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Street network measures and adults' walking for transport: Application of space syntax

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ABSTRACT

The street network underpins the walkability of local neighborhoods. We examined whether two street network measures (intersection density and street integration from space syntax) were independently associated with walking for transport (WT); and, to what extent the relationship of street integration with WT may be explained by the presence of destinations. In 2003–2004, adults living in Adelaide, Australia ($n=2544$) reported their past-week WT frequency and perceived distances to 16 destination types. Marginal models via generalized estimating equations tested mediation effects. Both intersection density and street integration were significantly associated with WT, after adjusting for each other. Perceived destination availability explained 42% of the association of street integration with WT; this may be because of an association between street integration and local destination availability – an important element of neighborhood walkability. The use of space syntax concepts and methods has the potential to provide novel insights into built-environment influences on walking.

1. Introduction

Regular physical activity confers health benefits, including reduced risk of chronic diseases such as type 2 diabetes, cardiovascular disease and some cancers (U.S. Department of Health and Human Services, 1996, 2008). Walking is the most common type of physical activity across most age groups (Lee and Buchner, 2008). Nevertheless, the population prevalence of walking that is sufficient for health benefits is low in North America and Australia (Kruger et al., 2008; Pucher et al., 2011). Given the limitations of individual-motivational approaches to encouraging physical activity, ecological models incorporate broader determinants (Sallis et al., 2008), and emphasize built environment attributes as significant facilitators or barriers for transport or recreation walking (Sallis et al., 2006).

Street network design underpins a walkable neighborhood. The street network is one built environment attribute consistently associated with walking behaviors (Sugiyama et al., 2012). Compared with less-connected street networks, well-connected networks provide residents with more direct route options to destinations (Frank et al., 2010). Street connectivity is typically operationalized as intersection density, i.e., the number of 3-way or more intersections per land area unit (Handy et al., 2003; Leslie et al., 2007; Wang et al., 2013). Several studies have shown positive associations of intersection density with walking, especially walking for transport (WT) (Badland et al., 2008; Saelens et al., 2012; Sugiyama et al., 2012). For instance, a study in the USA found higher intersection density to be positively associated with WT (Li et al., 2008). In Australia, a longitudinal study has found that

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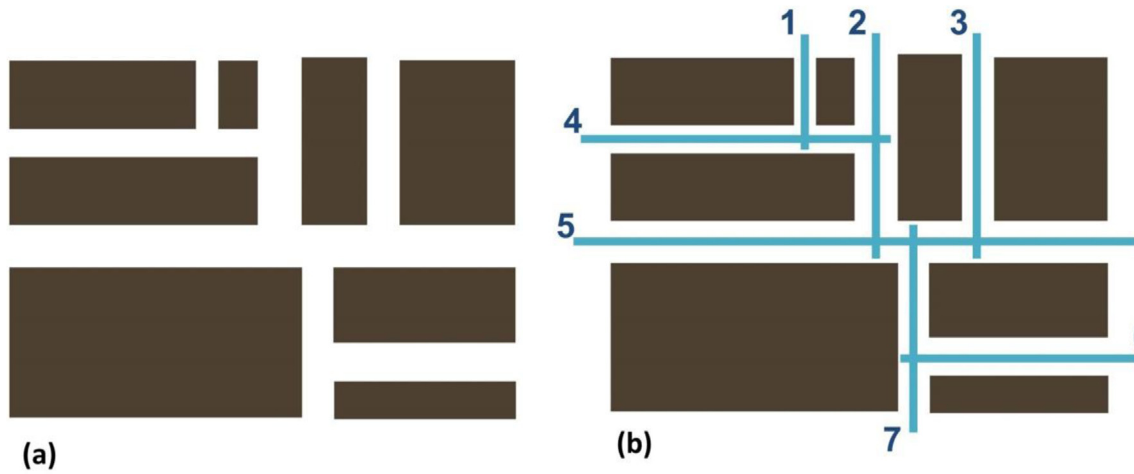

Fig. 1. (a) Neighborhood block and (b) its axial lines (numbers represent street names).

participants who relocated to areas with higher intersection density increased WT (Knuiman et al., 2014).

An alternative way of operationalizing street networks focuses on the spatial relationships between streets within a network (Hillier et al., 1987). This approach is based on space syntax theory, developed primarily in the fields of urban design and architecture to understand the structure or morphology of urban environments (Hillier and Hanson, 1984). Space syntax quantifies a spatial network using 'axial lines', which represent lines of sight (Liu and Jiang, 2012). Fig. 1 shows (a) a neighborhood block schematic and (b) its axial lines. Axial lines are the basis for measures of a network in space syntax. Each axial line is considered as a "node", and each node is connected to its other adjacent axial lines (nodes) by "links". The resulting set of nodes and links is called a "justified graph" (Klarqvist, 1993, 11). For example, Fig. 2 displays the justified graph for the neighborhood represented in Fig. 1, with node 5 as the base node. The main measure calculated from the justified graph is 'depth'. This is a measure of a street segment, and is "the sum of the links that must be traversed if one were to move from that space [street] to all other spaces [streets]" (Peponis and Wineman, 2002, 273). Simply, to reach a street that has a depth of 3, one has to make three turns. In Fig. 2, node 5 has a total depth of 10 (a), but node 1 has a total depth of 19 (b). Mean depth is a measure of a network, calculated by summing the depth value of every street within a network dividing by the number of total streets less one (Hillier and Hanson, 1984). Integration is another measure that is calculated from the inverse of the mean depth: the higher the integration value, the lower its mean depth. For example, highly integrated streets require fewer turns to reach; whereas less integrated streets require more turns to reach (Hillier, 2009). Space syntax measures detect how a street is topologically proximal to other streets within the network and how all streets within a network are connected to each other. Fig. 3 shows the levels of integration for streets in the neighborhood presented in Fig. 1.

Compared with intersection density, which measures the number of street intersections within a network, space syntax measure of integration considers the way in which streets are connected to each other within a network and whether some

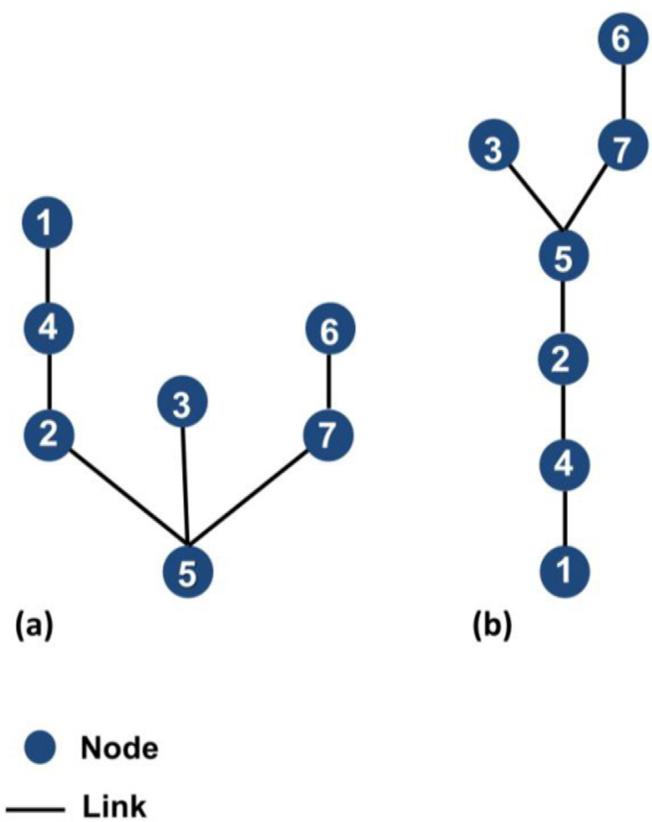

Fig. 2. Justified graph using nodes 5 (a) and 1 (b) as the root street.

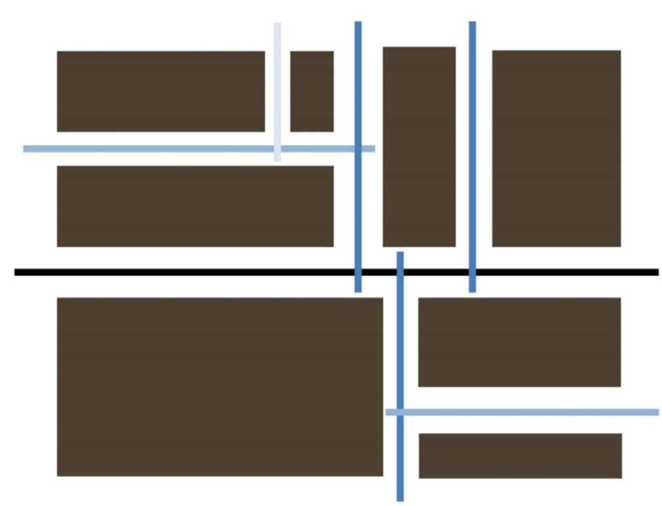

Fig. 3. Diagram showing the levels of integration (darker lines show more-integrated streets).