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Review Article

GIS-derived measures of the built environment determinants of mental health and activity participation in childhood and adolescence: A systematic review

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ABSTRACT

Studies increasingly use geographic information systems (GISs) to assess the impact of built environments on health in childhood. The extensive range of GIS measures and operational definitions of the built environment determinants, as well as definitions of the geographic areas of exposure, entail methodological challenges that need to be addressed. We aimed to identify, systematize and evaluate (1) operational definitions of GIS-derived built environment measures and (2) the geographic areas of exposure applied in studies examining the impact of built environments on mental health and activity participation among children and adolescents. A systematic literature review was conducted. We searched for peer-reviewed articles using Web of Science, PubMed, Medline, PsychINFO and SweMed+. The material was systematized using descriptive statistics and a synthesis approach. Numerous operational definitions were identified, which we grouped into the following categories of measures: population, built form, land-use, road/street environment, facility and amenity, neighborhood green and open space and composite measures. There was a large variability in the measures applied, and some studies lacked precise operational definitions. Most studies used ego-centered definitions, based on circular and/or network buffers with distances that ranged from 50 to 8050 m, to define the areas of exposure. This review elucidated that consistency in operational definitions is urgently needed. We suggest that the identified categories of measures represent an initial step towards establishing consensus about which determinants are important to measure. This could provide a basis for refining operational definitions, which eventually can ensure targeted use and consistency in measures applied across future studies.

1. Introduction

Children's heath and well-being are profoundly important for society, and are known to be related to multiple determinants at different levels (WHO, 1986). Moving beyond individual-based explanations, the built environment is suggested as an important determinant of influence (Sallis et al., 2006). Accordingly, increased interest in *how* local communities and neighborhoods may affect health and well-being has been evident within public health and epidemiological research (Diez Roux & Mair, 2010). Environmental determinants of public health are also given more attention in political agendas, which emphasize that concerns for people's health and well-being must be prioritized when creating healthier environments for sustainable development (UNICEF, 2004; WHO, 2014).

Investigating the impact of the built environment on health and well-being in childhood and adolescence raises questions about how to measure and operationalize the environmental determinants. For such purposes, geographic information systems (GISs) are a major advance (Diez Roux & Mair, 2010). However, using GIS is challenging as a multiplicity of measures and GIS-related operations, such as geocoding, buffering techniques, network analysis and cluster mapping, exist (Brownson, Hoehner, Day, Forsyth, & Sallis, 2009). To raise methodological awareness that can facilitate choices and computation of relevant GIS-derived measures, greater informativeness, systematization and evaluations of ways to operationalize the built environment determinants of health are needed. This study aims to address these issues.

1.1. Built environment determinants of health in childhood

A growing body of evidence has identified different characteristics of the built environment that promote active living, health and well-being among children and adolescents (Christian et al., 2015; Davison &

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Lawson, 2006; Ding, Sallis, Kerr, Lee, & Rosenberg, 2011). Structural features shown to promote an active lifestyle include mixed land-use, higher residential density and accessibility to versatile places, such as recreational and commercial areas (de Vries, Bakker, van Mechelen, & Hopman-Rock, 2007; Frank, Kerr, Chapman, & Sallis, 2007; van Loon, Frank, Nettlefold, & Naylor, 2014). A recent review concluded that safe neighborhoods, along with green space to be active, facilitated behaviors promoting child health and development. Furthermore, the presence of neighborhood facilities (e.g. recreation center) for children has been linked to their physical health, well-being and social competence (Christian et al., 2015). Kyttä, Broberg, and Kahila (2012) found that more densely built areas were associated with active travel to school and shorter distances to meaningful places for activities, whereas Broberg, Salminen, and Kyttä (2013) demonstrated that areas dominated by single-family housing promoted independent mobility and active transportation. Moreover, several road environment characteristics have been found to be associated with active living, such as higher intersection density (Frank et al., 2007; van Loon et al., 2014), traffic safety, and safe and diverse walking and cycling infrastructure (Carver, Timperio, Hesketh, & Crawford, 2010; de Vries et al., 2007; de Vries, Hopman-Rock, Bakker, Hirasing, & van Mechelen, 2010).

Neighborhood green space has also been found to influence health and well-being through different explanatory mechanisms (de Vries, 2010; Hartig, Mitchell, de Vries, & Frumkin, 2014; Lachowycz & Jones, 2013). In early childhood, more densely vegetated neighborhoods have been associated with increased playtime outdoors (Grigsby-Toussaint, Chi, Fiese, & Group, 2011). Larger proportions of neighborhood green space have been associated with higher levels of physical activity among older children and adolescents (Almanza, Jerrett, Dunton, Seto, & Pentz, 2012; de Vries et al., 2007). Access or proximity to green spaces, such as gardens and parks, and their relationship to physical activity has been widely investigated, and several studies have demonstrated positive associations (Boone-Heinonen, Popkin, Song, & Gordon-Larsen, 2010; Davison & Lawson, 2006; van Loon et al., 2014). In addition to physical activity and play, larger proportions of green space have been linked to better self-perceived health (Kyttä et al., 2012). Furthermore, emotional well-being has been positively associated with larger proportions of natural space among children and adolescents living in small towns compared to rural and metropolitan areas. However, the overall associations were weak and inconsistent (Huynh, Craig, Janssen, & Pickett, 2013).

1.2. Methodological issues and challenges with GIS-derived measures

The emergence of GIS has enabled public health researchers to quantify and analyze potential health-promoting determinants of the built environment (Diez Roux & Mair, 2010). Called one of the foremost scientific innovations (Butz & Torrey, 2006), GIS has the potential to increase our understanding of the importance of the built environment for health and well-being (Thornton, Pearce, & Kavanagh, 2011). Several definitions of what constitutes GIS exist in the literature (Burrough & McDonnell, 1998). From a user perspective, Burrough and McDonnell (1998) define GIS as “a collection of software modules for map systems, geographical data, procedures, and human knowledge and experience, which makes it possible to analyze and present the physical environment with digital technology”. GIS methods have important applications to population-level studies assessing the impact of the built environment on health, due to the ability to provide objective environmental measures in studies involving individuals spread across large geographic areas (Brownson et al., 2009). However, the processes of producing, analyzing and presenting geographic data involve making conceptual and formal abstractions of the reality (Burrough & McDonnell, 1998), and before data acquisition and analyses, researchers encounter challenges in terms of defining and operationalizing determinants relevant for the target group and the health outcomes of interest. Furthermore, the geographic area of exposure has to be defined (Diez Roux, 2007). Analyses of the built environment are conducted at several scales (national, regional, community, city and neighborhood) whereas decision-making mainly occurs at a regional or local level (e.g., municipality) and is highly context dependent. Discrepancies between the scales of analysis and decision-making may result in difficulty integrating research findings into planning and decision-making. Concerning these matters, several important methodological issues and challenges remain (Diez Roux & Mair, 2010; Matthews, Moudon, & Daniel, 2009; Oakes, Masse, & Messer, 2009).

1.2.1. Operationalization of determinants

Although there is a broad theoretical consensus that the built environment influences health and well-being (Sallis et al., 2006), the issues of precisely defining and documenting GIS-derived measures have been given little attention in the literature (Forsyth, Schmitz, Oakes, Zimmerman, & Koepp, 2006). Each built environment determinant has to be clearly defined and operationalized to obtain high-quality measures, which can be replicated and assessed for reliability and validity (Forsyth et al., 2006). A comprehensive review, addressing GIS-derived built environment measures for physical activity, showed large variability and a lack of clarity about operational definitions (Brownson et al., 2009). Furthermore, the interdisciplinary nature of built environment research implies that not all measures are relevant for every target group or health outcome of interest (Forsyth et al., 2006). This demonstrates the importance of identifying and systematizing the measured determinants and their operational definitions. Additionally, an overview of the determinants typically measured in studies investigating the impact of the built environment on health in childhood and adolescence does not exist to our knowledge. Such an overview could be important to ensure that researchers who aim to use GIS-derived measures make informed choices.

1.2.2. Defining the geographic area of exposure

How to define the geographic areas of exposure, in which built environment measures will be computed, is another important question (Diez Roux & Mair, 2010; Kwan, 2012; Spielman & Yoo, 2009). We distinguish between territorial and ego-centered definitions. Territorial definitions imply using predefined spatial units or administrative areas, whereas ego-centered definitions consider the geographic context from the residence of each individual (Chaix, Merlo, Evans, Leal, & Havard, 2009). GIS can be utilized to integrate spatial data from diverse sources to compute measures of the built environment surrounding each home (Thornton et al., 2011) or other locations, such as schools (Oliver, Schuurman, & Hall, 2007), by geocoding addresses and using buffering techniques. Different buffer types and varying distances are applied in studies (Brownson et al., 2009), and selecting inappropriate buffer distances can cause severe bias in associations of interest (Spielman & Yoo, 2009). This lack of agreement and considerable uncertainty in defining the geographic areas of exposure make buffering difficult (Diez Roux & Mair, 2010), which has been acknowledged in several studies (Colabianchi et al., 2007; van Loon et al., 2014).

1.3. Objectives and delimitation

We aimed to identify, systematize and evaluate (1) operational definitions of GIS-derived built environment measures and (2) the geographic areas of exposure applied in previous studies, assessing the impact of the built environment on the mental health of and activity participation by children and adolescents.

The terms health and well-being are broad concepts, covering large aspects of life. We focus on mental health and include a holistic perspective of health, in which mental health is an integral part of the definition. Mental health is defined as encompassing mental illness and a positive state of well-being, where an individual is able to realize his or her abilities and attain the fullest potential of health (WHO, 2004). Furthermore, mental health and well-being are related to the