

Minerva Access is the Institutional Repository of The University of Melbourne

Author/s:

Koohsari, MJ;Mavoa, S;Villianueva, K;Sugiyama, T;Badland, H;Kaczynski, AT;Owen, N;Giles-Corti, B

Title:

Public open space, physical activity, urban design and public health: Concepts, methods and research agenda

Date:

2015-05-01

Citation:

Koohsari, M. J., Mavoa, S., Villianueva, K., Sugiyama, T., Badland, H., Kaczynski, A. T., Owen, N. & Giles-Corti, B. (2015). Public open space, physical activity, urban design and public health: Concepts, methods and research agenda. *Health and Place*, 33, pp.75-82. <https://doi.org/10.1016/j.healthplace.2015.02.009>.

Persistent Link:

<https://hdl.handle.net/11343/52091>

Abstract

Public open spaces such as parks and green spaces are key built environment elements within neighbourhoods for encouraging a variety of physical activity behaviours. Over the past decade, there has been a burgeoning number of active living research studies examining the influence of public open space on physical activity. However, the evidence shows mixed associations between different aspects of public open space (e.g., proximity, size, quality) and physical activity. These inconsistencies hinder the development of specific evidence-based guidelines for urban designers and policy-makers for (re)designing public open space to encourage physical activity. This paper aims to move this research agenda forward, by identifying key conceptual and methodological issues that may contribute to inconsistencies in research examining relations between public open space and physical activity.

Keywords: Built environment, Neighbourhood, Urban form, Parks, Walking.

Introduction

There have been declines in physical activity in many countries over the past few decades (Brownson et al., 2005; Ng and Popkin, 2012). Given the limited success of individually-based approaches to behaviour change, public health researchers have increasingly used socio-ecological models to further understand determinants of physical activity (Sallis et al., 2008). Such conceptual frameworks suggest that the built environment is one important level of influence, as it can facilitate or inhibit participation in physical activity (Sallis et al., 2012; Sallis et al., 2008). Indeed, public open spaces, such as parks and green spaces, appear to be key built environment settings that provide opportunities for a variety of physical activity behaviours, such as recreational walking and playing sports (Bedimo-Rung et al., 2005; Kaczynski and Henderson, 2007).

A growing body of literature has examined how different aspects of public open space, such as access to, size and design features, are associated with physical activity participation. A review of 50 quantitative studies (Kaczynski and Henderson, 2007) found proximity to parks and recreational settings to be generally associated with greater physical activity. Qualitative evidence further shows that public open space safety, aesthetics, amenities, maintenance, and proximity are important attributes for supporting physical activity (McCormack et al., 2010). Despite the increasing number of studies in this field, there are some inconsistencies in the evidence base. For example, a review by Lachowycz & Jones (2011) shows that among studies examining the relationships between access-related measures of local green spaces and physical activity, only 40% found significant associations.

These inconsistencies are confusing to urban designers and policy-makers and prevent the development of clear evidence-based guidelines for (re)designing public open space to encourage physical activity. It is possible that variations in studies are contextual or cultural, and context-specific evidence-based guidelines are required. However, it is also plausible that

these mixed results may be caused by diverse ways employed in past studies to conceptualise and operationalise relevant constructs involved in this research. We sought to move this research agenda forward, by identifying key conceptual and methodological issues that might enhance public open space and physical activity studies.

Conceptual issues

Variability in definitions of public open space

There is a lack of consensus in definition of public open space within the broader built environment literature. Within active living research, public open space is mainly conceptualised as park and green space, with less focus on other types of public open space (e.g., public plazas, nature reserves, greenways). For example, within urban design research, public open space is defined as “managed open space, typically green and available and open to all, even if temporally controlled” (Carmona, 2010, 169). Yet, in active living research, public open space definitions are usually narrower. For example, Edwards et al. (2013, 23) who work with planning policy-makers and practitioners focus only on green spaces and natural environments defining public open space as “spaces reserved for the provision of green space and natural environments, accessible to the general public free of charge”. In contrast, another definition made in public health does not necessitate public open space to be green, but does require that the intended purpose of the space is for amenity or recreation purposes: “spaces within the urban environment that are readily and freely accessible to the wider community, regardless of size, design or physical features and are intended primarily for amenity or recreation purposes – whether active or passive” (National Heart Foundation of Australia, 2014).

The definition of public open space in studies examining relationships between public open space and physical activity is important for two reasons. First, the absence of a universally-accepted definition of public open space introduces difficulties in comparing and collating evidence across different studies. Second, while urban designers consider public open space to be broadly defined and include such elements as beaches and shared public areas, active living researchers have tended to define public open space as parks and green space. This means that active living researchers are potentially missing out on opportunities to study different types of public open space required to improve physical activity. While there is a lack of research into the influence different types of public open space have on physical activity, there is some evidence that non-park public open space might be important for physical activity. For example, several studies showed the positive influence of walking trails on walking (Brownson et al., 2001; Brownson et al., 2000). As such, there might be specific design requirements for designing a walking trail to accommodate a wide range of physical activities within a small linear place compared with a park. Hence, we argue that future studies within active living research should include a broader range of public open space beyond parks and green spaces

Moving towards causal relationships

The majority of studies examining public open space and physical activity have been cross-sectional in design, and unable to address the issue of ‘self-selection’ (Cao et al., 2006; Cao et al., 2009). Within the built environment and active living body of research, self-selection refers to “the tendency of people to choose locations based on their travel abilities, needs and preferences” (Litman, 2011, 8). For example, people who prefer to walk to and within public open space for recreation may choose to live in neighbourhoods that have more public open

space available. Therefore, these people may have certain characteristics that confound any associations, and could potentially lead to misleading findings. Kaczynski & Mowen (2011) found significant associations between public open space availability and physical activity accounting for self-selection issue. Nevertheless, if a study does not control for self-selection issue, observed associations between public open space and physical activity might be biased. Furthermore, if the study design is cross-sectional, a causal relationship between public open space and physical activity cannot be assumed. Research on public open space and physical activity would benefit from longitudinal research designs, including experimental studies that measure behaviours before and after the introduction of new public open space or renovation of existing public open space (e.g., Veitch et al., 2014).

Specific public open space attributes may have distinctive effects on the initiation or maintenance of physical activity, yet few studies have distinguished between the two behaviours (Cleland et al., 2008; Sugiyama et al., 2013). For example, a recent study in Australia (Sugiyama et al., 2013) found no associations between *initiation* of walking and public open space presence, quality, and proximity; however, the presence of public open space, perceived proximity and size of the largest public open space were associated with *maintenance* of walking over four years. Further evidence from studies with longitudinal research designs are needed to confirm these associations and explore how public open space influences physical activity over the long-term. However, another study of people who relocated from one neighbourhood to another, found that gaining access to three different types of public open space (i.e., a park, a sports field or a beach) increased walking by 18-21 minutes for each type of public open space gained (Giles-Corti et al., 2013).

Public open space in non-residential contexts

Previous studies have primarily focused on public open space in residential contexts; however, the extent to which public open space in other settings (e.g., around workplaces or schools) may influence people's physical activity has been largely ignored. It is possible that having a public open space next to workplaces may encourage workers to walk within that public open space during their break times. However, to date no study has examined the relationship between public open space and physical activity in non-residential contexts. A few recent studies in the broader built environment literature have examined how other (non-public open space) environmental attributes influence physical activity in settings frequented by children and adults (Dalton et al., 2013; Karusisi et al., 2014; Panter et al., 2013). For example, Karusisi et al. (2014) found that the number of supermarkets around workplaces was associated with walking for transport among workers. Another study found that active travel to work was negatively associated with the availability of free car parking at workplaces (Dalton et al., 2013), while Badland et al. (2014) found that the odds of commuting to work by transit rose to over 16 when participant had proximate transit stops both near home and work. Future research should identify the relevant attributes of public open spaces to support physical activity in a number of settings outside residential contexts.

Research methodologies to better understand public open space /physical activity relationships

Measuring public open space-related physical activity

The majority of previous studies have applied context-free measures of physical activity (Giles-Corti et al., 2005b), such as *total* amount of physical activity. Using these global measures limits our understanding of the amount of physical activity that can be directly attributed to travelling to and/or accumulated within a given public open space (e.g.,

Coutts et al., 2013; Roemmich et al., 2006). Using context-free measures include a substantial amount of physical activity that is not related to public open space-related activity (e.g. physical activity undertaken at home or workplace), and which may lead to inaccurate apportioning of physical activity attributable to public open space aspects such as presence or quality (Giles-Corti et al., 2006). For example, a recent study (Chaix et al., 2014) has shown that the presence of high-quality public open space is associated with recreational walking within neighbourhood, but not associated with overall recreational walking. However, some caution is required in taking this approach.

Public open space can influence physical activity in at least three ways. First, public open space can be a setting in where people engage in physical activity. Second, public open space can be a destination to which people actively travel either to be active or simply to socialise. Finally, public open space can be used as part of a route to pass through to reach another destination (e.g., passing through a greenway to reach a shop) or as part of a recreational walk or running route (Figure 1). Hence public open space can contribute to different types of physical activity behaviours. For example, public open space as a thoroughfare is related to active travel, as a destination to either active travel or recreational physical activity, or public open space as a setting might be related to recreational walking or cycling, running, dog walking, formal or informal sport, or children's active play.

To date, few studies have attempted to understand the variety of ways public open space influence physical activity, or used context- and behaviour- specific physical activity measures to examine relationships between public open space attributes and physical activity (Coombes et al., 2013; Dunton et al., 2014). However, new technologies and measurement approaches means that there are now more options to measure public open space-related physical activity. Context- and behaviour-specific physical activity can be assessed by activity logs (e.g., Kaczynski et al., 2009), combining physical activity sensors (e.g.

pedometers, accelerometers) with global positioning system technologies (e.g., Dunton et al., 2014; Evenson et al., 2013; Quigg et al., 2010) or wearable cameras such as SenseCam (e.g., Doherty et al., 2012; Kelly et al., 2011). Exploring physical activity related to public open space will help strengthen the evidence about the variety of ways public open space influences specific types of physical activity, thereby enabling urban designers and landscape architects to design public open space that target specific physical activity behaviours.

INSERT FIGURE 1 ABOUT HERE

Measures of proximity to public open space

Proximity to public open space is typically computed using geographic information systems software. There are a number of issues associated with calculating proximity measures using geographic information systems and these are highlighted below.

Representation of public open space: Methods used for capturing the public open space data layer and then preparing the layer for proximity analyses may both introduce inconsistencies in results. Different studies use different data sources to identify public open space. This may lead to different results in different studies examining associations between public open space and physical activity. For example, many studies use public open space data provided by park-related agencies; while others used general land use codes assigned to all parcels to capture public open space land uses.

Similarly different studies use different methods for assessing proximity to public open space. For the purpose of calculating proximity measures for active living research, the

optimal method is using the actual public open spaces entrances as destinations points (Hillsdon et al., 2006; Schipperijn et al., 2013; Schipperijn et al., 2010). Yet data on public open space entry points is rarely available and/or time-consuming to capture. Hence commonly the geographic centroids of public open space are used (Kaczynski and Henderson, 2008; Kaczynski et al., 2009). However, as shown in Figure 2, this method ignores the public open space shape and size, which might lead to “inaccuracy” and “misrepresentation” of proximity (Nicholls, 2001). To address this issue, some studies have used points separated by a predetermined distance (e.g., 10m intersections) along public open space boundaries (Apparicio and Seguin, 2006) (Figure 2). This method is clearly preferable. However, it could be further refined even further to filter out points that are unlikely to be access points, such as excluding those points further from a road centreline, which also has the advantage of reducing processing time (Mavoa et al., 2014). Another proxy for public open space entrances is the creation of points where the buffered public open space boundaries intersect with the road network (Adams et al., 2014). Together, attention to these issues could improve consistency between studies.

INSERT FIGURE 2 ABOUT HERE

Multiple public open space versus single nearest public open space: The majority of studies explore the association of access to the *nearest* public open space on physical activity (for exceptions see Giles-Corti et al., 2005a; Kaczynski et al., 2009; Koohsari et al., 2013c; Sugiyama et al., 2010). Using the single nearest public open space approach ignores

neighbourhoods where several public open spaces with different sizes and features are accessible (Figure 3). Kaczynski et al. (2009) did not find associations between the closest public open space and physical activity. However, when they explored the number and total area of public open space within 1 km of participants' homes, positive associations were shown between these and physical activity occurring in public open spaces. Schipperijn et al. (2010) found that for about half of their participants, their nearest public open space was not the most frequently used public open space. They also found that size of public open space predicted whether or not the nearest public open space was the most frequently used. Sugiyama et al. (2010) examined the size and attractiveness of local public open space, and found that having a larger and more attractive public open space within walking distance may be more important than simply having closer access to a public open space. Future research may consider advancing the concept of public open space accessibility that combines public open space measures (e.g., proximity, count, size, attractiveness).

INSERT FIGURE 3 ABOUT HERE

Distance to public open space: Distance from origin (e.g., home) to public open space is still commonly measured using the straight line (Euclidean) distance (e.g., Banda et al., 2014). However, street network distance better represents the true relevant spatial distance (Apparicio et al., 2008; Zhang et al., 2011). At the same time, this method often ignores routes unsuitable for walking or cycling (e.g., freeways), and does not capture the pedestrian-only network (e.g., pedestrian cut-through, and access ways). Several studies have shown that

overall neighbourhood connectivity is higher, if the pedestrian network is considered rather than the street network (Chin et al., 2008; Tal and Handy, 2011). Although time consuming to produce, capturing pedestrian pathways may be important for improving calculations of distance to public open space (Schipperijn et al., 2010). Advances in remote sensing to capture sidewalks, may help advance the field in the future.

Topological versus metric measures of proximity: While current metric measures such as the shortest distance (m) to public open space are commonly used, they do not entirely account for the spatial configuration of a street layout. Topological measures of proximity capture the spatial configuration of the street layout but are rarely considered in active living research (see exception, Koohsari et al., 2013b). The ‘topological’ aspect of a spatial pattern (such as streets) considers each space within that pattern in relation to the other available spaces. For example, in relation to public open space, topological distance calculates how many turns a person needs to traverse on roads to reach a public open space. People’s understanding of a network may also be more influenced by the topological rather than metric (e.g., shortest distance) distances (Penn et al., 1998). Different topological distances to public open space cannot be detected by using the current metric measures, while they are important in perceiving distance to and location of public open space (Koohsari et al., 2014). For example, two people may have similar metric distances to a public open space, yet their topological distances are very different (Figure 4). This topological aspect of proximity of public open space may influence physical activity, because people need to navigate the street network to reach a public open space. For example, Koohsari et al. (2013b) found that those people who lived in areas in which public open spaces were located on less integrated streets reported more public open space-related physical activity. Future research can apply space syntax, a

concept and method to conduct topological analysis (Hillier and Hanson, 1984), to analyse the topological aspects of proximity to public open space in relation to physical activity.

INSERT FIGURE 4 ABOUT HERE

Quality of public open space

The design of public open space covers a variety of features and amenities that are internal characteristics of the space. Several studies have examined the associations between public open space features and physical activity or walking (Giles-Corti et al., 2005a; Kaczynski et al., 2008; Schipperijn et al., 2013; Sugiyama et al., 2010). However, this body of research has several limitations. First, an overall score of public open space ‘attractiveness’ or ‘quality’ is usually used to examine its association with walking (e.g., Giles-Corti et al., 2005a). Thus, the individual influence of each feature and amenity (or their combination) is unclear. Few studies have examined the specific role each public open space feature has on physical activity (Baran et al., 2013; Kaczynski et al., 2008). For example, Kaczynski et al. (2008) found that park facilities (i.e., paved trail, water area, and playground) were more important than park amenities (i.e., drinking fountain, picnic area, and restroom) for public open space-related physical activity. Schipperijn et al. (2013) found a positive association with physical activity undertaken within the nearest public open spaces and a walking and/or cycling route, a wooded area, a water feature (e.g., lake, stream), lights along (some) trails, a pleasant view to the outside of the public open space, a bike rack, or a parking lot for cars. Exploring the specific role of each public open space feature (and

subsequent combinations thereof) on physical activity can provide landscape architects with useful information about prioritising features in new and upgraded public open space.

Secondly, previous studies show that objective measures of the built environment do not necessarily reflect people's perceptions of their environment (Gebel et al., 2009; Leslie et al., 2010). Studies on public open space and physical activity have objectively measured public open space features and amenities using audit tools (for exceptions see, Koohsari et al., 2013c; Sugiyama and Ward Thompson, 2008), but the influence of residents' perceptions about public open space features on their physical activity is yet to be explored. For example, residents may not perceive a public open space as being high quality, even if it is categorised 'high quality' by objective auditing tools. There are two potential reasons for this: 1) if people do not use the public open space, they may have limited awareness about the features and amenities available at the location (Lackey and Kaczynski, 2009; Macintyre et al., 2008); and, 2) people may base their perceptions on attributes not detected by audit tools (e.g., fear of crime, youth congregations, unattended dogs) (Foster et al., 2012). Simply adding new features and amenities to public open space may not therefore increase their use. Using a combination of objective and perceived measures of public open space features, further research should examine how specific public open space features can improve people's awareness of public open space, and in turn how it can improve people's physical activity in relation to public open space (Lackey and Kaczynski, 2009).

Characteristics of the surrounding built environment

Previous research has mostly focused on factors directly related to public open space such as proximity and attractiveness, with less attention paid to characteristics of the surrounding built environment through which people move through to access the public open

space. Objective and perceived characteristics of the built environment surrounding public open space may not only moderate the influence of factors related to public open space on physical activity (Sugiyama et al., 2014), they may also have their own distinct influences on public open space-related physical activity. For example, Kaczynski et al. (2014) found that regulating lower traffic speeds on streets surrounding public open space encourages public open space usage. Another study found perceived safety from crime, traffic and aesthetics in the surrounding neighbourhood was associated with greater public open space-related walking (Koohsari et al., 2013c).

Varying associations between public open space type, physical activity behaviours and user attributes/profiles

It is likely that different types of public open space facilitate diverse physical activity behaviours for different socio-demographic groups; while studies on public open space and physical activity typically focus on a particular age group. For example, Jones et al. (2009) found that attributes of public open space including accessibility and safety were moderated by deprivation level; people who were from more deprived areas reported poorer access to public open space and poorer safety.

In addition, attributes of the same type of public open space may affect socio-demographic groups differently (Floyd et al., 2008; Kaczynski et al., 2013). For example, in a study in the USA, Kaczynski et al. (2013) found playgrounds and pools were used more by male youth than female youth. Therefore, more research is needed to understand how public open space attributes attract and encourage use among a wide range of different socio-demographic groups, or how one type of facility conflicts with the use by another user group

(e.g., skate ramps may attract young male youth, but discourage public open space use by older adults).

Identifying thresholds

While there has been evidence of the associations between public open space accessibility and attributes with physical activity, it remains challenging to develop specific guidelines to (re)design these settings to support physical activity. This is mainly because there is a lack of prescriptive evidence for urban designers and policy makers for optimal amounts (also known as thresholds) of specific public open space attributes (such as attractiveness or proximity) needed to influence physical activity (Koohsari et al., 2013a; Sugiyama et al., 2012). For example, several studies have shown the positive influence on physical activity when there is access to a larger, attractive public open space within walking distance (Giles-Corti et al., 2005a; Sugiyama et al., 2010). However, it is still unknown ‘how large’ a public open space should be to increase public open space-related physical activity (Figure 5). Similarly, little is known about ‘how many’ amenities need to be provided to encourage public open space use. It is possible to identify whether and where such a threshold exists by examining a shape of association between public open space attributes and physical activity. Identifying thresholds across a wide range of public open space attributes should be a priority for future research on public open space and physical activity. Such evidence could facilitate translations of research into practice in this area of health promotion.

INSERT FIGURE 5 ABOUT HERE

Conclusion: research agenda

The body of research examining associations between public open spaces and physical activity is increasing. We have identified conceptual and methodological gaps that need to be addressed to progress research on public open space and physical activity. To summarise, the field needs to reach consensus on several issues. These include:

- defining (and expanding) definitions of public open space;
- using longitudinal study designs where possible;
- exploring public open space exposures in multiple contexts;
- moving towards public open space-specific measures of physical activity;
- using pedestrian networks and space syntax to understand distances to public open space;
- examining environments surrounding public open space;
- having a better understanding of how individual public open space attributes are associated with physical activity;
- understanding how different user-groups engage with public open space; and
- identifying thresholds (optimal values) needed to attract people to public open space.

Building the evidence base in these ways will provide much needed evidence to urban designers and policy-makers aiming to better provide and design public open space systems to promote public health.

References

- Adams, M.A., Frank, L.D., Schipperijn, J., Smith, G., Chapman, J., Christiansen, L.B., Coffee, N., Salvo, D., du Toit, L., Dygrýn, J., 2014. International variation in neighborhood walkability, transit, and recreation environments using geographic information systems: the IPEN adult study. *International Journal of Health Geographics* 13, 43.
- Apparicio, P., Abdelmajid, M., Riva, M., Shearmur, R., 2008. Comparing alternative approaches to measuring the geographical accessibility of urban health services: Distance types and aggregation-error issues. *International Journal of Health Geographics* 7, 1-14.
- Apparicio, P., Seguin, A.-M., 2006. Measuring the Accessibility of Services and Facilities for Residents of Public Housing in Montreal. *Urban Studies* 43, 187-211.
- Badland, H., Hickey, S., Bull, F., Giles-Corti, B., 2014. Public transport access and availability in the RESIDE study: Is it taking us where we want to go? *Journal of Transport & Health* 1, 45-49.
- Banda, J.A., Wilcox, S., Colabianchi, N., Hooker, S.P., Kaczynski, A.T., Hussey, J., 2014. The Associations Between Park Environments and Park Use in Southern US Communities. *The Journal of Rural Health*, n/a-n/a.
- Baran, P.K., Smith, W.R., Moore, R.C., Floyd, M.F., Bocarro, J.N., Cosco, N.G., Danninger, T.M., 2013. Park use among youth and adults: examination of individual, social, and urban form factors. *Environment and Behavior*, 0013916512470134.
- Bedimo-Rung, A.L., Mowen, A.J., Cohen, D.A., 2005. The significance of parks to physical activity and public health: a conceptual model. *American journal of preventive medicine* 28, 159-168.
- Brownson, R.C., Baker, E.A., Housemann, R.A., Brennan, L.K., Bacak, S.J., 2001. Environmental and policy determinants of physical activity in the United States. *American Journal of Public Health* 91, 1995-2003.
- Brownson, R.C., Boehmer, T.K., Luke, D.A., 2005. Declining rates of physical activity in the United States: what are the contributors? *Annu. Rev. Public Health* 26, 421-443.
- Brownson, R.C., Housemann, R.A., Brown, D.R., Jackson-Thompson, J., King, A.C., Malone, B.R., Sallis, J.F., 2000. Promoting physical activity in rural communities: Walking trail access, use, and effects. *American journal of preventive medicine* 18, 235-241.
- Cao, X., Handy, S., Mokhtarian, P., 2006. The Influences of the Built Environment and Residential Self-Selection on Pedestrian Behavior: Evidence from Austin, TX. *Transportation* 33, 1-20.
- Cao, X., Mokhtarian, P.L., Handy, S.L., 2009. Examining the impacts of residential self-selection on travel behaviour: a focus on empirical findings. *Transport Reviews* 29, 359-395.
- Carmona, M., 2010. Contemporary Public Space, Part Two: Classification. *Journal of Urban Design* 15, 157-173.
- Chaix, B., Simon, C., Charreire, H., Thomas, F., Kestens, Y., Karusisi, N., Vallee, J., Oppert, J.-M., Weber, C., Pannier, B., 2014. The environmental correlates of overall and neighborhood based recreational walking (a cross-sectional analysis of the RECORD Study). *International Journal of Behavioral Nutrition and Physical Activity* 11, 20.
- Chin, G.K., Van Niel, K.P., Giles-Corti, B., Knuiman, M., 2008. Accessibility and connectivity in physical activity studies: the impact of missing pedestrian data. *Preventive Medicine* 46, 41-45.
- Cleland, V.J., Timperio, A., Crawford, D., 2008. Are perceptions of the physical and social environment associated with mothers' walking for leisure and for transport? A longitudinal study. *Preventive Medicine* 47, 188-193.

Coombes, E., van Sluijs, E., Jones, A., 2013. Is environmental setting associated with the intensity and duration of children's physical activity? Findings from the SPEEDY GPS study. *Health & place* 20, 62-65.

Coutts, C., Chapin, T., Horner, M., Taylor, C., 2013. County-level effects of green space access on physical activity. *Journal of physical activity & health* 10.

Dalton, A.M., Jones, A.P., Panter, J.R., Ogilvie, D., 2013. Neighbourhood, Route and Workplace-Related Environmental Characteristics Predict Adults' Mode of Travel to Work. *PloS one* 8, e67575.

Doherty, A.R., Kelly, P., Kerr, J., Marshall, S., Oliver, M., Badland, H., Foster, C., 2012. Use of wearable cameras to assess population physical activity behaviours: an observational study. *The Lancet* 380, S35.

Dunton, G.F., Almanza, E., Jerrett, M., Wolch, J., Pentz, M.A., 2014. Neighborhood Park Use by Children: Use of Accelerometry and Global Positioning Systems. *American journal of preventive medicine* 46, 136-142.

Edwards, N., Hooper, P., Trapp, G.S.A., Bull, F., Boruff, B., Giles-Corti, B., 2013. Development of a Public Open Space Desktop Auditing Tool (POSDAT): A remote sensing approach. *Applied Geography* 38, 22-30.

Evenson, K.R., Wen, F., Hillier, A., Cohen, D.A., 2013. Assessing the contribution of parks to physical activity using global positioning system and accelerometry. *Medicine and science in sports and exercise* 45, 1981-1987.

Floyd, M.F., Spengler, J.O., Maddock, J.E., Gobster, P.H., Suau, L.J., 2008. Park-Based Physical Activity in Diverse Communities of Two U.S. Cities: An Observational Study. *American journal of preventive medicine* 34, 299-305.

Foster, S., Giles-Corti, B., Knuiman, M., 2012. Does fear of crime discourage walkers? A social-ecological exploration of fear as a deterrent to walking. *Environment and Behavior*, 0013916512465176.

Gebel, K., Bauman, A., Owen, N., 2009. Correlates of non-concordance between perceived and objective measures of walkability. *Annals of behavioral medicine* 37, 228-238.

Giles-Corti, B., Broomhall, M.H., Knuiman, M., Collins, C., Douglas, K., Ng, K., Lange, A., Donovan, R.J., 2005a. Increasing walking: how important is distance to, attractiveness, and size of public open space? *American journal of preventive medicine* 28, 169-176.

Giles-Corti, B., Bull, F., Knuiman, M., McCormack, G., Van Niel, K., Timperio, A., Christian, H., Foster, S., Divitini, M., Middleton, N., 2013. The influence of urban design on neighbourhood walking following residential relocation: longitudinal results from the RESIDE study. *Social Science & Medicine* 77, 20-30.

Giles-Corti, B., Timperio, A., Bull, F., Pikora, T., 2005b. Understanding physical activity environmental correlates: increased specificity for ecological models. *Exercise and Sport Sciences Reviews* 33, 175-181.

Giles-Corti, B., Timperio, A., Cutt, H., Pikora, T.J., Bull, F.C., Knuiman, M., Bulsara, M., Van Niel, K., Shilton, T., 2006. Development of a reliable measure of walking within and outside the local neighborhood: RESIDE's Neighborhood Physical Activity Questionnaire. *Preventive Medicine* 42, 455-459.

Hillier, B., Hanson, J., 1984. *The social logic of space*. Cambridge Univ. Press, Cambridge.

Hillsdon, M., Panter, J., Foster, C., Jones, A., 2006. The relationship between access and quality of urban green space with population physical activity. *Public health* 120, 1127-1132.

Jones, A., Hillsdon, M., Coombes, E., 2009. Greenspace access, use, and physical activity: Understanding the effects of area deprivation. *Preventive Medicine* 49, 500-505.

Kaczynski, A.T., Henderson, K.A., 2007. Environmental correlates of physical activity: a review of evidence about parks and recreation. *Leisure Sciences* 29, 315-354.

Kaczynski, A.T., Henderson, K.A., 2008. Parks and recreation settings and active living: a review of associations with physical activity function and intensity. *Journal of Physical Activity and Health* 5, 619-632.

Kaczynski, A.T., Koohsari, M.J., Stanis, S.A.W., Bergstrom, R., Sugiyama, T., 2014. Association of street connectivity and road traffic speed with park usage and park-based physical activity. *American journal of health promotion* 28, 197-203.

Kaczynski, A.T., Mowen, A.J., 2011. Does self-selection influence the relationship between park availability and physical activity? *Preventive Medicine* 52, 23-25.

Kaczynski, A.T., Potwarka, L.R., Saelens, B.E., 2008. Association of park size, distance, and features with physical activity in neighborhood parks. *American Journal of Public Health* 98, 1451.

Kaczynski, A.T., Potwarka, L.R., Smale, B.J.A., Havitz, M.E., 2009. Association of Parkland Proximity with Neighborhood and Park-based Physical Activity: Variations by Gender and Age. *Leisure Sciences: An Interdisciplinary Journal* 31, 174-191.

Kaczynski, A.T., Stanis, S.A.W., Besenyi, G.M., Child, S., 2013. Differences in Youth and Adult Physical Activity in Park Settings by Sex and Race/Ethnicity. *Preventing Chronic Disease* 10, E42.

Karusisi, N., Thomas, F., Méline, J., Brondeel, R., Chaix, B., 2014. Environmental Conditions around Itineraries to Destinations as Correlates of Walking for Transportation among Adults: The RECORD Cohort Study. *PloS one* 9, e88929.

Kelly, P., Doherty, A., Berry, E., Hodges, S., Batterham, A.M., Foster, C., 2011. Can we use digital life-log images to investigate active and sedentary travel behaviour? Results from a pilot study. *Int J Behav Nutr Phys Act* 8, 44.

Koohsari, M.J., 2012. Public open space and walking, Melbourne School of Design, Faculty of Architecture, Building and Planning. The University of Melbourne.

Koohsari, M.J., Badland, H., Giles-Corti, B., 2013a. (Re)Designing the built environment to support physical activity: Bringing public health back into urban design and planning. *Cities* 35, 294-298.

Koohsari, M.J., Kaczynski, A.T., Giles-Corti, B., Karakiewicz, J.A., 2013b. Effects of access to public open spaces on walking: Is proximity enough? *Landscape and Urban Planning* 117, 92-99.

Koohsari, M.J., Kaczynski, A.T., McCormack, G.R., Sugiyama, T., 2014. Using Space Syntax to Assess the Built Environment for Physical Activity: Applications to Research on Parks and Public Open Spaces. *Leisure Sciences* 36, 206-216.

Koohsari, M.J., Karakiewicz, J.A., Kaczynski, A.T., 2013c. Public Open Space and Walking: The Role of Proximity, Perceptual Qualities of the Surrounding Built Environment, and Street Configuration. *Environment and Behavior* 45, 706-736.

Lachowycz, K., Jones, A., 2011. Greenspace and obesity: a systematic review of the evidence. *Obesity Reviews* 12, e183-e189.

Lackey, K.J., Kaczynski, A.T., 2009. Correspondence of perceived vs. objective proximity to parks and their relationship to park-based physical activity. *International Journal of Behavioral Nutrition and Physical Activity* 6, 53.

Leslie, E., Sugiyama, T., Ierodiaconou, D., Kremer, P., 2010. Perceived and objectively measured greenness of neighbourhoods: Are they measuring the same thing? *Landscape and Urban Planning* 95, 28-33.

Litman, T.A., 2011. Land use impacts on transport: How land use factors affect travel behavior. Victoria Transport Institute.

Macintyre, S., Macdonald, L., Ellaway, A., 2008. Lack of agreement between measured and self-reported distance from public green parks in Glasgow, Scotland. *International Journal of Behavioral Nutrition and Physical Activity* 5, 26.

Mavoa, S., Koohsari, M.J., Badland, H.M., Davern, M., Feng, X., Astell-Burt, T., Giles-Corti, B., 2014. Area-Level Disparities of Public Open Space: A Geographic Information Systems Analysis in Metropolitan Melbourne. *Urban Policy and Research*, 1-18.

McCormack, G.R., Rock, M., Toohey, A.M., Hignell, D., 2010. Characteristics of urban parks associated with park use and physical activity: a review of qualitative research. *Health & place* 16, 712-726.

National Heart Foundation of Australia, 2014. Healthy Active by Design.

Ng, S.W., Popkin, B.M., 2012. Time use and physical activity: a shift away from movement across the globe. *Obesity Reviews* 13, 659-680.

Nicholls, S., 2001. Measuring the accessibility and equity of public parks: a case study using GIS. *Managing Leisure* 6, 201-219.

Panther, J., Desousa, C., Ogilvie, D., 2013. Incorporating walking or cycling into car journeys to and from work: The role of individual, workplace and environmental characteristics. *Preventive Medicine* 56, 211-217.

Penn, A., Hillier, B., Banister, D., Xu, J., 1998. Configurational modeling of urban movement networks. *Environment and Planning B: Planning and Design* 25, 59-84.

Quigg, R., Gray, A., Reeder, A.I., Holt, A., Waters, D.L., 2010. Using accelerometers and GPS units to identify the proportion of daily physical activity located in parks with playgrounds in New Zealand children. *Prev Med* 50, 235-240.

Roemmich, J.N., Epstein, L.H., Raja, S., Yin, L., Robinson, J., Winiewicz, D., 2006. Association of access to parks and recreational facilities with the physical activity of young children. *Preventive Medicine* 43, 437-441.

Sallis, J.F., Floyd, M.F., Rodríguez, D.A., Saelens, B.E., 2012. Role of built environments in physical activity, obesity, and cardiovascular disease. *Circulation* 125, 729-737.

Sallis, J.F., Owen, N., Fisher, E.B., 2008. Ecological models of health behavior in: Glanz, K., Rimer, B., Viswanath, K. (Eds.), *Health behavior and health education: theory, research, and practice*, 4th ed. Jossey-Bass, San Francisco, CA, pp. 465-482.

Schipperijn, J., Bentsen, P., Troelsen, J., Toftager, M., Stigsdotter, U.K., 2013. Associations between physical activity and characteristics of urban green space. *Urban Forestry & Urban Greening* 12, 109-116.

Schipperijn, J., Stigsdotter, U.K., Randrup, T.B., Troelsen, J., 2010. Influences on the use of urban green space—A case study in Odense, Denmark. *Urban Forestry & Urban Greening* 9, 25-32.

Sugiyama, T., Francis, J., Middleton, N.J., Owen, N., Giles-Corti, B., 2010. Associations between recreational walking and attractiveness, size, and proximity of neighborhood open spaces. *American Journal of Public Health* 100.

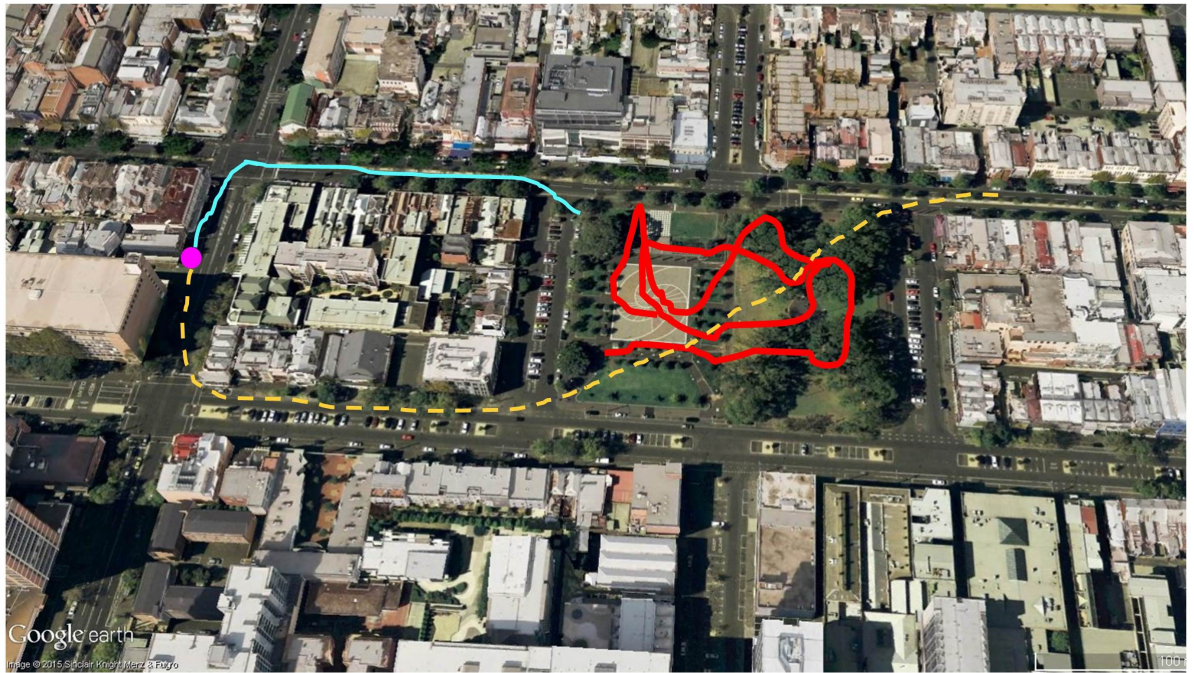
Sugiyama, T., Giles-Corti, B., Summers, J., du Toit, L., Leslie, E., Owen, N., 2013. Initiating and maintaining recreational walking: A longitudinal study on the influence of neighborhood green space. *Preventive Medicine* 57, 178-182.

Sugiyama, T., Neuhaus, M., Cole, R., Giles-Corti, B., Owen, N., 2012. Destination and Route Attributes Associated with Adults' Walking: A Review. *Medicine & Science in Sports & Exercise Online First*: 3 January 2012.

Sugiyama, T., Paquet, C., Howard, N.J., Coffee, N.T., Taylor, A.W., Adams, R.J., Daniel, M., 2014. Public open spaces and walking for recreation: Moderation by attributes of pedestrian environments. *Preventive Medicine* 62, 25-29.

Sugiyama, T., Ward Thompson, C., 2008. Associations between characteristics of neighbourhood open space and older people's walking. *Urban Forestry & Urban Greening* 7, 41-51.

- Tal, G., Handy, S., 2011. Measuring Non-motorized Accessibility and Connectivity in a Robust Pedestrian Network. Institute of Transportation Studies, University of California, Davis, Research Report UCD-ITS-RR-11-23.
- Veitch, J., Salmon, J., Carver, A., Timperio, A., Crawford, D., Fletcher, E., Giles-Corti, B., 2014. A natural experiment to examine the impact of park renewal on park-use and park-based physical activity in a disadvantaged neighbourhood: the REVAMP study methods. *BMC public health* 14, 600.
- Zhang, X., Lu, H., Holt, J., 2011. Modeling spatial accessibility to parks: a national study. *International Journal of Health Geographics* 10, 31.



● Participant's location

Public open space as a destination

Public open space as a setting

Public open space as a route

Figure 1. Three ways through which public open space influence physical activity



Figure 2. Calculating distance to public open space: (a) Using public open space centroid as destination (b) Using points separated by a predetermined distance along the public open space boundary as destination

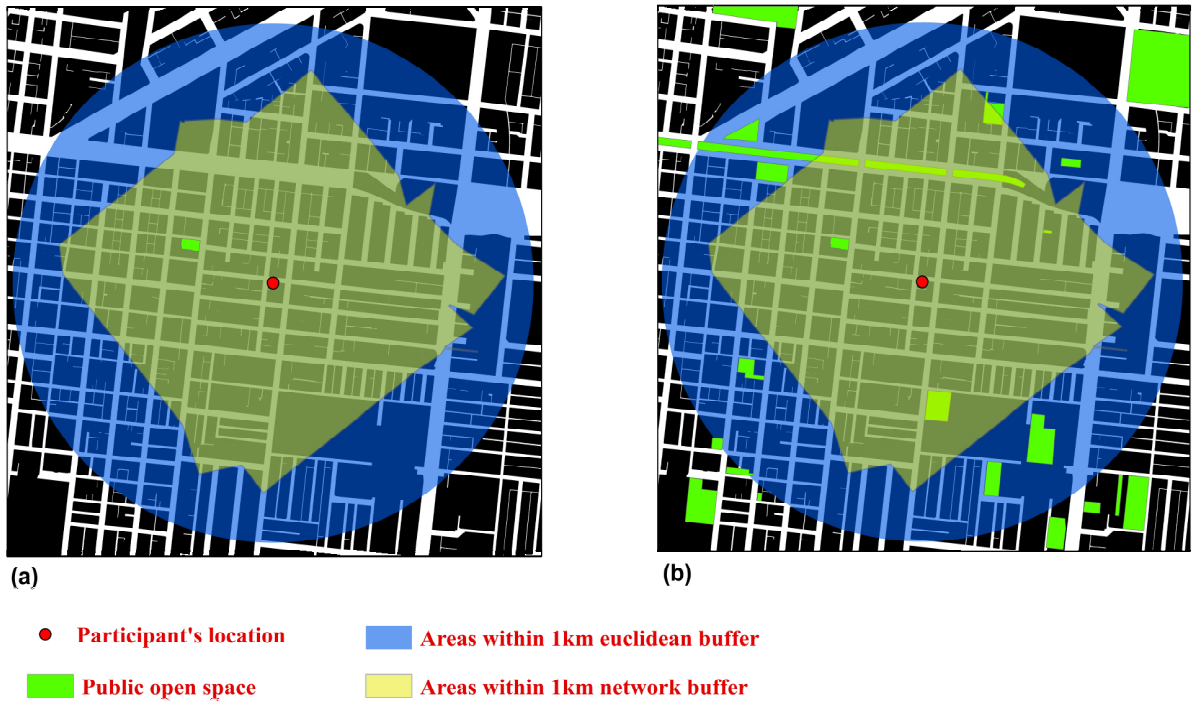


Figure 3. Multiple public open spaces around participant's home versus single closest one: (a) Considering just 'single closest' public open space (b) Real situation

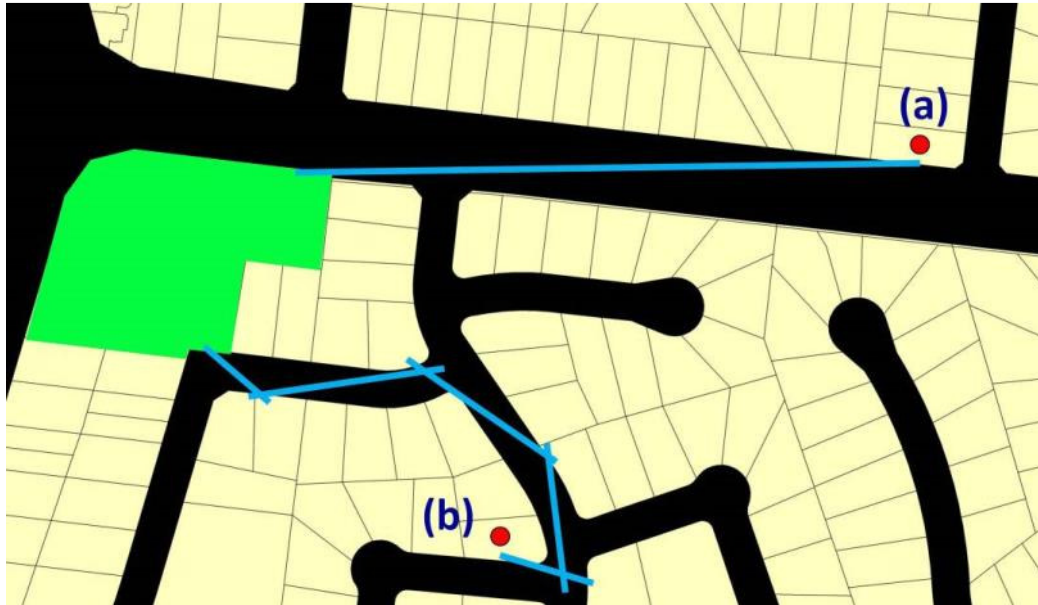


Figure 4. Same metric distances with different topological distances: Participants (a) and (b) have the same metric distances to public open space with different topological distances. Participant (b) has to change his/her way on route several times to reach to the public open space (Koohsari, 2012, 8)

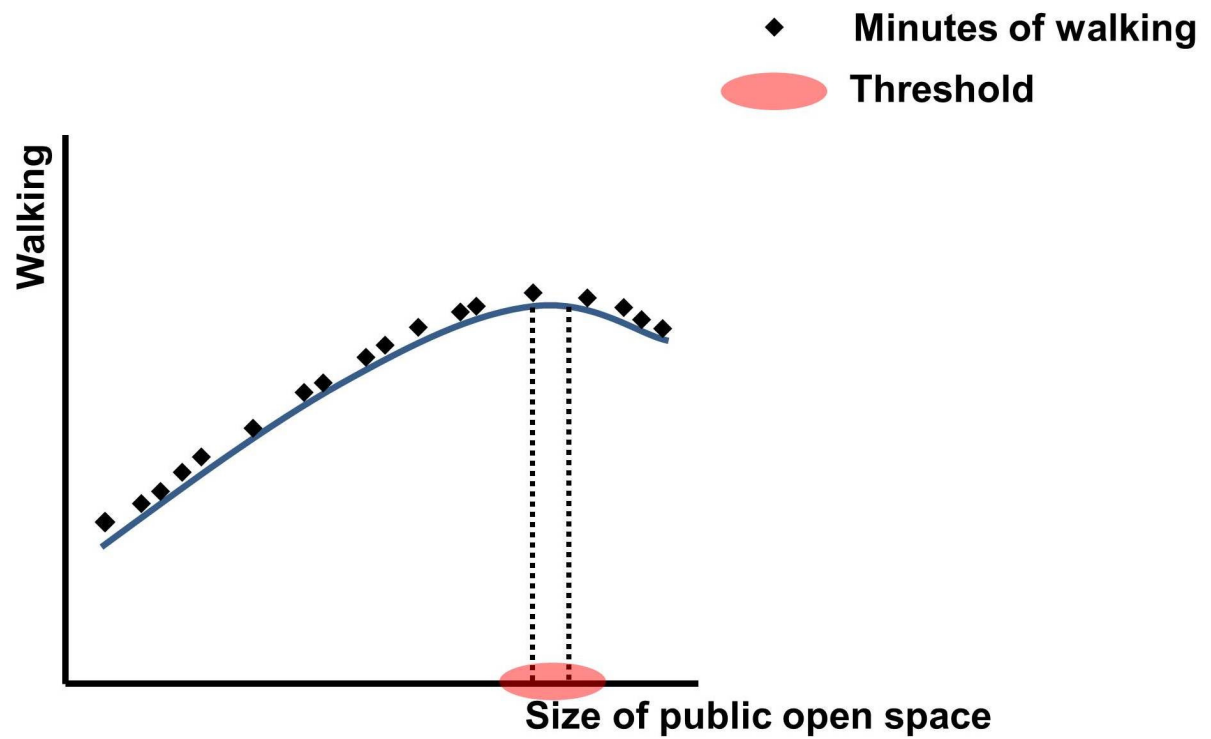


Figure 5. Hypothetical diagram showing thresholds for size of public open space supporting walking