



## Associations of street layout with walking and sedentary behaviors in an urban and a rural area of Japan



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### ABSTRACT

We examined whether street layout—a key urban design element—is associated with walking and sedentary behaviors in the context of a non-Western country; and, whether such associations differ between an urban and a rural area. In 2011, 1076 middle-to-older aged adults living in an urban and a rural area of Japan reported their walking and sedentary (sitting) behaviors. Two objective measures of street layout (intersection density and street integration) were calculated. Participants exposed to more-connected street layouts were more likely to walk for commuting and for errands, to meet physical activity recommendations through walking for commuting, and less likely to drive. These relationships differed between the urban and the rural area. This shows that previous findings from Western countries on associations of street connectivity with travel behaviors may also be applicable to Japan.

### 1. Introduction

Regular physical activity confers numerous health benefits, including reduced risk of chronic diseases such as type 2 diabetes, cardiovascular disease, obesity, and some cancers (Beaglehole et al., 2011). Sedentary behavior—too much sitting—has also been identified as a distinct behavior with adverse health consequences (Owen et al., 2010; Wijndaele and Healy, 2016). Despite public health efforts to promote active living, a more sedentary lifestyle (lack of physical activity and prolonged sitting) is highly prevalent in many countries. For example, according to the national household travel surveys less than 20% of US adults reported any walking (Pucher et al., 2011). In Japan, population-level physical activity has shown continued declines over the last few decades (Inoue et al., 2011). In addition, Japanese people spend a high proportion of their waking hours sitting. An international study with data from 20 countries found that adults in Japan reported the highest amount of sitting per day, with the median over 360 min/day (Bauman et al., 2009).

Ecological models of physical activity and sedentary behaviors emphasize the importance of people's surrounding built environments

in shaping their daily actions (Sallis and Owen, 2015). Over the past decade, a wide range of built environment attributes have been investigated in relation to physical activity, especially walking (Ewing and Cervero, 2010; Gebel et al., 2007; Saelens and Handy, 2008), which is a common physical activity of adults (Millward et al., 2014; Spinney et al., 2012). For example, many studies have found the walkability construct—which consists of residential density, land use mix, intersection density, and net retail area ratio—to be associated with several types of physical activity behaviors, particularly walking (Frank et al., 2005). In Japan, there are a few previous studies examining the relationships between population density and walking (Inoue et al., 2009, 2010). Although these studies used self-reported measures of density, their findings are consistent with studies in other countries (i.e., higher density is associated with more walking). On the other hand, there have been mixed findings on the associations of perceived street connectivity with walking, previously reported in one Japanese study (Inoue et al., 2010). Street connectivity—the way streets are connected in a neighborhood—has been consistently found to be related to active travel behaviors such as walking and bicycling (Koohsari et al., 2015b; Sugiyama et al., 2012). Street connectivity

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appears to be a fundamental component of urban form, which can be measured relatively easily using the street centerline data that typically are available through local instrumentalities (Koohsari et al., 2016a). Further evidence, especially from Asian countries, on the association of street layout with walking behavior should thus be particularly helpful for future research.

Compared with less-connected street layouts, well-connected street layouts are more conducive to active travel behaviors such as walking and bicycling, in part through providing more direct route options (Saelens et al., 2003). For example, a study conducted in 24 Californian cities found higher street connectivity to be associated with more walking, cycling, and transit use (Marshall and Garrick, 2010). A recent international study on the association of built environment attributes with active travel behaviors also found well-connected street layouts to be associated with transport-related walking and cycling (Christiansen et al., 2016). It has been also found that more connected areas tend to have more local destinations (Koohsari et al., 2016b, 2016c). For example, a recent study found the association between street layout and walking to be partly mediated through the availability of local destination (Koohsari et al., 2016c).

Nevertheless, this area of research has been limited in two important ways. First, studies on street layout measures correlates of physical activities and sedentary behaviors have been conducted predominantly in Western countries such as the United States, Australia, Canada, Belgium, and the United Kingdom. Little is known about these relationships in the context of non-Western countries. In Japan, there are a few studies that have examined the relationships between built environment attributes and specific physically-active behaviors, and these have mainly relied on self-report measures of neighborhood attributes and did not include sedentary behaviors (Chen et al., 2013; Inoue et al., 2010). Two recent reviews on built environment attributes related to walking and to sedentary behaviors in adults have identified only two (out of 63) studies from Japan on these topics (Koohsari et al., 2015b; Sugiyama et al., 2012). Japanese cities have different environmental attributes in comparison to Western cities. For example, average population and building densities in Japanese urban areas are generally higher than in Western cities, and Japanese cities have better public transport accessibility (Kaido, 2006; Kenworthy and Laube, 2002). Because of these unique environmental characteristics, evidence on street layouts associated with active behaviors obtained in previous research may not be applicable to Japan. Previous studies have also shown that urban and rural areas might differ in how built environment attributes are related to active travel behaviors (Frost et al., 2010; Hansen et al., 2015; Millward and Spinney, 2011). Nevertheless, the majority of previous studies examining the associations of street layout with active travel behaviors have been conducted in urban or suburban settings. It is unknown how street layouts are related to active travel behaviors in rural areas.

This paper therefore has two aims: to examine to what extent street layout is associated with walking and sedentary behaviors in the context of Japan; and, to examine whether associations of street layout with these behaviors differ between an urban and a rural area.

## 2. Methods

### 2.1. Data Source and Study Setting

This study used cross-sectional survey data from a part of the Healthy Built Environment in Japan (HEBEJ) project. The HEBEJ project, conducted at the Faculty of Sport Sciences, Waseda University, explores how the built environment may influence health behaviors and outcomes in Japan among middle-to-older aged adults. Middle-aged adults were included in this project because this is a life stage when people begin to experience age-related functional decline and other associated health problems (World Health Organization, 2002). Data were collected in 2011 from middle-to-older aged adult residents

living in Nerima Ward (urban area) and Kanuma City (rural area). The recruitment procedure of the current study was guided by the method of the International Physical Activity and the Environment Network (IPEN) studies in which participants were recruited from high walkable and low walkable areas (Kerr et al., 2013). The main reason for this procedure is to have a larger variability in the relevant environmental measures (Giles-Corti et al., 2005). Nerima Ward is part of the Tokyo Metropolitan area with 716,000 residents and an area of 48 km<sup>2</sup>, and Kanuma City is a regional area located about 120 km north of Tokyo with 102,000 residents and an area of 491 km<sup>2</sup>. A total of 1500 residents aged 40–69 years were randomly selected from the registry of residential addresses (balanced in gender and age group) from each city. The postal survey was completed by 1076 participants (response rate: 36%). Written informed consent was obtained from all respondents. This survey and its linkage with built environment measures received prior approval from the Institutional Ethics Committee of Waseda University (2010-238).

### 2.2. Measures

#### 2.2.1. Outcomes

**2.2.1.1. Walking behaviors.** Participants reported their walking in the past week for three specific purposes: for commuting; for errands; and, for exercise (defined as at least 5 min of continuous activity). The validity of walking questions were reported elsewhere (Inoue et al., 2010). Six dichotomized walking outcomes were calculated for each participant: whether they reported any walking or not for each purpose, and whether they met physical activity recommendations of at least 150 min of physical activity in the last week (Centers for Disease Control and Prevention, 2016) or not through walking for each purpose.

**2.2.1.2. Sedentary behaviors.** Using a validated questionnaire (Ishii et al., 2013; Salmon et al., 2003), participants were asked about time spent in TV viewing (TV viewing time did not include any other screen time) and car driving in the past week. Two dichotomized sedentary behavior outcomes were calculated for each participant: accumulating over two hours of TV viewing per day, or not; and, accumulating over one hour of car driving per day, or not. The cut-off of two hours/day was chosen for TV viewing time on the basis of previous studies showing its health risks (Bowman, 2006; Dunstan et al., 2005). For car driving, we used one hour/day as a cut-off based on a recent study showing adverse associations of car use over 1 h/day with markers of cardio-metabolic risk (Sugiyama et al., 2016).

#### 2.2.2. Exposures

**2.2.2.1. Street layout measures.** Two street layout measures — intersection density and street integration— were examined. Although related, these two street layout measures can have distinct associations with walking behavior (Koohsari et al., 2016c). Intersection density was calculated using geographic information systems (GIS), as the total number of three-way or more intersections per hectare within an 800 m radius buffer of participants' geocoded residential address. A 800 m radius buffer was selected to be consistent with previous studies examining environmental correlates of active behavior among middle-to-older adults (Nagel et al., 2008; Troped et al., 2014). Street integration, a key measure in space syntax, refers to how a street segment is 'topologically' close to other street segments within the network (Hillier, 2009). Compared with less-integrated segments, more integrated street segments require fewer turns to reach them from the other street segments, thus are considered to be more accessible

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