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Implications of the modifiable areal unit problem for assessing built environment correlates of moderate and vigorous physical activity

Douglas Houston*

Department of Planning, Policy, and Design, 300 Social Ecology I, University of California, Irvine, CA 92697-7075, USA

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A B S T R A C T

This study assesses the influence of the Modifiable Areal Unit Problem (MAUP) in analysis of the effect of built environment (BE) exposure on moderate and vigorous physical activity (MVPA) during walking periods. Adults ($n = 55$) wore a GPS unit and accelerometer for up to 7 days. More nearby green space, residential use, and open space were positively associated with MVPA after controlling for socio-demographics. Scale and zoning effects were observed in models of momentary BE-MVPA relationships using different scales and zone configurations. Compared to larger aggregation zones, proximate measures may be better for assessing green space and land use exposure during walking periods. Results do not support a prescriptive recommendation whether future studies should use a buffer- or grid-based zonal configuration.

Introduction

Understanding where physical activity (PA) occurs and the associated built environment (BE) contexts could help identify ways to encourage increased PA through improved neighborhood design. Development strategies such as smart growth, new urbanism, and transit-oriented development have received considerable attention in the planning sector given their potential to enhance urban sustainability by encouraging decreased automobile use and increased active travel (AT) (i.e., walking and cycling) which has been associated with positive health outcomes including reductions in heart disease, asthma, and obesity (Almanza, Jerrett, Dunton, Seto, & Pentz, 2012; Broberg, Salminen, & Kyttä, 2013; Brownson, Hoehner, Day, Forsyth, & Sallis, 2009; Ewing & Cervero, 2010; Ruth & Franklin, 2014). However, methodological challenges remain in assessing BE-PA relationships during periods of transport-related PA and in understanding how the geographic scale and zoning configuration used to classify BE exposure influences results.

Much of the recent evidence regarding the environmental correlates of PA has focused on the residential environment (Chaix et al., 2013; Clark & Scott, 2014; Feng, Glass, Curriero, Stewart, & Schwartz, 2010), but home neighborhoods may only partially reflect the features associated with daily activity given over 60% of daily moderate and vigorous physical activity (MVPA) can occur away from the home environment (Troped, Wilson, Matthews, Cromley, & Melly, 2010) and BE characteristics near home can differ significantly from those near non-home locations (Hurvitz & Moudon, 2012). Recognizing this shortcoming, recent studies have assessed the influence of BE factors near work, home, and school locations on PA intensity (Rodrıguez et al., 2012; Troped et al., 2010) and have assessed the importance of periods of transport-related PA on overall daily MVPA (Cooper et al., 2010; Oliver, Badland, Mavoa, Duncan, & Duncan, 2010; Rainham et al., 2012).

Studies focused on the influence of the "neighborhood" environment on PA suggest the optimal scale for BE measurement may vary by the location type and the neighborhood characteristic, behavioral outcome, and population under consideration. Restricting BE exposure classifications to within 1000 m of locations may be appropriate given most walks are shorter than 600 m and few exceed 1200 m; examining non-home neighborhoods is important given the majority of walking trips do not originate at home (Millward, Spinney, & Scott, 2013). Boone-Heinonen, Popkin, Song, and Gordon-Larsen (2010) considered associations between MVPA and BE characteristics within 1, 3, 5, and 8.05 km of participant homes and found that PA-related facilities within 3 km and intersection density within 1 km had the most consistent association with MVPA (Boone-Heinonen et al., 2010). Prins et al. (2011) found no association between MVPA and parks and sport facilities within 400, 800, and 2000 m of participant homes (Prins et al., 2011). Troped et al. (2010) quantified BE factors between 50 m and 1 km of home and work locations and found that intersection

* Tel.: +1 949 824 1870; fax: +1 949 824 8566.
E-mail address: houston@uci.edu.

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density, land use mix, and housing unit density were positively associated with MVPA in the near-home buffers, and that only population density and housing densities were associated with MVPA in the near-work buffers (Troped et al., 2010).

BE-PA relationships in such studies may not have been apparent because of the geographic scale at which exposure was specified (Duncan et al., 2010), and relationships may vary across geographic scales due to the modifiable areal unit problem (MAUP) (Dark & Bram, 2007; Gehlke & Biehl, 1934; Jelinski & Wu, 1996; Sexton & Linder, 2011). The MAUP refers to potential measurement error due to the definition of the areal units at which exposure is classified, and it has two components: (1) a scale effect, which refers to the sensitivity of results to the geographic size of the units used to define exposure, and (2) a zoning effect, which refers to the possibility that different configurations of zones of the same size may generate different results (Openshaw, 1984). A zoning effect, for instance, could exist if results using a 100-m continuous grid system differed from results using a 100-m grid system oriented in different ways. Past research, however, has conducted a pseudo analysis of the zoning effect by comparing different zonal categories of a similar area, such as a 400 m grid to a 200 m buffer (Clark & Scott, 2014; Mitra & Buliung, 2012; Zhang & Kukadia, 2005).

Zhang and Kukadia (2005) found scale and pseudo zoning effects in their comparison of five cell sizes and three planning and census zones of aggregation when analyzing BE factors (including land use, population density, and street networks) associated with travel mode choice (Zhang & Kukadia, 2005). Mitra and Buliung (2012) also found scale and pseudo zoning effects across six different spatial scales in their analysis of the influence of BE factors (including block and roadway configuration) on active school transport of children (Mitra & Buliung, 2012). Clark and Scott (2014) examined near-residence BE factors at 14 geographic scales and found that estimated relationships between them and PA were impacted by both scale and pseudo zone effects (Clark & Scott, 2014). Kwan and Weber (2008) indicate that MAUP and scale effect were not a problem when using aggregate data to estimate space-time measures of accessibility based on vehicle travel behavior because this measure incorporates individual spatial movement and activity patterns and ties together different spatial scales in its calculation (Kwan & Weber, 2008).

Studies of the environmental context of PA away from home have defined exposure to environmental features, such as parks, playgrounds, or green space areas, based on whether a given GPS point is located within the boundary of the feature (Lachowycz, Jones, Page, Wheeler, & Cooper, 2012; Quigg, Gray, Reeder, Holt, & Waters, 2010; Rainham et al., 2012; Wheeler, Cooper, Page, & Jago, 2010), but this approach fails to measure surrounding destinations or amenities along and near walking locations that could motivate greater levels of physical activity (Adams et al., 2011; Ewing & Cervero, 2010; Saelens, Sallis, & Frank, 2003). Studies have used GPS-based locational data matched with accelerometer-based monitoring to examine when and where PA occurs at a momentary level during periods traveling between locations (Chaix et al., 2013). They generally suggest higher daily rates of MVPA for children and youth are associated with greater daily exposure to green space in near-home environments and spaces occupied during daily activities (Almanza et al., 2012; Lachowycz et al., 2012; Rodrıguez et al., 2012) and that the features of areas occupied during daily activities are only weakly associated with the characteristics of home neighborhoods (Zenk et al., 2011). Zenk et al. (2011) found that exposure to park land use within 0.5 miles (805 m) of a participant's daily path was not associated with MVPA. Almanza et al. (2012) found exposure of children to greenness within 100 m of 30-s interval locations in the home neighborhood was associated with higher MVPA, and Rodrıguez et al. (2012) found that exposure of adolescent females to parks, schools, and high population density within 50 m of 1 min interval locations was associated with higher PA intensity.

These studies demonstrate that momentary analysis of matched GPS-accelerometer data could help expand our understanding of the influence of environmental features along or near daily walking locations on the intensity of physical activity, but they provide limited insights into how scale and zoning effects may influence results. Although previous research has examined the relationship between momentary exposures to environmental factors near daily walking locations and MVPA for children and youth based on matched GPS-accelerometer data (Almanza et al., 2012; Rodrıguez et al., 2012), the current study is the first investigation of the relationship between momentary exposure to BE factors near daily walking locations and MVPA for an adult population based on matched GPS-accelerometer data. Furthermore, although previous research has examined the influence of MAUP on estimations of the associations of the relationship of near-residence BE factors on travel mode, commute to school by AT, and daily physical activity (Clark & Scott, 2014; Mitra & Buliung, 2012; Zhang & Kukadia, 2005), this study is the first to examine the influence of MAUP on understanding the relationships of BE factors on MVPA at walking locations. Results improve our understanding of the sensitivity of BE-MVPA associations to the geographic scale and zoning configuration of BE exposure measures by assessing differences in the influence of momentary exposure to four built environment factors (green space, walkability, neighborhood-oriented businesses, and land use) on MVPA across three buffer-based scales (50, 250, and 500 m) and three corresponding grid-based scales (100, 500, and 1000 m).

Methods

Study area and participant recruitment

The study area consisted of about 31 square kilometers along the Exposition and Crenshaw corridors in south Los Angeles, California (Fig. 1). Overall, the population of the study area had a higher percentage of African-American residents than Los Angeles County (43% vs. 9%) and a lower percentage of Hispanic and Non-Hispanic White residents than the county (41% vs. 48%, and 53% vs. 28%, respectively) (US Census Bureau 2010 Decennial Census Summary File 1). About 30% of study area residents were foreign-born, 24% had a Bachelor's degree or higher, and 20% were in poverty compared to county residents overall who had a higher rate of being foreign born and having a Bachelor's degree or higher (36% and 28%, respectively) and lower rate of poverty (15%) (US Census Bureau. 2005–2009 American Community Survey). The present analysis is based on the first phase of a longitudinal, quasi-experimental study evaluating the impact of the Expo Line, a light rail transit line that started service in early 2012.

Study invitation letters were sent to all 27,275 households in the study area using addresses purchased from InfoUSA, a marketing information firm. A total of 143 households responded indicating one household adult was willing to participate in the seven day survey protocol, and all 143 were invited to participate. The overall response rate was 0.52%, which is comparable to the 1.4% response rate for the region's sample from the 2010–2012 California Household Travel Survey (defined as Los Angeles and Ventura County), which collected household data using a one day survey protocol (California Department of Transportation, 2013). A comparison of the final sample to the household marketing information associated with the address list used to contact households in the study area indicated that response rates did not vary greatly by household and demographic characteristics.