論文

Walk Score® and Space Syntax in Research on Activity-Friendly Built Environment and Cardiovascular Diseases

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Key words: Urban design, Public health, Environmental factors, Neighbourhood, Heart diseases

[Abstract]

Emerging research from Asian and Western counties demonstrates the potential impact of urban design on cardiovascular diseases. While motivating individual lifestyle changes (e.g., targeting individuals through behaviour change strategies) remains essential in preventing these diseases, sustainable built environment interventions that can impact a high percentage of the population are needed. Nevertheless, the science of modifying the built environment to enhance cardiovascular health outcomes is still in its infancy, with several challenges. This paper discusses how two built environment tools, Walk Score® and space syntax, can address some of this topic's methodological and policy-relevant issues. We also explain the next steps and future directions to enhance these tools and concepts.

スポーツ科学研究, 20, 27-38, 2023 年, 受付日:2023 年 1 月 20 日, 受理日:2023 年 3 月 29 日
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I. Introduction

Cardiovascular disease is number one cause of death in the world, responsible for about 17.9 million deaths per year (31% of all deaths worldwide) (World Health Organization, 2017). There has been a decline in cardiovascular disease burden over the last two decades (Vos et al., 2020). However, cardiovascular disease remains to be among the top leading cause of non-communicable disease problems and death. Several modifiable risk factors, such as obesity, physical inactivity, high blood cholesterol, high blood pressure, and smoking, are responsible for many cardiovascular diseases (Feigin et al., 2021; Yusuf et al., 2020). Nevertheless, these risk factors are common in most high- or low-income countries. For instance, about 20% of Canadian adults have elevated blood cholesterol (Public Health Agency of Canada, 2019). Therefore, there has been a call to reduce and manage these modifiable risk factors to control the burden of cardiovascular diseases.

Physical inactivity is one of the crucial modifiable risk factors for cardiovascular diseases. Mounting evidence suggests the beneficial effects of physical activity in preventing and managing cardiovascular diseases (Wahid et al., 2016). Nevertheless, the rate of physical activity is low in many countries (Dumith et al., 2011; Katzmarzyk et al., 2022; Kohl et al., 2012). People are also involved in too much sitting, a new cardiovascular risk factor (Katzmarzyk et al., 2020). Socioecological models in health behaviour indicate that several individuals, family, administrative, and policy levels influence people's active and sedentary behaviours (Sallis and Owen, 2015). These models have acknowledged the role of the built environment in promoting an active lifestyle. The built environment can be defined as "the human made space in which people live, work, and recreate on a day-to-day basis" (Roof and Oleru, 2008). It includes "homes, schools, workplaces, parks/recreation areas, greenways, business areas and transportation systems" (National Institute of Environmental Health Sciences, 2004). It is hypothesised that built environment attributes can facilitate or impede people's choices in engaging in physical activity behaviours in a long-term and sustainable way (Chokshi and Farley, 2014).

Several built environment attributes, such as population density, land-use mix, access to destinations, and availability of green spaces, have been linked to active and sedentary behaviours (Koohsari et al., 2015; Saelens and Handy, 2008). For instance, a longitudinal study in Australia found that people who moved to well-connected neighbourhoods increased their transportation walking (Knuiman et al., 2014). Another study in the USA found that neighbourhood greenness and walkability were associated with higher physical activity among adult women (James et al., 2017). There is also evidence of the role of the built environment on physical activity and sedentary behaviour in the context of Asia (Motomura et al., 2022; Müller et al., 2020). For example, a study conducted in Japan found that people who lived in neighbourhoods with well-connected streets were more likely to walk and less likely to drive (Koohsari et al., 2017). Additionally, there have been growing studies examining associations between activity-friendly built environments and cardiovascular diseases (Malambo et al., 2016; Nieuwenhuijsen, 2018). A PubMed search of published literature, including the keywords "built environment" and "cardiovascular diseases", undertaken in March 2023, revealed 112 articles, of which 81 were published since 2017. Therefore, this evidence suggests that built environment attributes that encourage an active lifestyle in multiple ways can influence cardiovascular health.

Nevertheless, the science of modifying the built environment to enhance cardiovascular health outcomes is still in its infancy, with several challenges (Diez Roux et al., 2016; Koohsari et al., 2020a; Koohsari et al., 2021). Notably, Koohsari et al. (2020a) have identified and categorised these challenges into three categories of conceptual (interactions between activity time and place; behavioural mechanisms; different effects of built environment attributes), methodological (variability in urban design variables; co-existence of urban design characteristics; causality), and policy-relevant issues (built environment standards; separating built environment indices). In this paper, we discuss how two built environment tools, Walk Score® and space syntax, can address some of this topic's methodological and policy-relevant issues. We also explain the next steps and future directions to enhance these tools and concepts.

II. An easily-available built environment composite index: Walk Score®

One of the critical challenges in the research on the built environment, active living, and cardiovascular health is that built environment characteristics co-exist in the real world and act together with people's behaviour (Koohsari et al., 2020a). It is essential then to investigate how composite built environment indices may influence active and sedentary behaviours. Neighbourhood walkability is a built environment index frequently used to understand built environment and physical activity relationships (Frank et al., 2010). It consists of four variables: population density, land use mix, intersection density, and net retail area ratio. Neighbourhood walkability has been found to be associated with active and sedentary behaviour across different countries (Frank et al., 2010; Kaczynski and Glover, 2012; Koohsari et al., 2014; Owen et al., 2007). Neighbourhood walkability was also found to be associated with cardiovascular diseases in several previous studies (Howell et al., 2019; Koohsari et al., 2020b; Makhlouf et al., 2022). However, this index requires detailed parcel-level spatial data, which are commonly unavailable or difficult to access (Kerr et al., 2013; Salvo et al., 2014). Additionally, this index is usually calculated by geographic information systems (GIS). Managing and analysing data using GIS software requires extensive training and unique computer equipment, which is an additional limitation. This special equipment and expertise may not be available to many local policymakers and developers to calculate this index. These issues underscore the need for developing and testing easily-available environmental indices in relation to active and sedentary behaviour is necessary.

1. What is Walk Score®?

Walk Score® is a publicly-available tool that allocates a score to any given geographical address (www.walkscore.com). Walk Score® employs a decay function to give a raw score to each address based on its network distance to near destinations such as stores, cafes, grocery stores, banks, restaurants, schools, bookshops, parks, fitness centres, and restaurants within a mile (1.6km) from that address (Walk Score, 2020). It then standardises the score from 0 to 100 with adjustment of population density and road metrics (intersection density and block length) around that address. Higher scores correspond to locations with more destinations nearby and conducive to walking.

2. Validation of Walk Score®

Walk Score® is produced by a commercial company aiming to provide real estate agencies with information about the walkability of properties. Some previous studies mentioned the detailed Walk Score's algorithm (Nykiforuk et al., 2016; Zhang et al., 2022). For example, according to Nykiforuk et al. (2016), Walk Score is "calculated by determining a raw score out of fifteen, normalising that score from zero to one hundred, and deducting two penalties for low intersection density and high average block length" as below (page 534):

Walk Score® = Raw Score / 15 x 6:67 − (intersection density + average block length)

Nevertheless, its detailed algorithm to compute a score is not fully open to the public on its website (at the time of writing this paper). This is a limitation of applying Walk Score® in research because if the algorithm is changed, comparing Walk Scores® in previous studies and checking the trend will be difficult or impossible. Additionally, their website states that Walk Score® uses data sources from Google, Open Street Map, Factual, Great Schools, and other open-source data. Different regions and countries likely use different methods in constructing these base maps, from which Walk Score® is derived. Therefore, it is necessary to examine the concurrent validity of the Walk

Score® and objectively derived walkability measures (i.e., using GIS, audits) in different geographical areas. Several studies have reported the concurrent validity of the Walk Score® in the USA and Canada (Duncan et al., 2011; Nykiforuk et al., 2016). For instance, a USA study found that Walk Score® was positively correlated with several walkability measures (Duncan et al., 2011). More recently, Koohsari et al. (2018a) tested the validity of the Walk Score® in the context of high-density areas in Japan. They found positive correlations between the Walk Score® and several objectively assessed walkability measures, such as intersection density and availability of local destinations in Japan (Koohsari et al., 2018a).

3. Walk Score® and active and sedentary behaviours

Several studies have found that a higher Walk Score® was associated with physical activity behaviours (Brown et al., 2013; Cole et al., 2015; Hirsch et al., 2013; Twardzik et al., 2019). For example, a study conducted in Australia observed that people who lived in areas with higher Walk Scores® were more likely to engage in walking for transport (Cole et al., 2015). A national study conducted in the USA found that Walk Score® was positively associated with adults' accelerometer-based moderate to vigorous physical activity behaviour (Twardzik et al., 2019). However, most of these studies were conducted in Western countries and did not include sedentary behaviours. Few studies have explored associations between Walk Score® and active and sedentary behaviours in Asia (Koohsari et al., 2018b; Liao et al., 2019). For instance, a recent Japanese study found that participants who lived in neighbourhoods with higher Walk Score® were more likely to engage in transportation walking and less likely to drive a car (Koohsari et al., 2018b). These findings emphasise the value of Walk Score® to car use, a typical sedentary behaviour among adults (Sugiyama et al., 2012). Only one previous study used Walk Score® to investigate the associations between built environment and cardiovascular diseases (Jia et al., 2018). Jia et al. (2018) found a negative association between Walk Score and coronary heart disease in a sample of middle-aged and older adults in China.

In summary, Walk Score® is a readily-available tool that provides local practitioners and policymakers to identify their neighbourhoods' walkability without needing detailed spatial data or GIS skills. Such knowledge, which can be gained from a free tool, would support decisions to increase physical activity, decrease sedentary behaviours in neighbourhoods, and support cardiovascular health.

III. A practical tool for (re)designing built environments: Space Syntax

Another key challenge in (re)designing the built environment to encourage active living and cardiovascular health is developing policy-relevant benchmarks (Koohsari et al., 2020a). Many studies have reported the significant 'associations' between built environment characteristics and physical activity. However, it remains challenging how to translate these findings into urban design and public health policies. There has been a recent urgent call to develop and test innovative built environment measures and indices that can provide policy-relevant knowledge on the built environment and cardiovascular health (Nichani et al., 2021). Space syntax can be one of the innovative methods to conceptualise the built environment supporting cardiovascular health.

1. What is Space Syntax?

Space syntax is a concept and method that has been established primarily in the fields of urban design and architecture. It was introduced mainly by Hillier & Hanson (1984) in their seminal book, *The social logic of space*. They proposed a spatial configuration approach to understand space and social life interactions. Space syntax is defined as "a research program that investigates the relationship between human societies and space from the perspective of a general theory of the structure of inhabited space in all its diverse forms: buildings, settlements, cities, or even landscapes" (Bafna, 2003). Space syntax can analyse the effect of the configuration of built environments on residents' movement. Although the pedestrian movement was the original core of space syntax theory (Ratti, 2004), it has been widely employed to solve social problems such as crime, housing prices, and environmental cognition.

2. Space Syntax principles and elements

Space syntax analyses urban forms by first modelling their network of open spaces such as streets, parks, and squares. It uses a set of measures calculated based on the concept of 'axial lines'. Axial lines can be defined as "lines of sight" in a network (Liu and Jiang, 2012). Figure 1 represents (left) a neighbourhood and (right) its axial lines. Each axial line is a "node", and each node is attached to its other nearby axial lines (nodes) by "links". The subsequent collection of nodes and links is named a 'justified graph' (Klarqvist, 1993). For instance, Figure 2 shows the justified graph for the neighbourhood in Figure 1, with nodes c and g as the base nodes. All space syntax measures are calculated based on the justified graph. Connectivity is the most straightforward space syntax measure, which refers to "the number of nodes directly linked to each individual node in the connectivity graph" (Jiang et al., 2000), and it calculates "the number of immediate neighbours that are directly connected to a space" (Klarqvist, 1993). Figure 3 shows the axial lines in Figure 1 labelled by the connectivity measure.

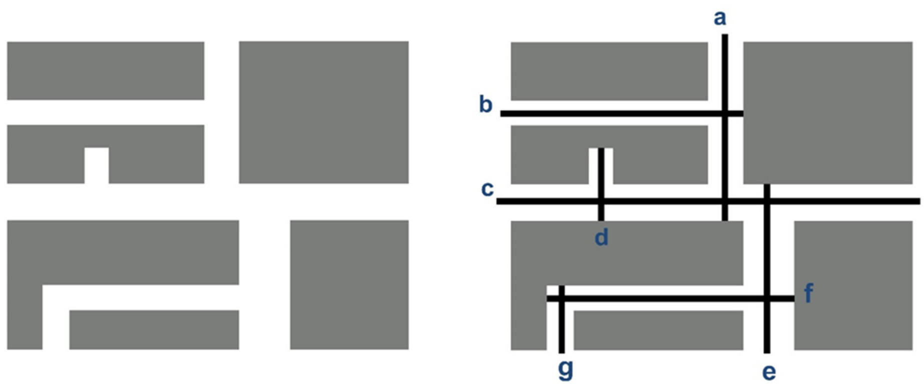

Figure 1. (left) Neighbourhood block and (right) its axial lines

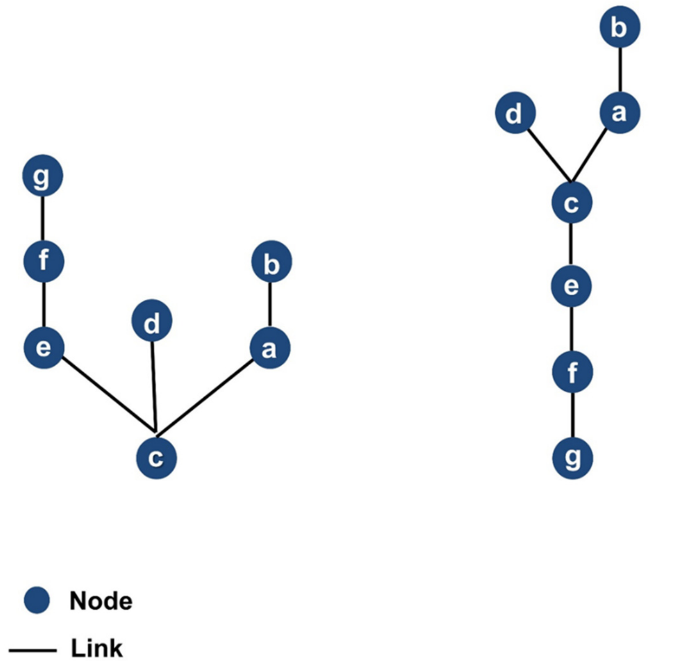

Figure 2. Justified graphs using the nodes c (right) and g (left) as the root streets

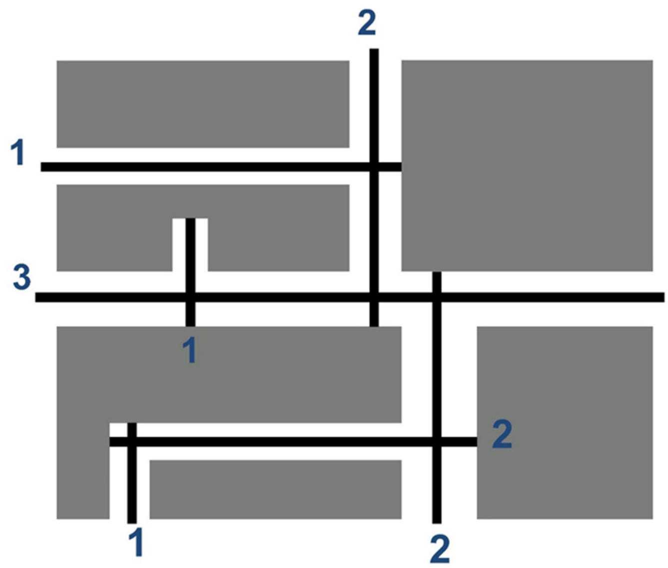

Figure 3. The levels of connectivity measure

"Depth" can be calculated based on the justified graph as "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). Mean depth is calculated as the total number of links from each node to the base node split by the total number of nodes minus one (Hillier and Hanson, 1984). Integration is a major measure of space syntax: the lower the mean depth, the higher the integration. For instance, fewer turns are needed to reach a highly integrated street than a less integrated street (Hillier, 2009). Figure 4 depicts the integration levels for streets in the neighbourhood in Figure 1. Integration can be calculated both as a global and a local measure. Global integration refers to the integration of a street relative to the whole of the other streets in a system. In contrast, local integration considers the relationship between a street and a certain number of its neighbours.

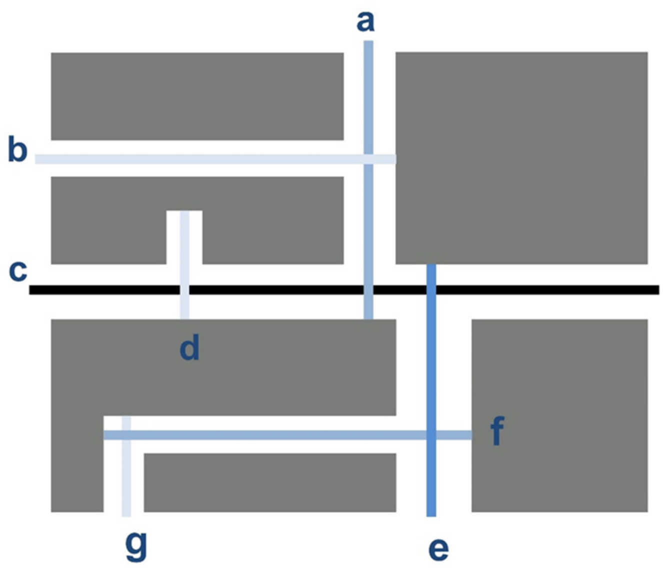

Figure 4. The street integration (darker lines show more-integrated streets)

3. Space Syntax and active and sedentary behaviours

Space syntax links physical built environments, functions, and walking behaviours. Several studies have provided preliminary evidence on the associations between space syntax measures and physical activity, mainly walking (Baran et al., 2008; Koohsari et al., 2016). Higher street integration was found to be associated with higher walking behaviours in the USA (Baran et al., 2008), Australia (Koohsari et al., 2016), and Japan (Koohsari et al., 2017). Natural movement theory in space syntax suggests that more integrated streets attract more pedestrians (Hillier et al., 1993). A common reason for these associations is that journey distance is shorter between two destinations in neighbourhoods with well-connected streets (Frank, 2000). The natural movement theory also states that the co-location of commercial and public destinations along more integrated streets can also lead to more pedestrian movement in such areas (Hillier et al., 1993; Koohsari et al., 2019). Space syntax measures were also found to be associated with sedentary behaviours (Koohsari et al., 2020c; Koohsari et al., 2017). For instance, a study conducted in Canada found that people living in less integrated areas were more likely to spend time in cars (Koohsari et al., 2020c). Nevertheless, no previous studies have examined the direct associations between space syntax measures and cardiovascular diseases.

In summary, the space syntax concept has a significant potential to conceptualise built environment attributes in relation to active and sedentary behaviours. Space syntax has been used in urban design and architecture for a relatively long time. Therefore, it can provide a bridge between the research and practice on how to (re)design built environments to support cardiovascular health.

IV. Conclusions and future directions

Modifying the built environment attributes is likely to be effective in triggering behaviours conducive to cardiovascular health. In contrast with most individually-based strategies, built environmental changes to promote active and sedentary behaviours can affect a large number of the population lasting for a long time (Marteau et al., 2012). Although this new, interdisciplinary field of science is promising, understanding the challenges in the relationships between the built environment and cardiovascular diseases must be improved. As discussed above, the application of Walk Score® and space syntax can address several challenges on this topic. The following issues, however, need to be considered to move research in this field forwards:

- Explore how Walk Score® and space syntax measures may influence active and sedentary behaviours across different geographical contexts.
- Test the concurrent validity of Walk Score® and objectively assessed walkability measures in different countries.
- Develop standard manuals to consistently conceptualise and measure the built environment using space syntax with active and sedentary behaviours.
- Explore the validity of Walk Score® as a measure of activity-friendly built environments across different regions and countries.
- Conduct longitudinal studies using Walk Score® and space syntax measures.
- Identify Walk Score® thresholds necessary to influence the behaviours promoting cardiovascular health.
- Examine how space syntax measures are related to objectively assessed physical activity and sedentary behaviours.
- Explore how new technologies such as geospatial artificial intelligence can be combined with space syntax to analyse built environments supporting cardiovascular health.

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