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Does the effect of walkable built environments vary by neighborhood socioeconomic status?

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ABSTRACT

Objective. To examine socioeconomic status as a moderator of the relationship between the built environment and active transportation such as walking or cycling using measures of built environment exposure derived from individuals transport trips.

Methods. The 2008 Montreal Origin–destination (OD) survey provided origin–destination coordinates for a sample of 156,700 participants. We selected participants from this survey that had traveled within the census metropolitan area of Montreal the day preceding the interview, and that were between 18–65 years of age. Measures of connectivity, land-use mix, and density of business and services were collected using 400-m buffers of the trip routes. Logistic regression was used to model the relationship between built environment variables and active transportation.

Results. Trip routes in the 2nd, 3rd, and 4th quartile of density of business and services or connectivity translated into greater odds of taking AT (compared to a trip in the lowest quartile). Trip routes in the 2nd, 3rd, and 4th quartile of land-use mix translated into lower odds of taking AT. Trips in the highest quartiles of connectivity and density of business and services were found to have a weaker association with active transportation if the individual undergoing the trip was from a low SES neighborhood.

Conclusion. Our results suggest that previous studies finding no effect modification may have been due to the limitation of measurements of exposures to the residential neighborhood.

Introduction

Studies examining disparities in physical activity find that those of low socioeconomic status (SES) engage in insufficient recreational physical exercise to meet recommended physical activity guidelines (Giles-Corti and Donovan, 2002). Given the health benefits of active transportation (AT) (Hamer and Chida, 2008; Pucher et al., 2010), and its higher prevalence among those of low SES (Adams, 2010; Giles-Corti and Donovan, 2002; Goodman, 2013; Miles et al., 2008; Owen et al., 2007; Pliakas et al., 2014; Turrell et al., 2013, 2014; Van Dyck et al., 2010; Van Lenthe et al., 2005), implementing health promotion efforts to induce further increases in AT in disadvantaged areas may be an effective way of diminishing health disparities (Sallis et al., 2011; Turrell et al., 2013; Van Dyck et al., 2010) and in inducing widespread population level increases in physical activity (De Nazelle et al., 2011; Ogilvie et al., 2004).

A vast body of literature has focused on examining the association between aspects of the built environment and mode choice (Broberg and Sarjala, 2015; Cervero, 2002; Cervero and Kockelman, 1997; Dalton et al., 2013; Ding et al., 2014; Ewing and Cervero, 2001; Ewing et al., 2015; Guo et al., 2007). The literature studying the relationship between physical activity and the physical environment have found that 3 key elements of the physical environment of the neighborhood, greater proximity to retail destinations (Ball et al., 2001; Cerin et al., 2007; Craig et al., 2002; Forsyth et al., 2008; Hoehner et al., 2005; King et al., 2003; Lee and Moudon, 2006; van Heeswijck et al., 2015), high connectivity (Cleland et al., 2008; Deforche et al., 2010; Grow et al., 2008; Nelson and Woods, 2010; Saelens et al., 2003; Sugiyama et al., 2012; Trapp et al., 2012; Witten et al., 2012), and high land-use mix (Giles-Corti and Donovan, 2002; Saelens et al., 2003; Sallis et al., 2004; Sugiyama et al., 2012) are related to walking and biking for transportation.

The modification of the physical environment to create walkable built environments in areas of low SES has been suggested as a method of increasing physical activity levels in low SES communities (Lee and Moudon, 2006; Sallis et al., 2009; Turrell et al., 2013; Van Dyck et al., 2010), subsequently reducing SES inequalities in physical activity. However, it is possible that not all socioeconomic groups benefit equally from walkable built environments (Sallis et al., 2009).

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Studies that have examined whether the influence of the built environment on AT differs for different socioeconomic groups have obtained mixed results (Kerr et al., 2006, 2007; Owen et al., 2007; Sallis et al., 2009; Van Dyck et al., 2010). The equivocal nature of these findings could be due to the way measures of the built environment were determined. More specifically, most studies have examined the built environment in residential settings ignoring non-residential destinations. Limiting the analysis to the residential neighborhood may be justifiable for people with reduced mobility such as the elderly, young children, and some spatially segregated groups such as certain ethnic minorities. However, most individuals are mobile and access destinations with heterogeneous environmental features that lie outside their residential neighborhood (Perchoux et al., 2013). Built environment features along the entirety of the spatial trajectory between origin and destination may have the potential to influence AT mode choice. Thus, the current practice of limiting our measurements of exposures to the residential neighborhood when examining environment–individual interactions can result in the neglect of many exposures that could act as key drivers of this behavior.

One method of taking into account the non-residential context when examining mobility is to use buffers of the trip route to measure environmental exposure(Badland et al., 2008; Chaix et al., 2014; van Heeswijck et al., 2015; Winters et al., 2010). Among the studies using this method, some have conducted their analyses at the individual level by combining trip measures in order to obtain measures of activity space environmental exposure, whereas others have conducted their analyses at the trip level (Badland et al., 2008; Chaix et al., 2014; Winters et al., 2010). Trip level analyses may allow for a more accurate prediction of AT by potentially avoiding a loss in measurement precision that may occur during the aggregation of trip level measures.

Yet, to our knowledge, no studies have conducted a trip level analysis when examining interactions between SES and the built environment. In our research, we aim to examine whether individual SES modifies the relationship between built environment attributes and AT using a sample of 201,189 trips. We address previous methodological limitations by performing a trip level analysis using estimated travel routes between origin and destination pairs.

Methods

Study Sample

The sample was drawn from the 2008 Montreal Origin–destination computer-assisted phone interview survey. This survey provides geographic coordinates for the origins and destinations of trips taken for a representative sample of participants above the age of four residing in the metropolitan region of Montreal. Respondents provided by phone individual information such as age, sex, possession of a driver's license, employment, and travel information for themselves and for their household members for the day preceding the interview. For every trip, phone respondents were asked to report travel mode, starting point (origin), and ending point (destination). The 2008 survey provided weekday travel information for a sample of 156,700 people undergoing 354,915 trips. All trips made within the census metropolitan area of Montreal by participants aged between 18 and 65 years were retained for this study.

Measures

We integrated travel survey data with spatial information on roads, land-use, commercial destinations, and the census within the MEGAPHONE (Daniel and Kestens, 2007) GIS using ArcGIS 10.1. The shortest route between each origin–destination pair, that didn't include travel by highway or ferry, was computed using Network Analyst. We included only walkable segments (i.e. elimination of highways) of the route network in our analysis, since we wanted to compute the walking or biking pathway for each origin–destination pair. We assumed that the shortest route between two origin–destination pairs has a high probability of being similar to a route that would be picked by an individual for AT. Each route served as a basis for the computation of a 400-m buffer area that was used to calculate measures of density of business and services, connectivity, and land-use mix. Even if the actual route may differ a bit from the shortest path, we hypothesized that participants wouldn't engage in too long of a detour, so that a 400-m buffer along the shortest path would adequately represent the actual route.

Active transport

The dependent variable active transport was created using the variable travel mode for each trip that was self-reported during the Origin–destination survey. The answers of respondents were categorized to form the binary dependent variable active (walking, biking) versus passive (all other) means of transport. For multimodal trips, the travel mode was only considered active if one of the reported modes was either walking or cycling.

Density of business and service destinations

The businesses and services were obtained from the 2008 DMTI Enhanced Points of Interest database of Quebec, a provincial database containing 363,191 businesses and services. We excluded businesses and services that were industrial or utilities in our analysis, as they were not considered to be destination that will incite individuals to take active means of transportation. Kernel density estimations were computed for the final sample of destinations lying within the boundaries of the census metropolitan area of Montreal (n = 191,688). We used quartic kernels with an adaptive bandwidth using 5% of the observations for the computation. The use of an adaptive bandwidth reflected our conceptualization of the influence that destinations would have on walking behaviors. We hypothesized that the spatial influence of a given business or service was inversely related to its proximity to similar destinations (Kestens et al., 2010). Destinations located in areas with few other businesses and services (low density areas) will have a greater catchment area than destinations in high-density locations, since they are likely to be associated with longer trips. This is because in dense areas competition prevents individuals from having to travel long distances (Kestens et al., 2010).

A measure of average density of business and service destinations was computed using the buffers of the trip routes. Densities were then categorized into quartiles due to their non-normal distribution.

Connectivity

We calculated connectivity using the DMTI 2010 road-network file by computing the density of 4-way or more intersections falling within the trip route buffer areas. Connectivity was also categorized into quartiles due to its non-normal distribution

Land-use mix

We used the DMTI 2007 land-use file to identify land-uses within our buffers. We used the following 5 land-use categories: commercial, government, open area, residential, and parks and recreational. We excluded land-uses that were not considered to be relevant in terms of inciting people to walk or bicycle (industrial land-uses, and resource-based land-uses such as power plants and sewage treatment plants). The land-use mix measures were calculated using the following formula (entropy index) (Duncan et al., 2010; Frank et al., 2004; Hajna et al., 2014):

$$\mathrm{EZ} = -\sum\nolimits_k \left(\frac{A_{kz} \ln A_{kz}}{\ln N} \right)$$

where E_Z is the entropy index of buffer zone Z, k is the category of land-use, A_{kz} is the percent of land-use k in buffer zone Z, and N is the number of land-use categories. Our N was a constant value, since it represented the number of land-use categories considered within the study area rather than the number of land-uses present within each individual trip buffer (Hajna et al., 2014). The index values vary between 0 and 1 where 0 represents a single land-use, and 1, the most diversified set of land-uses. Land-use mix was categorized into quartiles.

Neighborhood socioeconomic status

SES of the neighborhood was used as a proxy for individual SES and was calculated using the 2006 Pampalon index of material disadvantage (Pampalon et al., 2012) using a 400-m road-network buffer centered on the residence of each participant. This index is created from a principal component analysis at the dissemination area level using the following census variables: the proportion of people without a high school diploma, personal average income, and the ratio of employed to the population. Assuming that the population is spread evenly across the dissemination areas, the average material deprivation around each home was computed using the following formula:

$$M_z = \frac{\sum_d M_d C_{zd} P_d}{\sum_d C_{zd} P_d}$$