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Research paper

Exploring associations between urban green, street design and walking: Results from the Greater London boroughs

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HIGHLIGHTS

- The study examines *salutogenic* environment effects of urban green upon walking.
- The study comprised $N = 15{,}354$ respondents of the London Travel Demand Survey.
- Density of street trees was associated with higher odds of walking.
- Street-level *betweenness* at 400 m was associated with higher odds of walking.
- NDVI and density of street trees were positively associated with *distance walked*.

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ABSTRACT

In recent years, a series of studies have highlighted the positive effects of urban green on individual activity behaviour and health. In this paper, we examine *salutogenic* environment effects of urban green upon walking behaviour and how such effects are mediated by built environment configuration and street-level physical accessibility. The dwelling locations of $N = 15{,}354$ respondents of the London Travel Demand Survey were geocoded and individual walking behaviour was extracted from the travel diary. A 0.5-m resolution normalized difference vegetation (NDVI) index derived from spectral reflectance measurements in remotely sensed colour infrared data was employed as an objective measure of *greenness*, while density of street trees acted as proxy of perceived environmental quality in street corridors. A network model of street-level physical accessibility was developed using spatial Design Network Analysis (sDNA). Logistic regression models reported a significant association of odds of walking with density of street trees and street-level *betweenness* (a measure of street network connectivity), while sensitivity analyses with continuous regression models for participants doing some walking indicated beneficial associations of distance walked with NDVI greenness and street trees. The results illustrate the necessity for targeted intervention strategies in activity-friendly planning via greening and optimized physical design of urban built environments.

1. Introduction

With the alarming increase in the prevalence of obesity and associated chronic cardio-metabolic diseases, *active travel*, has in recent years, emerged as a new mantra for public health promotion (APHA, 2012; Lee & Buchner, 2008; NICE, 2012; WHO, 2002). Walking is the most common form of moderate-intensity physical activity (Pate et al., 1995; USDHHS, 1996). Accumulated epidemiological evidence has highlighted that active travel in the form of walking and cycling can minimize or offset health costs of sedentary lifestyles via increments in individual energy expenditures (Eyler, Brownson, Bacak, & Housemann, 2003; Flint, Cummins, & Sacker, 2014; Jarrett et al., 2012; Sallis, Frank, Saelens, & Kraft, 2004; Warburton, Nicol, & Bredin, 2006).

Constituent components of the built environment have been shown independently to promote walking and influence other physical activity behaviour (Lee & Moudon, 2006; Nagel, Carlson, Bosworth, & Michael, 2008; Owen, Humpel, Leslie, Bauman, & Sallis, 2004; Pikora et al., 2006; Saelens & Handy, 2008; Saelens, Sallis, & Frank, 2003; Suminski, Poston, Petosa, Stevens, & Katzenmoyer, 2005). In their many forms, urban green spaces constitute one of the most important components of the built environment in

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influencing walking, physical activity, health and mortality (Astell-Burt, Mitchell, & Hartig, 2014; De Vries, Verheij, Groenewegen, & Spreeuwenberg, 2003; Giles-Corti & Donovan, 2002; Lee & Maheswaran, 2011; Mitchell & Popham, 2008; Sugiyama, Leslie, Giles-Corti, & Owen, 2008; Takano, Nakamura, & Watanabe, 2002). The planting of trees in urban streetscapes has been practised for many centuries, as manifested in some of the earliest historic plans and paintings of European cities from the Renaissance period. Lawrence (2008) sets out the history of street trees in Europe and America, and their impact on the social and economic activity of the city. Following late 17th century French and Dutch landscape design traditions, street trees have been typically formalized as *allées/avenues and boulevards* of tall, evenly sized trees planted along major thoroughfares; and these continue to constitute an integral part of contemporary urban design practices (Grey & Deneke, 1986; Southworth, 2005). The health-promoting role of street trees has been highlighted in several studies (Lovasi, Quinn, Neckerman, Perzanowski, & Rundle, 2008; Lovasi et al., 2013).

Urban green has been shown to influence walking, physical activity and health outcomes (Hartig, Mitchell, De Vries, & Frumkin, 2014; Webster et al., 2015) and five underlying causal mechanisms have been identified:

- providing facilitative settings that promote physical activity in the form of enhanced walking, green exercise and cycling (Bedimo-Rung, Mowen, & Cohen, 2005; Maas, Verheij, Spreeuwenberg, & Groenewegen, 2008),
- facilitating social contact and fostering a sense of community (Kweon, Sullivan, & Wiley, 1998; Maas, Van Dillen, Verheij, & Groenewegen, 2009),
- providing opportunities for natural healing through recovery from physiological and psychological stress (Grahn & Stigsdotter, 2003; Hartig, Evans, Jamner, Davis, & Gärling, 2003; Ward Thompson et al., 2012; Woo, Tang, Suen, Leung, & Wong, 2009),
- acting as natural sieves, absorbing and diluting urban pollution and thereby ameliorating adverse environmental exposures (Nowak, Crane, & Stevens, 2006) and
- mitigating adverse health impacts of urban heat island effects (Loughner et al., 2012; Shashua-Bar & Hoffman, 2000).

Considerable research effort has begun to be focussed on both understanding the causal mechanisms listed above as well as on the design and configuration of walkable cities (Boer, Zheng, Overton, Ridgeway, & Cohen, 2007; Cerin, Leslie, Toit, Owen, & Frank, 2007; Forsyth, Hearst, Oakes, & Schmitz, 2008; Gómez et al., 2010; King et al., 2003). This agenda is gathering momentum as public health scientists and professionals have discovered a renewed appreciation of the link between health and the built environment. The urgency from the landscape and planning side is influenced, among other factors, by the continuing threat to city eco-systems brought about by densification and, ironically, restrictive growth boundary policies (Moll, 1989 on New York; Pauleit, Ennos, & Golding, 2005 on Sheffiled and Länsstyrelsen, 1996, on Stockholm). A recent survey of cities by the WHO European Healthy Cities Network highlights significant cross-country variability in accessibility to urban green; with almost all residents of the Northern European cities of Brussels, Copenhagen and Glasgow, for example, having access to neighbourhood green space within 15 minutes, but only 47% of the population of the cities of Bratislava and Kiev having the same level of access (Tsourou, 1998). In England, English Nature has stipulated standards for assessing provision of natural green space, termed the Accessible Natural Green space Standard (ANGsT). ANGsT recommends that everyone should have access to natural green space of:

- At least 2 ha within 300 m of their home,
- At least 20 ha within 2 km,
- At least 100 ha within 5 km, and
- At least 500 ha within 10 km.

Traditionally, greening pedestrianization has largely been limited to a small proportion of segments around city centres where pedestrian use outweighs vehicular movement needs. Contemporary landscape design practices continue generally to aim towards the creation of *shared places*, creating provisions for appropriate mixed modes of travel. In the Greater London Authority (GLA), approximately 47% of land area is green with 33% of this being vegetated public space and an additional 14% vegetated private green space and domestic gardens (http://www.gigl.org.uk/our-data-holdings/keyfigures/). The Mayor's London Plan has set standards of accessibility to urban greenery that aim for every Londoner to have a small or local park (less than 20 ha) within 400 m of their home, a district park (20–60 ha) within 1.2 km and a metropolitan scale park (60–400 ha) within 3.2 km (Mayor of London, 2008). A study of the English city of Bristol found that 55% of people live within 300 m of an urban green space with mean distances ranging from 2207 m for young people's type of space, 1758 m for formal, 1082 m for sports, 570 m for natural green, and 481 m for informal green space types (Hillsdon, Jones, & Coombes, 2011).

Recently, The Marmot Review (2010) highlighted the benefits of improving quality and accessibility of green spaces across socio-economic gradients as well as emphasizing the role of well-designed car-free pleasant streets in achieving this. In the UK several studies have highlighted significant spatial inequalities in access to health-promoting physical environments, urban parks and hence health induced by neighbourhood deprivation (CABE, 2010; Mitchell & Popham, 2008; Pearce, Richardson, Mitchell, & Shortt, 2010; Shortt, Rind, Pearce, & Mitchell, 2014).

Notwithstanding the heightened interest and the scientific research and official reports mentioned above, there is still ambiguity in the evidence about the relationship between access to urban greenery and walking and physical activity. This arises primarily as a result of the varied definitions of urban green; diverse methods employed to parameterize them; as well as the problem of causal inference. It is difficult to establish causality as a large proportion of studies focus on parks and open spaces as the unit of analysis in defining 'urban green', thereby conflating their functional roles in delivering a specific health benefit. It is difficult in such studies to conclude whether the health benefits have accrued from their functional roles as 'purely recreational spaces' or from their role more generally as 'salutogenic' environmental spaces'. Furthermore, there have been very few studies of the direct associations between urban greenery and individual-level active travel behaviour that adjust for urban morphology, neighbouhood-level deprivation and other confounding factors. In the absence of such adjustments (statistical controls), it cannot be confidently asserted that any variations in walking behaviour observed between individuals or between sampled neighbourhoods or other spatial units of analysis, is caused by differences in green space access and configuration per se. Where studies use aggregate measures, for example, correlating green space density and walking trips for sampled zones, there are the additional complications of the so called Modifiable Area Unit Problem and Ecological Fallacy. The former means that we cannot be sure whether a measured relationship between greenery and walking is reliable because alternative methods of aggregating will always yield different results. The latter problem means that we cannot reliably make generalised statements about individuals, the fundamental agents of an urban eco-system, on the basis of aggregate data because we are not accounting for possibly causally significant variations of individual patterns within the population in aggregated spatial units.