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The effect of street-level greenery on walking behavior: Evidence from Hong Kong

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ABSTRACT

Accumulating evidence shows that urban greenspaces have great health benefits, but establishing a causal relationship is difficult. It is often hypothesized that walking and physical activity are mediators in the relationship between urban greenspaces and health outcomes. Furthermore, most urban greenspace–physical activity studies have focused on parks rather than on landscaped streets, even though the latter are the most popular places for physical activity. The lack of research attention for landscaped streets is largely due to the fact that street greenery is difficult to measure, especially at eye level.

Using readily available Google Street View images, we developed methods and tools to assess the availability of eye-level street greenery. A two-layered study was developed that 1) examined the association between urban greenspaces and the odds of walking (versus not walking) for 90,445 participants in the Hong Kong Travel Characteristics Survey and 2) carried out sensitivity analysis of the association between urban greenspaces and total walking time for a subset of 6770 participants. Multilevel regression models were developed to reveal the associations between street greenery and walking behaviors while controlling for sociodemographic characteristics and other activity-influencing built environment factors, taking into account the inherent clustering within the data.

The results showed that both street greenery and the number of parks were associated with higher odds of walking; street greenery but not parks was associated with total walking time. Our results suggest that walking behavior is at least as strongly affected by eye-level street greenery as by parks. They also implicitly support the health benefits of urban greenspaces via walking and physical activity. With the large sample size, our findings pertain to the entire population of Hong Kong. Furthermore, the use of Google Street View is a sound and effective way to assess eye-level greenery, which may benefit further health studies.

1. Introduction

It is projected that nearly 70% of the global population will be living in urban areas by 2050. This rapid urbanization has made and will continue to make daily exposure to nature rarer. The lack of greenspaces in residential neighborhoods has been shown to have negative effects on residents' health and well-being (Gascon et al., 2015; Hartig et al., 2014; A. C. K. Lee and Maheswaran, 2011).

1.1. Effects of urban greenspaces on health

Many experimental studies have established that physical and visual exposure to greenspaces generate significant psychological and physiological benefits, such a reduction in long-term stress (Coon et al., 2011), increased recovery speed after surgery (Ulrich, 1984), healthier weight outcomes (Sarkar, 2017), lower risk of chronic diseases (Mitchell and Popham, 2008). Proximity to urban green spaces has been further linked to longevity and decreased mental stress (Takano et al., 2002; Ward Thompson et al., 2012).

1.2. Urban greenspaces and physical activity

In addition to its direct health benefits, exposure to greenspaces may indirectly promote health via three additional mediating pathways: 1) by providing settings that promote any form of physical activity; 2) by fostering social contact and a sense of community; and 3)

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by improving air quality (Hartig et al., 2014; Markevych et al., 2017). Many studies have focused on the *physical activity* pathway because physical activity in the presence of nature provides the synergistic beneficial effects of physical activity (Pretty et al., 2006; Pretty et al., 2005).

It is worth noting that most empirical greenspace–physical activity studies have focused on parks and open greenspaces. More precisely, however, urban greenspaces comprise landscaped streets, parks, open green fields, or any urban public areas with substantial green elements (Almanza et al., 2012). After reviewing 50 studies of parks, Kaczynski and Henderson (2007) reported that most studies revealed positive associations between the presence of parks in a neighborhood and physical activity. Some studies, however, have reported a counter-intuitive negative association (Duncan and Mummery, 2005) or no association (King et al., 2005) between greenspaces and physical activity. The ambiguity in the evidence may be explained by different definitions and the measurement accuracy of greenspace exposure (e.g., green streets are often excluded from empirical studies).

1.3. Street greenery and physical activity

According to several national surveys, streets are the most popular setting for walking, cycling, and physical activity, followed by home and then parks (Bauman, 1997; Rosenberg et al., 2010). However, evidence on the relationship between street greenery and physical activity is scarce, although street greenery has shown demonstrated associations with various health outcomes. The density of street trees, for instance, has been linked to a decreased prevalence of obesity (Lovasi et al., 2013), and a decreased prevalence of asthma for children (Lovasi et al., 2008). The presence of walkable green streets is also related to longer life spans for older adults (Takano et al., 2002).

1.4. The gaps and our approach

In a nutshell, urban greenspaces have been determined to provide significant health benefits to residents. Specific insights on how the design of greenspaces, including street-level greenery, may independently influence walking and physical activity patterns may help us gain deeper insight regarding which type of greenery has a health impact, what kinds of physical activity can be promoted, and what kinds of health benefits can be delivered (I. M. Lee et al., 2012; Sallis et al., 2012).

As shown in several reviews, street greenery has received less research attention than parks (Kaczynski and Henderson, 2007; Lachowycz and Jones, 2011). The omission is largely due to methodological limitations. Street greenery includes a variety of vegetation, such as street trees, shrubs, lawns, green walls, or front gardens next to streets. Nearly all current studies used one of three methods to assess street greenery in health studies: questionnaires (Takano et al., 2002), field audits (De Vries et al., 2013; van Dillen et al., 2012), and Geographic Information System (GIS) (Lovasi et al., 2008, 2011, 2013; Sarkar et al., 2015). All three methods have their strengths and inherent limits. Questionnaires may be subject to people's biases. Field audits are more objective, but they are time-consuming. GIS is objective and time-efficient; however, GIS data often do not include street vegetation, especially small one. Even when GIS data are available, such as street tree count or vegetation extraction from remote sensing imagery, the overhead-view street greenery assessed by GIS often differs from street greenery perceived by a person on the ground (Fig. 1). Thus, GIS assessment cannot accurately measure the level of street greenery perceived by a person on the street, especially in locations with high-density street greenery (Jiang et al., 2017; X. J. Li et al., 2015).

To address these inherent methodological limitations, we used Google Street View (GSV) images to assess the eye-level street imagery and associate it with residents' walking behaviors. GSV is a free image service that provides panoramic views from locations along streets in many worldwide cities. By retrieving GSV images with the GSV API, streetscape images of various locations can be obtained (Google Inc, 2016). Those panoramic images bear a close resemblance to what pedestrians see. It has already been demonstrated to be an effective and free data source for various built environment assessments, such as neighborhood environment audits (Rundle et al., 2011), urban open space evaluation (Edwards et al., 2013), and sky openness assessment (Liang et al., 2017). To our knowledge, it has not yet been used to study the association between greenspace and walking or physical activity.

In this study, we examined the associations of eye-level street greenery and the number of parks with walking behavior for a large population size in Hong Kong after adjusting for other activity-promoting built environments. Emerging from prior research evidence, we hypothesized positive effects of urban greenspaces upon individual walkability.

2. Methods

2.1. Participants and walking data

Hong Kong is a highly dense global city on the southeast coast of China, with a population of 7.29 million and a gross population density of 6603 people per km^2 (Census & Statistics Department of Hong Kong, 2016).

The walking behavior data were obtained from Hong Kong Travel Characteristics Survey (HKTCS) of 2011, which was conducted by the Transport Department to study travel patterns among Hong Kong residents. The HKTCS of 2011 comprised one main survey and five linked supplemental surveys, one of which focused on walking behavior.

The main travel survey had a large sample size, comprising 101,385 residents of 35,401 households spatially distributed throughout the territory of Hong Kong. Interviews were conducted by trained interviewers to collect data about participants' demographic and household information, and travel behaviors. In the main travel survey, one question was asked about "Did you make any trips during the reference 24-h period? If so, have you used any mechanized mode of transport or a bicycle?" If a person responded "Yes, but I have not used any mechanized transport or a bicycle" (i.e., the participant only made walking trips) or "No, I did not make any trips," he or she was not required to report further detailed trip information. The participants who answered "Yes, and I have used mechanized transport or a bicycle" were required to report detailed information about any trips, including walking trips, made during the reference 24-h period. Hence, we identified participants who had done some walking versus those who had not done any walking using the main travel survey data. After excluding participants who made no trips, the study analytic sample comprised 90,445 participants. The total walking time could not be obtained because subjects who made only walking trips did not report trip information.

In addition to the main travel survey, a supplemental walking travel survey was carried out on a subset of 6770 participants who made at least one walking trip during the reference 24-h period to extract detailed information for all walking trips made during that period (including walk trip start time, ending time, and trip origin and destination). Hence, we further summed the total walking time (in minutes) for the subset of 6770 participants. The dwelling locations of all participants were geocoded to latitude and longitude coordinates and visualized on a map in ArcGIS 10.5 (Fig. 2).

Corresponding to the data structure of HKTCS, a two-layered analysis strategy was designed: 1) examination of the association between urban greenspaces and the odds of walking (versus not walking) for the 90,445 participants who responded to the main survey, 2) sensitivity analyses of the association of urban greenspace and total walking time for the subset of 6770 participants who responded to the supplemental walking travel survey.