

The mean age was 50.7 years, and about two-thirds (62.8%) were female, about 45% had completed a university degree, approximately 30% had an annual gross household income lower than $60 000/year, about 70% were married or living together, just about two-thirds (66.5) had no children at home <18 years of age and approximately 44% reported very good or excellent health status (table 1). Participants reported an average of 12.6 and 9.8 h/week leisure screen time and car driving, respectively.

Adjusting for covariates, a one standard deviation increase in SSW was associated with a 0.43 (95% CI −0.85, −0.02) hours/week decrease in leisure screen time (table 2). None of the other built environment attributes was significantly associated with leisure screen time. Adjusting for covariates, all built environment attributes (except the availability of sidewalks) were negatively associated with car driving (table 2). The strongest association was observed between SSW and car driving—a one standard deviation increase in SSW was associated with 0.77 (95% CI −0.85, −0.02) hours/week decrease in the car driving.

4. Discussion

This study examined associations of built environment attributes and SSW with two common sedentary behaviours, leisure screen time and car driving, among a sample of Canadian adults. Consistent with some previous studies (Fields *et al* 2013, Koohsari *et al* 2017b), we found no significant associations between objectively-measured built environment attributes such as population density and street connectivity with leisure screen time. Nevertheless, a previous study conducted on the same dataset used in our study found that participants from neighbourhoods with higher population density, larger walkshed area, more path/cycleway availability, a mix of recreational destinations, more business destinations, and bus stops (i.e., high walkability) reported less leisure screen time than those in less walkable neighbourhoods (McCormack and Mardinger 2015). Another study conducted in Australia found that a composite measure of neighbourhood walkability including dwelling density, land use mix, intersection density, and net retail area was negatively associated with women's television viewing time (Sugiyama *et al* 2007). These indicate that the combined effects of built environment attributes on sedentary behaviours may be different from their individual effects.

Notably, examining the effects of individual built environment attributes on sedentary behaviour is still useful for providing an evidence-base for urban designers and policymakers. In contrast with leisure screen time, car driving was found to be significantly associated with built environment attributes: those who lived in highly populated and more connected areas with a variety of destinations nearby were less likely to report car driving. A study conducted in Japan found that objectively-measured environmental attributes including population

Table 1. Characteristics of study participants (N = 1904).

n	Mean (SD) or N (%)
Age (mean)	50.7 (15.4)
Gender	
Female	1195 (62.8)
Men	709 (37.2)
Education	
High school or less	572 (30.0)
College	488 (25.6)
University	844 (44.3)
Annual gross household income	
<∃60 000/year	572 (30.0)
∃60 000–119 999/year	612 (32.1)
⩾∃120 000/year	554 (29.1)
Don't know/refused	166 (8.7)
Marital status	
Married/living together	1316 (69.1)
Single/divorced/separated	588 (30.9)
Children at home <18 years of age	
No child	1267 (66.5)
At least one child	637 (33.5)
Self-rated health	
Poor/fair	287 (15.1)
Good	781 (41.0)
Very good	640 (33.6)
Excellent	196 (10.3)
Leisure screen time (hours/week)	12.6 (10.6)
Car driving (hours/week)	9.8 (10.2)

Table 2. Associations between built environment attributes and leisure screen time and car driving (hours/week).

Built environment attributes	Leisure screen time β (95% CI)	Car driving β (95% CI)
Population density	−0.34 (−0.75, 0.07)	−0.48 (−0.87, −0.10)*
Intersection density	−0.29 (−0.73, 0.14)	−0.51 (−0.96, −0.07)*
Availability of sidewalks	−0.21 (−0.66, 0.23)	−0.34 (−0.75, 0.07)
Availability of destinations	−0.31 (−0.74, 0.12)	−0.75 (−1.02, −0.49)*
Space syntax walkability	−0.43 (−0.85, −0.02)*	−0.77 (−1.20, −0.33)*

β = regression coefficients for standardized environmental variables; CI = confidence interval; All models adjusted for age, gender, education, income, marital status, children at home, and self-rated health. * $p < 0.05$.
Each built environment attribute was examined separately in each model.

density, destinations, street connectivity, sidewalks, and access to public transportation to be associated with lower transportation sitting time (Liao *et al* 2016). Another study in Australia also found that living in less connected areas was associated with higher time spent in cars (Koohsari *et al* 2017a). These findings provided further evidence on the importance of built environment attributes on two types of highly-common sedentary behaviours. This evidence is particularly important given the dose-response relationships that exist between time spent driving and outcomes such as obesity (McCormack and Virk 2014) and cardiometabolic risk (Sugiyama *et al* 2016), overall health, quality of life psychological wellbeing (Ding *et al* 2014) and between sedentary time in general (including leisure-based screen time) and the increased risk of cardiovascular disease, type II diabetes, and all-cause mortality (Biswas *et al* 2015).

This is the first study, to our knowledge, examining associations between newly-developed SSW and sedentary behaviours. SSW was found to be significantly associated with both leisure screen time and car driving: those who lived in higher SSW areas reported less time engaged in leisure screen and driving sedentary activities. Importantly, SSW can be calculated without the need for detailed parcel land-use data, which are often either unavailable or difficult to obtain (Adams *et al* 2014). Therefore, the SSW can be estimated for different geographical locations, meaning that associations between the built environment and sedentary behaviours, as well as physical activities, can potentially be directly compared between cities and countries and across studies.

Our findings underscore the relevance of SSW for sedentary behaviours. Future longitudinal studies are needed to confirm these findings and to expand them into different contexts and sedentary behaviours.

This study has limitations. Although self-reports provide reliable estimates of sedentary behaviour (Clark *et al* 2009), they may still be subject to recall bias. Despite our measure of screen time capturing behaviour undertaken outside of the workplace, neither measure, screen time nor driving time, provided context-specific information about where the behaviours occurred. Additionally, while this study focused on leisure-based television and computer use and driving time, sedentary behaviour includes a broad range of activities and domains (e.g., occupational and non-occupational sitting, use of tablets or smartphones). While some screen time was not measured in our study, we focussed on leisure-based television and computer use and driving as these behaviours may be more amendable due to modifications to the neighbourhood built environment. Notably, some recent evidence suggests that self-reported time spent using smartphones and tablets may be less reliable than self-reported television and computer time (Vizcaino *et al* 2019). Future studies can investigate environmental correlates of other types of sedentary behaviour. Moreover, evidence suggests that it is not just too much sitting, but also prolonged bouts of sitting which are deleterious to health (Credeur *et al* 2019; Dempsey *et al* 2018). Further research is needed to identify how environmental attributes may support breaking prolonged bouts of sitting. As a cross-sectional study, causal relationships cannot be inferred. Additionally, increased car driving may also be related to the location of neighbourhoods within Calgary. In essence,the more walkable neighbourhoods tend to be closer to the city core and less walkable on the periphery (McCormack *et al* 2012). Furthermore, only one geographical buffer was used in this study to calculate built environment attributes, and we did not include a measure of public open spaces—more neighbourhood greenspace may be associated with increased sedentary behaviour during leisure time (Storgaard *et al* 2013). Future studies need to test how various built environment attributes calculated within different geographical buffer sizes may influence different sedentary behaviours. Our analysis included survey and environment data that was a decade old; however, our findings are supported by more recent studies. In Canada, the amount of time watching television has remained relatively stable since 2007, while the amount of time in passive travel has slowly increased (Prince *et al* 2020). Thus, despite the age of the data our findings are still considered relevant in today's context.

5. Conclusions and recommendations

This study suggests that urban design attributes may influence adults' sedentary behaviours. Notably, our findings highlight that the composite measure of SSW, which can be calculated using readily-available geographical data, is associated with leisure screen time and car driving. Neighbourhoods with well-connected street layouts and higher residential density were supportive of reducing two common adults' sedentary behaviours in a Canadian environment. Such evidence can help urban designers and policymakers in developing environmental guidelines to (re)design neighbourhoods in order to support adults' healthy behaviours in the Canadian context. Application of SSW can extend research on built environment correlates on sedentary behaviours into different geographical locations, where obtaining geographically detailed data is a challenge.

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