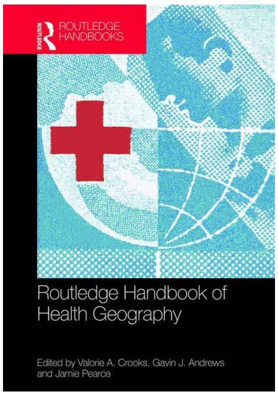

Routledge Handbook of Health Geography

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Walkability and physical activity

Publication details
https://www.routledgehandbooks.com/doi/10.4324/9781315104584-41
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Published online on: 11 Jun 2018

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WALKABILITY AND PHYSICAL ACTIVITY

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Walkability has become an important research area across the fields of geography, public health, urban planning and transportation. Walkable neighborhoods, characterized by density, land-use diversity and well-connected transportation networks, may encourage walking for daily activities among residents. Currently, physical inactivity is the fourth leading underlying cause of mortality worldwide, with an estimated 3.3 million deaths annually due to inactivity (World Health Organization, 2009). Individual characteristics such as age, gender and attitudes are important determinants of physical activity. More recently, neighborhood contexts have also been recognized to promote or discourage physical activity. Since walking is linked with significant health benefits at the population level, such as reduced rates of chronic disease, walkability has emerged as an important policy intervention (Giles-Corti et al., 2016; Sallis et al., 2016).

This area of research has been and remains highly interdisciplinary, though there are important contributions by health geographers. In the late 19th century, efforts to reduce harmful effects of rapid industrialization and urbanization resulted in planning approaches that separated industry and residential areas using zoning (Corburn, 2007). In the 20th century, fields diverged as public health shifted to a biomedical model of disease focusing on individuals, and planning turned toward large infrastructure and transportation projects. These disparate foci had the detrimental consequence of promoting urban sprawl and reliance on the automobile, ultimately impacting health through increased pedestrian injuries, decreased physical activity and environmental costs. By the early 21st century, the fields converged again, in part motivated by rising attention to chronic disease and obesity. This era was associated with increased awareness of the role of context in shaping health behaviors (Corburn, 2007; Sallis et al., 2004) – specifically, how neighborhood walkability, access to healthy foods or other amenities might encourage positive changes in health (Sallis et al., 2004; Schulz and Northridge, 2004). In the most recent decade, walkability has blossomed as a rich and well-investigated field, with hundreds of papers crossing a number of disciplines, such as public health, population health, social epidemiology and urban planning (Andrews et al., 2012).

Numerous reviews summarize the walkability, physical activity and health literature (see, e.g., Lovasi, Grady and Rundle, 2011; Van Cauwenberg et al., 2011). In general, these reviews find that walkable neighborhoods have been linked with increased walking, lower obesity and lower cardiovascular disease. Despite findings that support these links, real challenges remain in terms of the strength of evidence regarding walkability and its links to health. Most of the evidence comes from observational cross-sectional studies that describe the health behaviors of different people living in different settings at a single point in time. Some of these studies are large and capture populations across multiple countries, with diverse built-environment conditions (Sallis et al., 2016). However, cross-sectional studies do not contribute toward building a causal evidence base.

With the majority of people worldwide living in urban areas, cities remain a crucial component of population health. Designing vibrant, walkable urban spaces is an opportunity to engage residents and to influence physical, mental and social health. Walkability is a key pillar of urban futures, and it may be a strategy to help combat air pollution, noise, physical inactivity and isolation. Thus, more research is needed. For the field of walkability in health geography and beyond to advance, there is a need for longitudinal studies and quasi-experimental studies, examining the impacts of changes in walkability on changes in health over time. Notably, there has been an emergence of studies that follow the health behaviors of people who move to areas with different walkability (Giles-Corti et al., 2013; Hirsch et al., 2014a), as well as natural experiment studies that examine how health behaviors change as modifications are made to the built environment (Benton et al., 2016). This work reveals that effect sizes from longitudinal studies may be smaller than observed in cross-sectional studies, reopening the question as to the potential of walkability to promote health after decades of work.

Roadmap for research methods on walkability and physical activity

Research on walkability requires specific attention to how spatial concepts are measured, or operationalized, and health geography has much to contribute. We present a roadmap for geographically relevant considerations in research on walkability and physical activity that may be of value to those new to the area (Table 41.1). While the considerations are presented sequentially, in practice they are always iterative. Further, depending on the research approach, considerations may be concurrent or in a different order. To date, health geographers have been most involved in considerations A and B (around *where* and *what*), and somewhat less so in consideration C (*how much*), relating walkability with health outcomes.

Consideration A: defining the spatial dimension (where)

Researchers have used a variety of methods to operationalize neighborhoods, including administrative units, buffers, activity spaces and self-defined neighborhoods (Thornton, Pearce and Kavanagh, 2011) (Figure 41.1). In this section, we present these broad types, along with their respective advantages and disadvantages.

Table 41.1 Roadmap for research on walkability and health

Methodological considerations	*Examples*
A. defining the spatial dimension (*where*)	administrative boundaries buffers GPS/activity spaces self-defined boundaries
B. selecting and measuring relevant built environment features (*what*)	walkability indices individual components of the built environment (e.g., residential density, land-use mix, density of parks)
C. obtaining physical-activity data (*how much*)	aggregated data self-report accelerometry GPS

Much early walkability research used administrative boundaries, such as counties, census tracts or zip codes, to define spatial dimensions (Leal and Chaix, 2011). Administrative boundaries are useful if health data (walking, physical activity, outcomes) needs to be aggregated to protect the identities of individuals. Additionally, some administrative boundaries have utility as political, social or jurisdictional areas. For example, if examining how walkability relates to active travel to school, researchers might choose to use school district as a meaningful spatial dimension. Similarly, researchers may use city boundaries to make policy recommendations for city planners.

To generate more individual-specific spatial dimensions for walkability research, many studies geocode individuals' residential addresses in geographic information systems (GIS) and generate distance-based buffers. There are two dominant approaches: Euclidean buffers and network buffers (Figure 41.1). Euclidean (crow-fly) buffers are created by drawing a straight line to a given distance from a home address (Thornton, Pearce and Kavanagh, 2011), whereas network (line-based) buffers are created by drawing a line a given distance along a network, usually a street, and then buffering that line a short distance (e.g., 50 meters) (Oliver, Schuurman and Hall, 2007; Thornton, Pearce and Kavanagh, 2011). In a review of literature using buffers, 65% of studies used Euclidean buffers (Leal and Chaix, 2011). However, as network buffers are widely considered to provide more accurate representations of the spatial context that might influence walking, this trend may change.

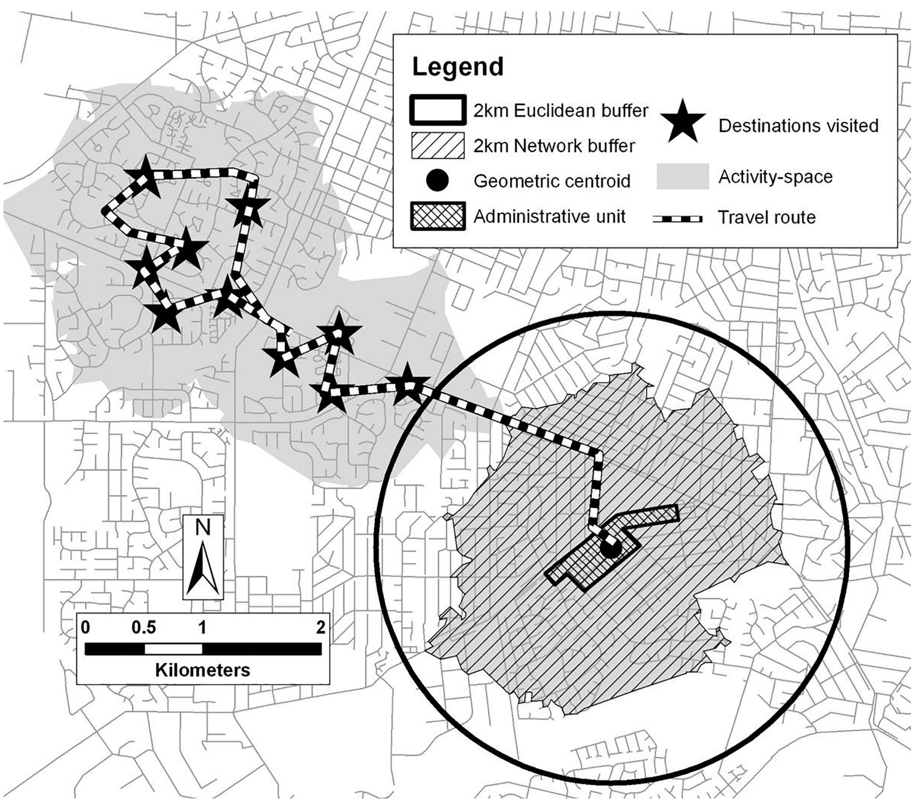

Figure 41.1 Methods of operationalizing neighborhoods

There has been a rise in the use of Global Positioning System (GPS) devices within the walkability field. GPS provides point data and reveals the true spatial context that individuals experience. When linked with accelerometry data, GPS data can provide insights as to where and when individuals are physically active (Jankowska, Schipperijn and Kerr, 2015). GPS has been especially critical in defining spatial extents in a more fluid, individualized way known as *activity spaces*, which reflect a subset of locations that individuals experience during their day-to-day activities. Three major types of activity spaces in walkability research are (1) the standard deviation ellipse, (2) the minimum convex polygon and (3) the daily path area (Hirsch et al., 2014b) (Figure 41.2).

Some research has also relied on spatial dimensions as defined by participants. This work is reminiscent of behavioral-geography work from the 1960s and 1970s, drawing mental maps by defining neighborhoods through the lived experience of residents and humanist-geography work from the 1970s and 1980s, interested in the notion of place as the subjective experiences of a physical location, endowed with meaning and associated with certain activities and social relations. In the handful of published studies on walkability that have asked participants to draw their neighborhood boundaries, it is clear that self-defined boundaries vary between people, as well as differ from other approaches to determining boundaries. For example, one study found substantial differences between participants in the shape and area of neighborhoods, as well as large inconsistencies between the size and amenities (including restaurants, recreation centers, food stores, parks) of self-drawn boundaries as compared to buffer and administrative boundaries (Colabianchi et al., 2014). Nonetheless, self-defined boundaries have the advantage of capturing participants' perceptions of their boundaries and have been very useful as an engagement or qualitative research tool for sparking discussion around neighborhood amenities.

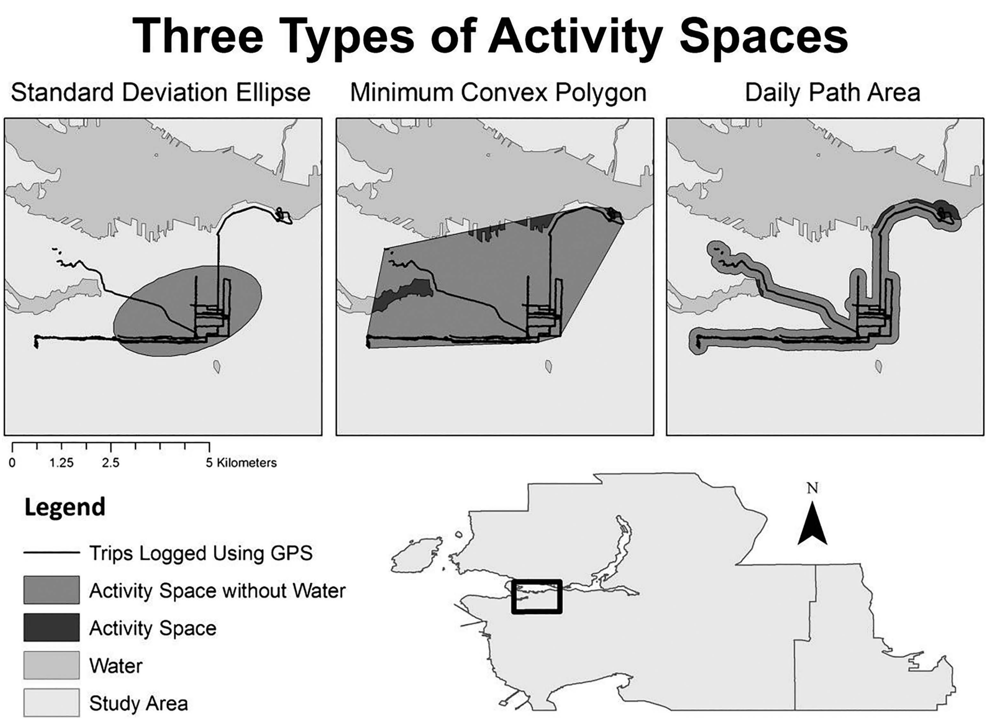

Figure 41.2 Major types of activity spaces in walkability research

Three common geospatial issues occur during the operationalization of spatial extent in walkability research: the Uncertain Geographic Context problem; the Modifiable Areal Unit Problem (MAUP); and the focus on residential environments. First, the Uncertain Geographic Context problem, first put forward by Kwan (2012), relates to the operationalization of neighborhood, specifically uncertainty whether the selected spatial dimension is the relevant space to influence behavior. The diverse and sometimes arbitrary nature of spatial dimensions employed in walkability research highlights this problem. For example, in research on buffer-based neighborhoods, Euclidean buffers range from 100 to 4,800 meters and network buffers range from 640 to 2,000 meters (Leal and Chaix, 2011). This lack of uniformity in size, combined with the lack of uniformity in shape (Euclidean versus network) raises questions around relevance and comparability across studies. Further, the appropriate distance may differ by individual sociodemographic or health characteristics – for example, older adults with mobility issues travel shorter distances. To discern the relevant spatial dimension, researchers require a clear understanding of the underlying causal processes (Diez Roux and Mair, 2010), an area needing much attention.

Second, the MAUP is a widespread issue in walkability research, as with other fields of geography. MAUP is the phenomenon in which changes in either scale or shape of spatial units result in differences in measures (e.g., environment features, walking rates) and/or the observed relationship between them (Openshaw, 1984). MAUP occurs in two different dimensions: scale effect and zoning effect. The scale effect relates to different levels or sizes of spatial aggregation (e.g., census-block groups compared to counties). The zoning effect relates to the patterns of configuration, even with a fixed level of spatial aggregation (e.g., if census-block groups were rotated 180 degrees). The administrative boundaries used in walkability research may be particularly at risk for MAUP, since daily travel is not spatially constrained to census boundaries or zip codes. Investigations within this area have found substantial scale and zoning effects (Clark and Scott, 2014; Haynes et al., 2007; Houston, 2014; Mitra and Buliung, 2012). Clark and Scott (2014) provide guidance, including the use of policy-relevant zones, the use of study-relevant distances to define buffers and the use of disaggregate data, to minimize MAUP in walkability research.

Third, another concern in operationalizing neighborhoods for walkability research is the heavy reliance on residential neighborhoods. Many have argued that relevant spatial dimension should include other common settings, including work, school or leisure-time environments (Chaix, 2009). The bias toward residential environments is ubiquitous: in a review of 131 studies on built environment and chronic disease, 90% of studies investigated exclusively residential exposures (Leal and Chaix, 2011). This typically arises as home addresses are the only available geographic identifier; future studies may want to query work locations or third places. Studies using a self-defined or GPS-based operationalization of neighborhood may alleviate this issue but bring their own issues. For one, despite a long history in space-time geography (Hägerstrand, 1970), the application of activity spaces in walkability research is relatively new. Time-geography frameworks explicitly consider individual constraints (e.g., capability, authority, coupling constraints) that may limit movement and define a time pattern of mobility. These concepts have received little attention in the walkability and health work to date.

Consideration B: selecting and measuring relevant built environment features (what)

Health geography contributes to decisions about relevant environmental features and the translation of these into metrics for walkability. Metrics for walkability may fall into two broad categories: those created using GIS, often called objective; and those generated through surveys of residents or audit tools, sometimes referred to as perceived or subjective. Several recent articles provide a thorough review of this area (Brownson et al., 2009; Eyler et al., 2015; Thornton, Pearce and Kavanagh, 2011).

Walkability is operationalized in GIS using a plethora of metrics. Table 41.2 lists common concepts and metrics.

Table 41.2 Common metrics used in research on walkability and health

Built-environment feature	*Description*	*Examples of operationalization*	*Conceptual relationship with physical-activity behaviors*	*Typical data source*
Land use	Composition of land use (residential, office, commercial, industrial, recreational, etc.)	Density: Area of (specific land use)/total land area	Lower residential land use, more walking; Higher commercial/ recreational/ industrial land use, more walking	Zoning data, land-use parcel data
Land-use mix	Extent to which there is evenness in the land-use categories across an area	Entropy measures, low values for more homogenous land use	Higher land-use mix, more walking	Zoning data, land-use parcel data
Destinations	Accessibility of various destinations (banks, grocery stores, parks, recreation centers)	Availability: presence of (specific destination) in area Distance: meters to the nearest (specific destination) Density: number of (specific destination)/area	Shorter distance, more walkable; higher density, more walking	Point data from commercial databases
Street connectivity	Degree of route connectivity from a location to a destination – for example, the diversity of route choices	Intersection density Average block length Link-to-node ratio	Higher street connectivity, more walking	Road-network data
Urban design features	Traffic calming, benches, greenness, etc.	Availability: presence of [specific feature] in area Distance: meters to the nearest [specific feature] Density: number of [specific feature]/area	Higher values for urban design, more walking	Municipal files
Walkability	Composite measures that combine built-environment components into a single index	Z-score based walkability index including residential density, street connectivity, land-use mix Walk Score™: availability of common destinations in nearby areas	Higher walkability, more walking	Researcher-derived or commercially available

(Brownson et al., 2009; Thornton, Pearce and Kavanagh, 2011)

Survey tools exist to capture analogous or complementary data to objective measures. These data are subjective or perceived in nature. One of the most popular, the Neighborhood Environment Walkability Scale (NEWS) (Saelens et al., 2003), includes measures related to land-use mix, street connectivity, walking and cycling infrastructure, aesthetics, traffic safety and more. There are also dozens of audit tools for walkability, which can be used by research teams or members of the public (Moudon and Lee, 2003), with a majority examining sidewalks, roads, intersections, vehicles, pleasantness and safety (Maghelal and Capp, 2011). In general, more attention must be placed on perceived measures *in addition to* more objective measures as valid, credible metrics (Andrews et al., 2012).

Consideration C: obtaining physical-activity data (how much)

A third consideration in walkability research is characterizing physical activity – sometimes more specifically by intensity (e.g., moderate to vigorous physical activity, sedentary time), by activity (walking, cycling) or by purpose (commuting, leisure). Unfortunately, at times there seems to be a singular focus on walking, perhaps leading to a lack of attention to other forms of mobility (Andrews et al., 2012).

The physical-activity data may be linked to place in different ways. Some studies use data aggregated to administrative boundaries – for example, commute-to-work data for census tracts, or self-reported physical activity data for health regions from the US Behavioral Risk Factor Surveillance System (BRFSS) or the Canadian Community Health Survey (CCHS). Other studies collect individual-level physical activity, including self-reported or accelerometry data. This disaggregated data may be related to place through residential address and the use of buffers. Finally, some studies use mobile sensing data, linking GPS, accelerometry and built-environment data in GIS to analyze location-specific physical activity. A useful framework for this element of the roadmap is provided elsewhere (Jankowska, Schipperijn and Kerr, 2015).

Future directions

Moving forward, health geographers are poised to inform a number of outstanding questions for walkability research (Andrews et al., 2012; Rosenberg, 2016). For example, do changes in walkability reduce or exacerbate health inequities? Which population groups benefit most from changes in walkability? What is the potential for urban form change across different settings (urban, suburban, rural), and what is the potential for behavior change in each? In studies that focus on behavioral impacts, have other co-benefits and risks been considered (e.g., air pollution, noise, traffic safety, personal safety)? What can the research say about the different motivations for walking and the experiences of different demographic and social groups with different capacities and desires? Are different types of walking (strolling, short trips) sufficient to result in health benefits? Is the innate focus on walking limiting research on other forms of mobility (wheeling, skateboarding, cycling)? Critical health geographers can help shape future research directions to address these questions while engaging with and across all considerations that make up the roadmap we have presented in this chapter.

Methodologically, research on walkability can further benefit from analysis methods emerging from health geography. For example, despite the fact that neighborhood exposures or health behaviors are not randomly distributed in space, but rather naturally clustered, most studies in this area do not recognize spatial autocorrelation (Spielman and Yoo, 2009). Conventional regression methods used in walkability research may introduce bias by not accounting for place (Cerin, 2010). Some studies do use multilevel modeling approaches that account for clustering by administrative units (e.g., individuals in the same city or neighborhood). More nuanced spatial-regression methods, such as spatial auto-regressive models, are beginning to be used, and these may be promising avenues to advance rigor in this field. As well, the patterns of spatial autocorrelation can enrich our understanding of the impact of the built environment, as it is precisely the non-random patterns that help contextualize the role of the built environment relative to other socioeconomic factors, such as education.

An ongoing hurdle in research on walkability is the heterogeneity observed in the size and direction of associations across settings and studies. This heterogeneity may be due to historical contexts, city development patterns, sociodemographic patterning or cultural norms. In recent years, geographically weighted regression (GWR) has gained popularity for exploring these types of spatial heterogeneity. In GWR, the parameter estimates can vary locally, emphasizing the spatial patterning of relationships. GWR is very new to this field, but it could become a cornerstone in walkability research.

Emerging technologies and big data bring new questions. For example, GPS has enabled researchers to generate activity spaces, which provide enhanced specificity of spatial dimension and built-environment measurement (*where* and *what*, on the roadmap) and location-specific activities (*how much*). However, Chaix et al. have warned that these methods may introduce new biases, via selective daily mobility (Chaix et al., 2013). For example, a GPS/accelerometer study might find that more physical activity happens in parks. Yet if participants who like (and do) more activity are going to the park specifically to be active, then this will result in selective daily mobility bias. Additionally, methodologies that capture a more holistic view of mobility are often more burdensome to participants and researchers (Jankowska, Schipperijn and Kerr, 2015) and invite potential privacy issues, especially when GPS is used to identify frequently visited destinations or with vulnerable populations. Health geographers should be contributing research design and study interpretations to ensure that nuanced issues associated with high-resolution geospatial data are considered.

Health geographers can help lead exploration of the role of place in health inequities by being mindful of avoiding environmental determinism (Andrews et al., 2012). There is an increasing focus on equity across diverse disciplines working on walkability, and findings are conflicting. One of the largest studies, spanning almost 65,000 census tracts in 48 US states, found disadvantaged neighborhoods and those with more educated residents to be more walkable (coined the disadvantaged advantage) (King and Clarke, 2014). Other studies cite opposite trends, suggesting that local context plays a large role (Bereitschaft, 2017). Geographers may have contributions to make in terms of differences by scale and measurement (of both social factors and walkability), as well as including urbanism, history and development patterns in characterizing context.

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