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# Built environmental factors and adults' travel behaviors: Role of street layout and local destinations

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ABSTRACT

Street layout is consistently associated with adults' travel behaviors, however factors influencing this association are unclear.
We examined associations of street layout with travel behaviors: walking for transport (WT) and car use; and, the extent to which these relationships may be accounted for by availability of local destinations.
A 24-h travel diary was completed in 2009 by 16,345 adult participants of the South-East Queensland Household Travel Survey, Australia. Three travel-behavior outcomes were derived: any home-based WT; over 30 min of home-based WT; and, over 60 min of car use. For street layout, a space syntax measure of street integration was calculated for each Statistical Area 1 (SA1, the smallest geographic unit in Australia). An objective measure of availability of destinations – Walk Score – was also derived for each SA1. Logistic regression examined associations of street layout with travel behaviors. Mediation analyses examined to what extent availability of destinations explained the associations.
Street integration was significantly associated with travel behaviors. Each one-decile increment in street integration was associated with an 18% (95%CI: 1.15, 1.21) higher odds of any home-based WT; a 10% (95%CI: 1.06, 1.15) higher odds of over 30 min of home-based WT; and a 5% (95%CI: 0.94, 0.96) lower odds of using a car over 60 min. Local destinations partially mediated the effects of street layout on travel behaviors.
Well-connected street layout contributes to active travel partially through availability of more local destinations. Urban design strategies need to address street layout and destinations to promote active travel among residents.


## 1. Introduction

Regular physical activity has substantial health benefits including reduced risk of several of the most common chronic diseases, including type 2 diabetes, cardiovascular disease and some common cancers (U.S. Department of Health and Human Services, 2008). Sedentary behavior — too much sitting — has also been found as a distinct behavior associated with chronic disease risk (Owen et al., 2010; Rohm et al., 2016; Thorp et al., 2011). Physical inactivity and sedentary behavior can have synergistic impacts on health outcomes, including all-cause mortality (Ekelund et al., 2016). Given the limitations of individually-based approaches to increasing physical activity and reducing sitting time, ecological models are increasingly used to underpin the inclusion of broader determinants (Sallis et al., 2008). In particular, recent research findings building on the models emphasize the potential of the neighborhood built environment for facilitating physical activity and reducing sedentary behavior (Kerr et al., 2016; Owen et al., 2011; Sallis et al., 2008). For example, a recent international study on the associations of objectively-assessed environment attributes with accelerometer-measured physical activity identified a number of built environmental factors that are associated with adults' physical activity (Sallis et al., 2016).

Street layout — the way in which streets are laid out and connected in neighborhoods — is one of the built environment elements related to

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physical activity such as walking (Koohsari et al., 2014; Sugiyama et al., 2012b). For example, a study conducted in Australia found that residents of neighborhoods with highly-connected street layouts were more likely to walk, compared with those who living in less-connected areas (Kamruzzaman et al., 2014). In the USA, a longitudinal study found increases in street connectivity to be associated with greater increases in transportation walking over time (Hirsch et al., 2014).

Well-connected street layouts are hypothesised to support walking by providing short and direct routes between origins and destinations and permitting more route options to reach destinations (Dill, 2004; Handy et al., 2003; Handy et al., 2010; Saelens et al., 2003). Another potential factor involved in the relationship between street layout and walking is the presence of local destinations, which may exist in areas with well-connected street layouts (Tsou and Cheng, 2013). Koohsari et al. (2014, 2016) found availability of utilitarian destinations partially mediated the associations of street layout measures (intersection density and street integration) with transportation walking. However, these previous studies examining the role of destinations in associations of street layout with walking relied on self-reported availability of destinations within walking distance, which may not truly reflect the overall availability of local destinations. In addition, these studies used a non-location-specific measure of walking, which could cause spatial mismatch between the location where walking took place and the area where environmental attributes were measured. These methodological issues need to be addressed to accurately assess how destinations are involved in the relationships between street layout and walking. In addition, previous studies did not examine whether street layout is related to car use — a common sedentary behavior with known health impact (Sugiyama et al., 2012a; Sugiyama et al., 2016) — and the role of local destinations in the relationship between them.

We examined the associations of street layout with active and sedentary travel behaviors: home-based walking for transport (WT) and car use, and evaluated to what extent the relationship of street layout with these two types of travel behaviors may be explained by objectively-assessed availability of local destinations.

## 2. Methods

### 2.1. Data source and study setting

Data from the 2009 South-East Queensland Household Travel Survey (SEQHTS) were used in this study. The SEQHTS is a large-scale repeated cross-sectional survey administered by the Queensland Government Department of Transport and Main Roads. Detailed methods of sampling, recruitment and data collection have been described elsewhere (Queensland Government, 2010). Briefly, the SEQHTS has a multistage random sampling design in which Census Collection Districts (CCD, a geographical unit comprising of about 250 households) were first selected, followed by recruitment of households from each CCD. The median size of selected CCDs was 0.36 $km^2$ (interquartile range: 0.61 $km^2$). About 4.4% of households from selected CCDs (10,335 households) participated in this study (response rate of about 60%). The total number of participants in the 2009 SEQHTS was 27,213. Of these, this study examined adult participants aged between 18 and 64 years old who reported any trip on the day of the survey ($N = 16.345$). The SEQHTS was administered in accordance with ethical guidelines under Queensland government statutes and regulations. Informed consent was obtained from participants.

### 2.2. Measures

#### 2.2.1. Outcomes: travel behaviors

All members of participating households were asked to report their travel behaviors using a 24-h travel diary. For each travel, they reported the start time, end time, origin, destination (place the person went to for the particular trip), purpose, and mode of travel. This study focused on two types of travel behaviors: WT and car use that originated or ended at home (home-based WT and home-based car use). Based on the travel diary, we calculated the following three dichotomised outcomes for each participant: any home-based WT or not; accumulating over 30 min of home-based WT or not, and accumulating over 60 min of car use or not. The cut-off of 30 min was chosen for walking on the basis of current physical activity guidelines (Australian Government Department of Health and Ageing, 2005). For car use, we used 60 min as a cut-off based on a recent study showing adverse associations of spending more than 60 min per day in car with markers of cardio-metabolic risk (Sugiyama et al., 2016).

#### 2.2.2. Exposure: street layout

A space syntax measure of street integration was calculated for each street segment using Axwoman (Jiang, 2012) and University College London DepthMap (Turner, 2004) software. Street integration, which indicates how topologically "close" a street segment is to the other segments within the street layout, is a key measure of space syntax (Hillier, 2009). We used this space syntax measure for street layout, building on our previous study in which integration was found associated with perceived availability of local destinations (Koohsari et al., 2016). Although space syntax is relatively new in research on active living, it has been used widely in urban design and planning practice (Lerman et al., 2014). There were two aggregation steps in the calculation of integration score. The first step was street-level identification: an integration score was assigned to each street segment considering all the other street segments within a 1 km distance from its centre. We chose 1 km as the buffer size in this step, as it is reported that walk to local destinations does not often exceed this distance (Millward et al., 2013). The second step was area-level calculation of integration. For each participating Statistical Area 1 (SA1), the mean integration score was calculated for all street segments within the area. SA1 is the smallest geographic unit for Census data in Australia from 2011 (Australian Bureau of Statistics, 2011). Although CCDs were used for recruitment, SA1s were used for analyses because they tend to be more consistent in population size and homogeneous in characteristics than CCD (Australian Bureau of Statistics, 2011). The study area contained 1348 SA1s, which were classified into deciles according to the mean integration score. Since the exact address of each participant was unavailable, participants were assigned the integration score of the SA1 they lived in.

#### 2.2.3. Potential mediator: availability of local destinations

Walk Score – a web-based, publicly-available tool that scores places based on proximity to various local destinations – was used as a measure of objectively-assessed availability of local destinations (www.walkscore.com). Walk Score was determined for each SA1, using the score obtained for the centroid of SA1. SA1s were classified into deciles according to their Walk Score (Cole et al., 2015).

#### 2.2.4. Covariates: socio-demographic variables

The following socio-demographic characteristics were collected in household travel survey: age, gender, employment, living arrangements living arrangements, and household income.

### 2.3. Statistical analysis

For the first question (associations of street layout with travel behaviors), we used logistic regression to estimate the odds of engaging in these travel behaviors according to the level of street integration.

The second question of this study was how much the associations of street layout with travel behaviors may be mediated by the availability of local destinations. We followed the procedure proposed by Baron and Kenny (1986), which consists of the following four steps (Fig. 1). The first step is to establish a non-zero association between street layout (exposure) and travel behaviors (outcomes). This is the same as the first question discussed above, and corresponds to path C in Fig. 1. The