Health & Place 17 (2011) 1191–1201

Contents lists available at SciVerse ScienceDirect

Health & Place

journal homepage: www.elsevier.com/locate/healthplace

Development and application of a moveability index to quantify possibilities for physical activity in the built environment of children

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ARTICLE INFO

Article history:
Received 15 March 2011
Received in revised form
15 August 2011
Accepted 24 August 2011
Available online 5 September 2011

Keywords:
Built environment
Children
Geographic information system
Physical activity
Walkability

ABSTRACT

Several studies show that urban forms are environmental correlates of physical activity. Most of these studies used data based on questionnaires while only a few used geographic information systems (GIS) to objectively assess urban forms. Based on GIS data, we applied a kernel density method to measure urban forms and combined these measures to a moveability index to assess the opportunities for physical activity in the German intervention region of the IDEFICS study. In this proof-of-principal analysis, we linked the moveability index with physical activity data obtained from the baseline survey of the IDEFICS study. Regression analyses revealed a modest but significant impact of the built environment on the physical activity of 596 school children in the study region, supporting the potential application of the moveability index.

1. Background

Characteristics of the built environment do have an impact on the physical activity (PA) of residents, but there are great disparities in the design of studies related to the physical environment. On the one hand, different field surveys (Millington et al., 2009) or questionnaires (De Bourdeaudhuij et al., 2003; Cerin et al., 2006, 2007; Spittaels et al., 2010) that provide perceived data on urban forms were used depending on the study area and the country in which the study was conducted. On the other hand, geographic information systems (GIS) were used to collect geodata on aspects of the built environment and to objectively assess urban forms with measures for distance, density or diversity. In this respect, indices were developed that combine measures of urban forms to reflect the impact of the built environment on PA in one single value (Krizek, 2003; Rodriguez et al., 2006; Owen et al., 2007; Leslie et al., 2007), but these measures were mostly averaged regionally on a large scale, although they are combined with individual level data (Frank et al., 2005).

In particular, Frank et al. (2005, 2010) developed the concept of walkability using GIS to objectively assess urban forms for studies of the physical environment. The walkability is assessed using measures of urban form that characterize possibilities for walking using individual pedestrian catchment areas within a 1 km buffer zone. Compared to this definition of an individual home environment in GIS-based studies, Lee et al. (2008) used buffer zones with a radius of 0.25 mile (approx 400 m) to assess walking suitability around schools and Oreskovic et al. (2009) implemented also 400 m buffer zones based on the distance an average adult can walk in 5 min. However, in some studies, individual pedestrian catchment areas were substituted by census districts (Leslie et al., 2007; Owen et al., 2007) which is the so-called "container approach" (Maroko et al., 2009). This approach is based on the simple density to measure the accessibility to urban forms, i.e. the accessibility is measured by the number of urban elements within a particular geographic unit of aggregation (e.g. census tracts) (Maroko et al., 2009). This method is worth discussing and may be improved using more refined geostatistical methods which are described below.

Additionally, physical environment studies that use objective measures of urban form calculated in GIS are mostly examined in the US (Frank et al., 2005, 2010; Evenson et al., 2009) or Australia (Leslie et al., 2007; Owen et al., 2007), but rarely in Europe (Bringolf-Isler et al., 2008; Panter and Jones, 2008). Findings from

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[1] On behalf of the IDEFICS Consortium.

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doi:10.1016/j.healthplace.2011.08.011

these physical environment studies cannot be adapted in a straightforward manner, because (1) the environments in the US and Australia differ from urban areas in many European towns and cities (Millington et al., 2009) and (2) built environments do have a different impact on PA across different countries (Sallis et al., 2009).

Finally, physical environment studies mainly focus on the impact on the PA of adults. Considering particular urban forms like intersections and sidewalks, there is a strong evidence for their impact on the PA of adults. However, whether there exists a comparable association in children has not been sufficiently examined. Some recently published studies showed evidence that some urban forms may influence PA with regard to transportation or recreation in children (Panter et al., 2008; Jones et al., 2009), but studies that use objective measures based on GIS are lacking.

Therefore the aim of this pilot study was to investigate the impact of the built environment in a European context, using Germany as the pilot area, on the PA of children, This was achieved by adapting the concept of walkability from Frank et al. (2005, 2010) which was developed for adults and included recreational facilities offering possibilities for PA particularly for children.

This paper aims to address three main objectives. First, we describe the density and diversity as measures of urban form that are used to objectively assess opportunities for PA. Second, we propose a process that combines several dimensions of urban forms to a moveability index in order to measure opportunities for PA of children in urban areas. Finally, statistical analyses are performed to investigate the practicability of the moveability index linking the index with selected self-reported questionnaire information on travel mode and leisure time PA using data collected within the IDEFICS (Identification and prevention of Dietary- and lifestyle-induced health EFfects in Children and infantS) study.

2. Methods

We also conducted a review of physical environment studies to identify objectively assessed and perceived urban forms that showed evidence of being environmental correlates of PA. Urban forms are presented in categories that were used to derive urban form features (for an overview see Table 1).

2.1. Street connectivity

Street connectivity comprises measures characterizing the urban infrastructure within the neighborhood environment. Studies using GIS to assess the urban environment, in general, only intersections are considered to describe the connectivity of the street network (Frank et al., 2005, 2007; Schlossberg et al., 2006; Kerr et al., 2007; Leslie et al., 2007; Owen et al., 2007; Holt et al., 2008). As a result, intersection density was positively associated with weekly frequency of walking for transport in adults (Frank et al., 2005, 2007; Owen et al., 2007) and active travel mode of children on their way to school (Schlossberg et al., 2006; Kerr et al., 2007; Holt et al., 2008).

Other studies using questionnaires or field surveys also showed associations between sidewalks (De Bourdeaudhuij et al., 2003, 2005; Sallis et al., 2009), bikeways, and public transit stations (Sallis et al., 2009) and reported PA of residents. Higher levels of PA in adults were found in neighborhoods whose residents reported a higher availability of sidewalks (De Bourdeaudhuij et al., 2003, 2005). Particularly, Edwards (2008) found that using public transit was associated with walking 8.3 more minutes per day on average in adults.

Since the considered urban forms that were used to assess the street network differ from one study to another, we included all four urban forms, i.e. sidewalks, bikeways, intersections, and public transit stations, in our street connectivity feature to cover all possibilities for PA.

2.2. Destination density

Environmental correlates of recreational PA are destinations like parks, playgrounds, and sports facilities that impact on the PA of residents. Studies showed that higher levels of PA in children were reported, if such destinations were located in the neighborhood (Davison and Lawson, 2006; Frank et al., 2007; Kerr et al., 2007; Scott et al., 2007; Black and Macinko, 2008). For example, the PA of children was positively associated with the proportion of green space (DeVries et al., 2007) or access to parks and recreational facilities (Roemmich et al., 2006). In a sample of English adults, it was also shown that those who reported five sessions of activity per week tended to live closer to sports facilities than their less active counterparts (Panter and Jones, 2008). Furthermore, Giles-Corti et al. (2005) showed for adults that the use of public open space for physical recreation was positively associated with accessibility to public open space.

Therefore, the destination density feature includes public playgrounds, sports facilities, and parks and green spaces to account for recreational areas where children can be physically active.

2.3. Level of urbanization

Characteristics like land use and number of residents or dwellings, respectively, are associated with the infrastructure and the number and variety of destinations within urban areas. Therefore, we derived the urban form feature called 'level of urbanization' including both urban forms that influence the walkability and the possibilities

Table 1
Description of the considered urban forms, the resulting measures of urban form as well as the urban form features including abbreviations.

Urban form feature	Abbr.	Description	Urban forms	Measures	Abbr.
Street connectivity	*SC*	Characterizes the infrastructure of the built environment. Higher density values of urban forms reflect a connected infrastructure for pedestrians and cyclists	Sidewalks Bikeways Intersections Public transit stops	Density	*WD* *BD* *ID* *TD*
Destination density	*DD*	Characterizes the accessibility to facilities that provide possibilities for PA. Higher density of urban forms provide more possibilities for PA in the neighborhood	Public playgrounds Sports facilities Parks/green space	Density	*PD* *FD* *GD*
Level of urbanization	*LU*	Characterizes the urbanity. Areas with high residential or dwelling density and diverse land use types are considered as urban	Residents/dwellings Land use types	Density Diversity	*RD* *LM*