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An index for assessing activity friendliness for children in urban environments of Berlin

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Abstract

The physical environment strongly influences physical activity in urban settings. While walkability is frequently assessed for adults, an approach for mapping the friendliness of urban environments focusing on children's activities is not available. The aim of the presented approach was to identify supporting and limiting factors of activity friendliness in urban environments and incorporate them into a children's physical activity index (CAI). We conducted qualitative guided interviews with nine- to ten-year-old children and parents of primary school children in Berlin to identify the factors and their importance for describing activity friendliness. Access to activity and recreational destinations, land use, traffic and road safety, and the social environment were the most prominent factors identified for the activity friendliness for children. The newly developed CAI enables a differentiation in the activity friendliness of urban neighborhoods for children.

Zusammenfassung

Die urbane Umwelt beeinflusst die körperliche Aktivität ihrer Bewohner. Zur Bewertung der Fußgängerfreundlichkeit wurde für Erwachsene das Konzept der Walkability entwickelt und vielfach angewandt. Eine Methode zur Messung der Bewegungsfreundlichkeit der urbanen Umwelt für Kinder existiert jedoch nicht. Ziel dieser Studie ist die Bestimmung bewegungsfördernder und -hemmender Faktoren im urbanen Raum und eine Zusammenführung dieser in dem *children's physical activity index* (CAI). Es wurden qualitative leitfadengestützte Interviews mit neun- bis zehnjährigen Kindern und Eltern von Grundschulkindern in Berlin durchgeführt, um die Faktoren und ihre Gewichtung zur Beschreibung von Bewegungsfreundlichkeit zu identifizieren. Der Zugang zu Bewegungs- und Freizeitdestinationen, Landnutzung, Straßenverkehr und Verkehrssicherheit und die soziale Umwelt waren die wichtigsten Bewegungsfreundlichkeitsfaktoren. Der entwickelte CAI ermöglicht eine differenzierte räumliche Darstellung der Bewegungsfreundlichkeit der urbanen Umwelt für Kinder.

Keywords walkability, childhood, neighborhood, urban health, spatial index

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1. Introduction

The physical activity of children is decreasing in Western developed countries, both in recreation and active mobility (*Bringolf-Isler* et al. 2014; *Whitzman* et al. 2007). Sedentary activities involving computers or smartphones and the increased use of cars by parents are just some of the reasons (*Bringolf-Isler* et al. 2014; *De Bourdeaudhuij* et al. 2013; *Giles-Corti* et al. 2009; *Robert Koch-Institut* 2014; *Whitzman* et al. 2007). In addition, increased parental restrictions enforced on children by their parents in terms of walking or playing somewhere unobserved as well as a shift of the areas where children play to the private sphere act as limiting factors to children's movements (*Holt* et al. 2008). Nowadays, in Germany, only half of the recommended two hours of physical activity, including 30 minutes of intensive sports, 60 minutes of free play outdoors and 30 minutes of active mobility per day is actually realized (*Buck* et al. 2015; *Graf* et al. 2009).

The physical activity of children is known to be influenced by a complex set of factors including individual, social, environmental, cultural, and institutional aspects (*Sallis* et al. 2006). The built-up and non-built-up environment has been shown to be a strong determinant of children's activities (*Buck* et al. 2015; *Gose* et al. 2013). In order to assess "the extent to which the built environment is walking-friendly" (*Abley* 2005: 3), the walkability index was developed by *Frank* et al. (2010). It suggests that the more densely populated, the better connected the streets and the more mixed the land use is, the more 'walkable' a neighborhood is (*Cervero* and *Kockelman* 1997; *Frank* et al. 2010). However, it only focuses on the activities of adults. An assessment of children's physical activities – not only in terms of active transport, but also in terms of free play and sports also has to be considered (*Bringolf-Isler* 2014).

To identify the factors that characterize how the environment supports the physical activities of children, initial studies in European countries have recently been undertaken with different sets of methods and outcomes: *Holt* et al. (2008) worked with mental maps, *Bringolf-Isler* et al. (2014) used accelerometer-based data combined with the spatial data of the residential environment, *Babb* et al. (2011) and *Giles-Corti* et al. (2011) focused on the school surroundings with the help of distance measurements. Factors affecting children's choice of route when walking or cycling to school were evaluated by *Dessing* et al. (2016). In Germany, *Gose* et al. (2013) statistically analyzed how the social and built environment (objectively measured and subjectively perceived) affect the Body Mass Index of six-year-old children. *Buck* et al. (2011, 2015) developed a moveability index based on subjectively measured physical activity and environmental variables.

These recently undertaken studies show a wide variety of qualitative (*Holt* et al. 2008) and quantitative methods (*Bringolf-Isler* et al. 2014; *Gose* et al. 2013). Statistical approaches do not cover children's individual perspective and behavior and qualitative studies provide limited information about the urban environment. Therefore, an adaptable method design is required combining those established methods. The approach from *Buck* et al. (2015) analyzes how the neighborhood, e.g. availability of public open spaces, influences the activity behavior of children. Additionally, their approach points out the difficulties interpreting objectively measured together with subjectively perceived data (*Buck* et al. 2011). The moveability index (*Buck* et al. 2011; *Buck* et al. 2015) as a data-driven approach might be further developed including children's and parent's perspectives.

Bringolf-Isler (2014) reviewed the current state of the art and stated that factors from the following four categories were relevant for activity friendliness: access to activity and to recreational destinations, spatial planning, traffic and road safety and the social environment. In particular, access to parks, playgrounds and sports grounds were identified as factors influencing children's activity levels (*Bringolf-Isler* et al. 2010; *Buck* et al. 2011; *Davison* and *Lawson* 2006; *Timperio* et al. 2004; *Veitch* et al. 2006) as well as the availability of private gardens and courtyards (*Gose* et al. 2013; *Veitch* et al. 2006). Spatial planning factors have been discussed controversially: while mixed land use is classed as being friendly for walking (*Bringolf-Isler* et al. 2010; *Rahman* et al. 2011), population density merely shows a weak relationship with physical activity (*Davison* and *Lawson* 2006; *Ding* et al. 2011) whereas a high intersection density is shown in some studies to have either a positive effect, representing a high connectivity, or negative effect on walking behavior, associated with a high traffic density (*Bringolf-Isler* et al. 2010; *Holt* et al. 2008; *Spence* et al. 2008; *Veitch* et al. 2006). Factors related to traffic range from the presence of pavements (*Dessing* et al. 2016; *Rahman* et al. 2011), the absence of main roads (*Babb* et al. 2011; *Davison* and *Lawson* 2006;

Veitch et al. 2006), a low traffic density (*Bringolf-Isler* et al. 2010; *Ding* et al. 2011; *Gose* et al. 2013) to parents perception of road safety (*Rahman* et al. 2011). In terms of the social environment, the crime rate (*Bringolf-Isler* et al. 2010) as well as the perceived safety of the neighborhood (*Davison* and *Lawson* 2006; *Rahman* et al. 2011) have also been found to affect the physical activity of children. In addition, neighborhoods with a high percentage of children of the same age encourage active playing (*Mackett* et al. 2007; *Veitch* et al. 2006).

While there seems to be an initial common ground for supporting and limiting factors of activity-friendly urban environments, a systematic study that combines quantitative measures with qualitatively derived factors in a transparent, systematic and spatial index is missing. The aims of this paper are therefore 1) to identify which supporting and limiting environmental factors can be assessed by a qualitative approach including children's and parent's perceptions and are relevant for assessing activity-friendly urban environments for children in the study area in Berlin and 2) to develop an index based on these qualitatively assessed factors that enables area-wide and comparable assessments. We aim to establish a transferable method, which builds upon individually perceived and objectively measured factors to describe the activity friendliness of urban environments for active transport, free play and the sports of children.

2. Methods

2.1 Study Area

The study took place in Berlin, Germany, focusing on a primary school in a densely-populated central area in the district of Schöneberg. The catchment area of this public primary school consists of six planning units (*Fig. 1*). The city of Berlin is divided into twelve districts and subdivided into 447 planning units, the latter combine small-scale social and statistical areas. The population living in these planning units is characterized by a large socio-economic and ethnic heterogeneity, especially in terms of migration backgrounds (*Senatsverwaltung für Stadtentwicklung und Umwelt Berlin (SenStadtUm)* 2013). The area offers numerous opportunities that support outdoor physical activities (e.g. playgrounds, parks, soccer fields, streets with very little traffic) on the one hand, but also limiting elements (e.g. main roads, blind bends and limited crossings) on the other.

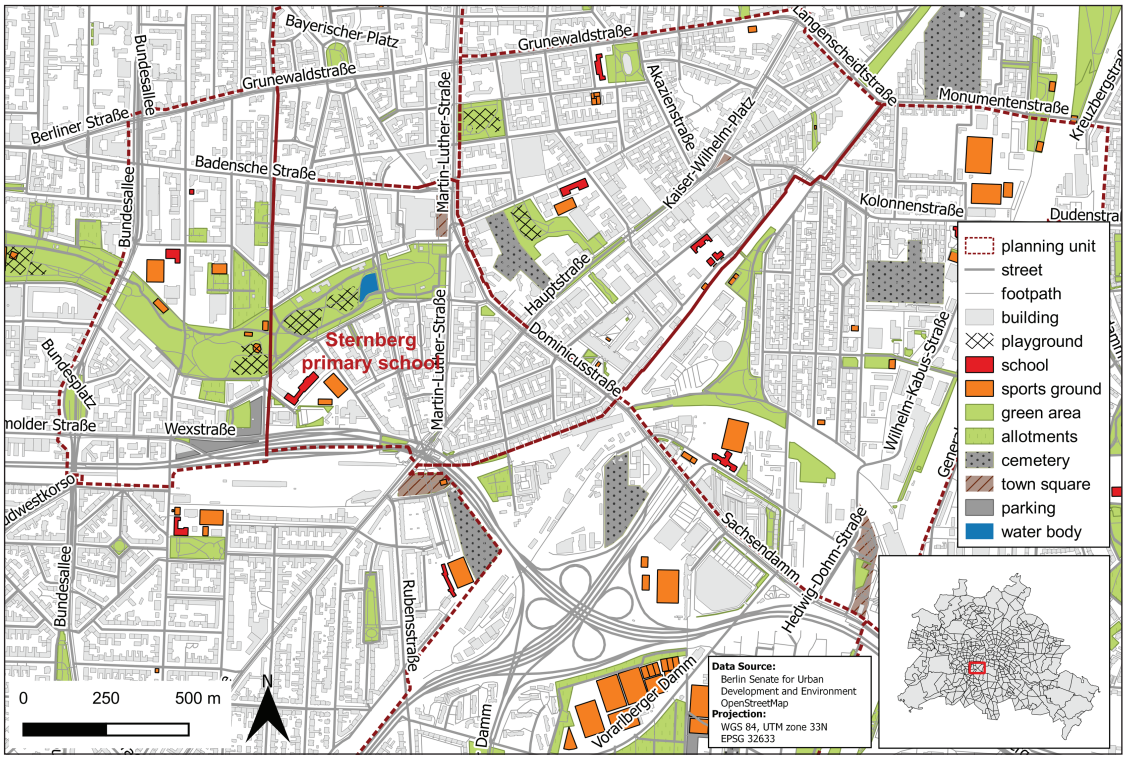

Fig. 1 Study area around the primary school (Sternberg Grundschule) in Schöneberg. Source: Own elaboration

2.2 Study population: Nine- to ten-year-old primary school children and their parents

This study focuses on the age group of nine- to ten-year-old children, assuming that these children are allowed to go outside on their own (*Mackett* et al. 2007; *Wheeler* et al. 2010), that they play outside and walk or cycle to school and attend leisure activities that are predominately in the neighborhood of their home and school. For this study, 18 nine- to ten-year-old children of a school class and twelve individual parents from primary school children (average age: 8.7 years) were interviewed at a school celebration in order to cover both perspectives: supporting and limiting factors identified by children and by parents. This allows us to cope with the potential discrepancies in the parentally perceived and idealized physical activities of their children on the one hand (*Holt* et al. 2008) and with the dominance of parents' opinions on the actual behavior of children at that age on the other (*Bringolf-Isler* 2014).

2.3 Focus group interview with children and qualitative interviews with parents

Guided qualitative interviews to identify supporting and limiting environmental factors of activity-friendly neighborhoods were conducted at the primary school in June 2015. A focus group session with 18 children was guided in a 60-minute-lesson at the school. After a short introduction and questions about their outdoor activities (e.g. *"Who walks to school?", "Who does sports regularly?", "Who spends active leisure time outside after school?"*), children were asked to report about factors which restrict their physical activity (*"Why do you avoid certain places and what is it that disturbs you or frightens you about those places?"*). Afterwards, following the mental map approach by *Holt* et al. (2008) the children were asked to draw their ideal district for physical activity *("What should your neighborhood look like for you to enjoy it more and spend more time outside?"*).

Interviews with the parents followed the same scheme. Parents of primary school children were interviewed during a summer school celebration. Each interview took between 5 and 15 minutes. The parents were asked about the general physical activities of their children, and where and why they are physically active (e.g. *"How often and for how long does your daughter/son spend time outside?", "Where does your daughter/son walk, play or do sports outside? Could you locate these areas on the map?"*). A map of the school catchment area was provided to help link physical activities with specific areas (*Fig. 1*). They were then asked to report on the specifics of activity-limiting areas (e.g. *"Which places or areas does your daughter/son avoid for example on her/his way to school and where do you not allow her/him to go and why?"*). Finally, parents were able to express their wishes about how the district should be designed to improve the movements of their children (e.g. *"If you could adapt your own neighborhood to the needs of your daughter/son, what would you change?"*).

2.4 Interview data analysis

The interviews were recorded and logged. First, supporting and limiting factors of physical activity were identified and collected from the interview protocols and children's paintings. Second, the qualitative and individual perceptions were translated into quantifiable variables. For example, parents and children reported regular outdoor activities in parks located in their neighborhood. This perception was translated into the supporting factor of activity friendliness: 'proximity to parks'. In a similar way, the drawings of soccer fields and swimming pools were translated into 'proximity to soccer fields and public swimming pools'. Avoiding main roads on the way to school and showing a preference for streets with light traffic was translated into the factors: 'distance to main roads' and 'proximity to traffic-calmed streets'. The description of children's preferences to go to places where friends or potential playmates spend their time was converted into 'high proportion of children per block'. The preference of clean sidewalks well equipped with bins was translated into 'bin density' and the preference of road safety into the 'density of accidents involving pedestrians'.

In a next step, those factors were selected that fulfill the requirements for a spatial index as they are spatially explicit, quantifiable and measurable in terms of available data. For factors such as sufficiently long sequences of pedestrian traffic lights and the maintenance of playgrounds or the presence of homeless people/alcoholics/drug addicts, traffic volume etc. no data was available, meaning that they had to be dismissed from further analysis. The same was done for contradicting factors, e.g. pedestrian underpasses (some perceived them as safe, others as scary).

To calculate the area-wide values for the factors we mainly relied on open data services, such as the Open Data platform of the Berlin Senate for Economy, Technology and Research (*Senatsverwaltung für Wirtschaft* 2015), the wfs-database from the Berlin Senate for Urban Development and Environment (*Senatsverwaltung für Stadtentwicklung und Umwelt Berlin (SenStadtUm)* 2015) and OpenStreetMap (*OpenStreetMap (OSM)* 2015). Traffic accident data from the Berlin Police (*Polizei Berlin* 2015) was also added. The geo data that was collected was processed in a geographic information system (GIS).

All factors were converted into distance, density or diversity raster values. Distance values to points, polylines or polygons (e.g. fountains, traffic-calmed streets, parks) were measured with the Euclidean distance based on the Pythagorean metric. Density was calculated per planning unit (proportion of children) or as a statistical block unit (population density), depending on the available data units or as a point density within a walking distance of 800m (e.g. bin density). The land use mix was computed according to *Dobesova* and *Krivka* (2012), whereby land use classes were adapted from *Reyer* et al. (2014) and sorted into the categories living, commercial, services, recreational, industrial, water and others. The higher the entropy value, the higher the number and proportion of different land use classes per planning unit.

2.5 A weighted integration of standardized factors into a children's physical activity index

The distance, density and diversity raster values were standardized and classified on a scale from 0 to 10 for comparability reasons (*Giles-Corti* et al. 2011). High values correspond to areas which support physical activity, low values to those areas which restrict activity. Classes of relative density and diversity values are defined by percentiles and distance classes according to reasonable walking distances for children. *Rattan* et al. (2012) define 400m as a reasonable walking distance to grocery stores and (bus) stops, 800m to supermarkets and a maximum distance of 1500m to primary schools. Therefore, distances longer than 1500m were classified as 0. The limiting factor 'distance to casinos, night clubs and erotic shops' was treated differently. Because parents reported children changing roads to avoid passing these places directly, shorter distances were applied for this factor (10, 50, 100m).

The reclassified factors were weighted based on the number of reports and relevance in the qualitative interviews. For example, both parents and children mentioned playgrounds, private gardens and courtyards as regularly frequented destinations. As a result, they were given a higher weighting than the public volleyball field that was only mentioned by one parent (e.g. *"We try to go there almost every day."*, *"She regularly spends time after school in our garden."*). Numerous and concrete negative associations referring to main roads (e.g. *"He avoids this busy road on his way to school and has to take this small detour."*) were rated higher than vague desires (e.g. a general preference for streets with light traffic).

Finally, all classified and weighted factors on the grid level were summarized into one GIS-based index and for every 10x10 m-grid cell, the weighted sum was calculated. The index approach enables one relative activity friendliness value to be derived for each specific grid cell and depicts disparities on a citywide level for Berlin (*Lakes* et al. 2014).

3. Results

3.1 Factors supporting or limiting the physical activity of children

From the interviews with the nine- to ten-year-old children and parents of the case study school we identified a number of supporting and limiting environmental factors that were reported to be relevant for assessing activity-friendly urban environments for children (*Table 1*). Moreover, our knowledge from previous studies was integrated into the process of deriving these environmental factors.

Both children and parents reported spending time at parks and/or playgrounds at least once a week so that distances to such leisure destinations were included as one of the most important factors. Another factor supporting activity was the availability and proximity to recreational facilities, including sports grounds, especially soccer fields and swimming pools. Both of these were mainly painted by the children: swimming pools by three girls and soccer fields by four boys. Two parents of children with younger siblings described spending time near fountains or other water features. Another factor that was often mentioned was the access to green back yards or gardens. From the parents' perspective unobserved, safe outdoor activities

Table 1 All reported factors influencing physical activity with their classification, weighting and data source. Source: Own elaboration

Perception children parents both **Access to activity and recreational destinations**	Activity factor	Classification	Weighting	Data source (date)
Frequent and regular visit of parks in the neighborhood and the school vicinity	*Short distance to* parks	*walking distance* 0-200-400-800-1500-4025m	0,15	SenStadtUm* (2015)
Frequent and regular visit of playgrounds in the neighborhood and the school vicinity	playgrounds	0-200-400-800-1500-6500m	0,2	SenStadtUm (2015)
Regular outings to public swimming pools with parents	public swimming pools	200-400-800-1500-5964m	0,05	OSM** (July 2015)
Use of public soccer fields	soccer fields	200-400-800-1500-6867m	0,05	OSM (July 2015)
Use of public volleyball fields	volleyball fields	200-400-800-1500-18057m	0,01	OSM (July 2015)
Use of public basketball fields	basketball fields	200-400-800-1500-15377m	0,01	OSM (July 2015)
Preference of parks or playgrounds with fountains	fountains	200-400-800-1500-14110m	0,02	OSM (July 2015)
Frequent and regular time spent in own courtyard/garden or that of family or friends	houses with private gardens/courtyards	0-200-400-800-1500-3235m	0,15	SenStadtUm (2010)
Spatial planning				
Streets, public spaces and parks can be easily visited	High population density per housing block	percentile + class for no. of inhabitants	0,02	SenStadtUm (2014)
Daily routines (e.g. shopping, the way to the kindergarten of younger siblings) are covered with parents	High land use mix per planning unit	percentile	0,02	SenStadtUm (2011)
Preference of quiet side streets with a minimum of crossings on the way to school	Low intersection density	rounded percentile	0,04	SenStadtUm (2015)
Traffic and road safety				
Perception of streets for playing as the safest	Short distance to play streets	walking distance (200-400-800-1500-6041m)	0,02	OSM (July 2015)
Preference to walk on streets with light traffic	Distance to traffic-calmed streets (≤ 30km/h)	walking distance (200-400-800-1500-6041m)	0,02	OSM (July 2015)
Roads and crossings perceived to be unsafe or with a known high number of accidents involving pedestrians (particularly children) were avoided	Density of accidents involving pedestrians	rounded percentiles + class for no. of accidents (0-1-2-4-7-11-15-20-32-54-162 accidents within distance of 800m)	0,05	Polizei Berlin (2014-2015)
Main roads, perceived as too large, unobserved and unsafe, were avoided	Long distance to main roads	negative distance (10-50-100-200-400-800-1500-4360m)	0,1	SenStadtUm (2015)
Preference of streets with a low number of passing vehicles (low traffic volume)	Factor not included because of missing data (covered by distance to traffic-calmed streets)			
Desired long sequences of pedestrian traffic lights without having to wait too long	Factor not included because of missing data			
Crossings with specific characteristics avoided (e.g. where parents pull up in the car in the morning)	Factor not included because of missing data due to high temporal variability (e.g. for traffic jams)			
Routes with safe pedestrian crossings preferred	Factor not included because of missing data (data is only partly mapped in OSM)			
Pedestrian underpasses preferred	Factor not included because of the contradictory perceptions of parents and children (safer than main road crossing, but frightening)			

Perception children parents both Social environment	Activity factor	Classification	Weighting	Data source (date)
Well attended playgrounds and parks preferred, or being outside together with friends or visiting friends in the neighborhood	High proportion of children per planning unit	percentiles + class for no. of children	0,05	AfS*** (2014)
Roads perceived to be unsafe with casinos, night clubs and erotic shops next to each other	Long distance to casinos, night clubs, erotic shops	negative distance (10-50-100-1500-15366m)	0,02	OSM (July 2015)
Preference of clean playgrounds and places with sufficient bins	High bin density	manual classification percentiles (0-1-2-3-5-10-100 bins within a distance of 800m)	0,02	OSM (July 2015)
Fear of darkness, well illuminated places preferred, children not allowed going out alone after dark	Factor not included because of missing data (only partly mapped in OSM)			
Feeling disturbed and unsafe where dogs roam without their owners, complaints about dog excrement	Factor not included because of missing data (data of proportion of dog owners only available on the district level)			
Temporary meeting points of youths, homeless people, alcoholics or drug addicts perceived to be unsafe and their side effects perceived as unacceptable (e.g. litter, shards, used injections)	Factor not included because of missing data (temporary and spatially highly variable)			

* Senatsverwaltung für Stadtentwicklung und Umwelt Berlin
** Open Street Map
*** Amt für Statistik Berlin Brandenburg

take place in their own yards or gardens or those of family and friends.

Factors belonging to the spatial planning category correspond with the classic walkability approach (*Frank* et al. 2010) and were mainly reported by parents. Their children prefer well-attended playgrounds and parks as well as walking along crowded streets. The presence of other people was perceived as a safe form of social control, which implies a high population density. Many daily routines, such as grocery shopping, were covered by parents and children together. Therefore, areas with mixed use were positively associated because destinations such as workplaces, supermarkets or leisure destinations were accessible on foot. In addition, parents preferred school routes for their children with low traffic volumes and a minimum number of crossings. This can be measured in the form of a low intersection density.

Activity factors regarding traffic and road safety were discussed by both parents and children but in different ways. Children expressed their wishes for safe crossings or pedestrian-friendly traffic lights. Parents were more concerned about avoiding dangerous intersections where accidents happen frequently or which are poorly observed. The safety that was perceived subjectively by parents played an important role in terms of the areas where their children were allowed to be active. Therefore, the following measurable factors were included: short distances to streets for playing and traffic-calmed streets (up to 30 km/h), a low density of accidents involving pedestrians and a long distance to main streets.

The fourth category of factors that support and limit activities is very diverse. The subjective perceptions of certain social groups or facilities, which can be spatially measured, can affect the physical activity patterns of children. The spatial concentration of casinos, night clubs and erotic shops were perceived to be a frightening barrier. Some parents reported how their children would cross over to the other side of the road in such instances. In addition, activity-friendly places were described as clean and well-equipped with bins. For this reason, the high bin density factor was included. Half of the parents described the environment of the district as being children-friendly. The higher the proportion of children from the overall population, the more parents felt safe to leave their children playing outside on their own and the higher the probability of meeting other children or families outside.

3.2 Spatial index for assessing activity-friendly urban areas

The factors identified as supporting and limiting activity, which can be measured spatially and based on available data were then classified, weighted and integrated into one spatial index. Thresholds for classes of the factors were extracted from the literature and weights given from the interviews as described in *Table 1*. The resulting CAI enables area-wide assessments of activity friendliness for children in the study area (*Fig. 2*) but shows certain limitations for the entire city of Berlin (*Fig. 3*).

The mapped index for the school vicinity shows that in general the area is relatively activity-friendly and does not reveal any positive or negative extreme values. Most of the housing areas were assessed as activity-friendly, as most of them are old buildings with yards and a high population density. In contrast, the streets are mapped with lower activity friendliness values, as not only active transport was included in the index but also free play outside (in private and public spaces). Negative values accumulate for main streets, their crossings and brownfields. Parents confirmed these results, by reporting that they try to avoid specific main streets and intersections.

The Berlin-wide index shows a wider range of values and areas which are rated as very activity-friendly or activity-unfriendly. High values can be found in the city center and densely inhabited areas, whereas low values are mainly located in suburban or uninhabited areas. As the index focuses on the daily routines determining physical activity patterns in neighborhoods, areas visited on weekends or longer journeys were not considered. Therefore, forests, water bodies and agricultural land were masked out.

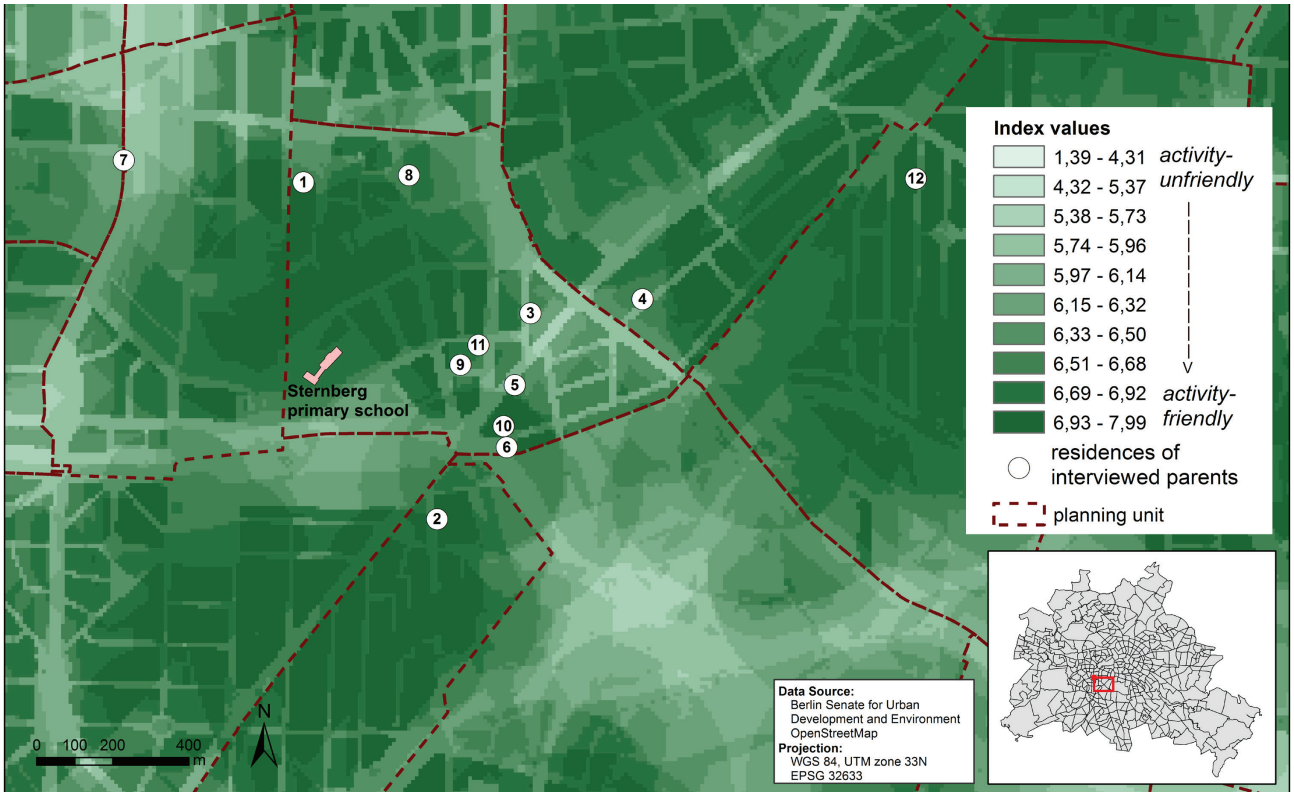

Fig. 2 Activity friendliness of the school study area for children in Schöneberg, Berlin. Source: Own elaboration

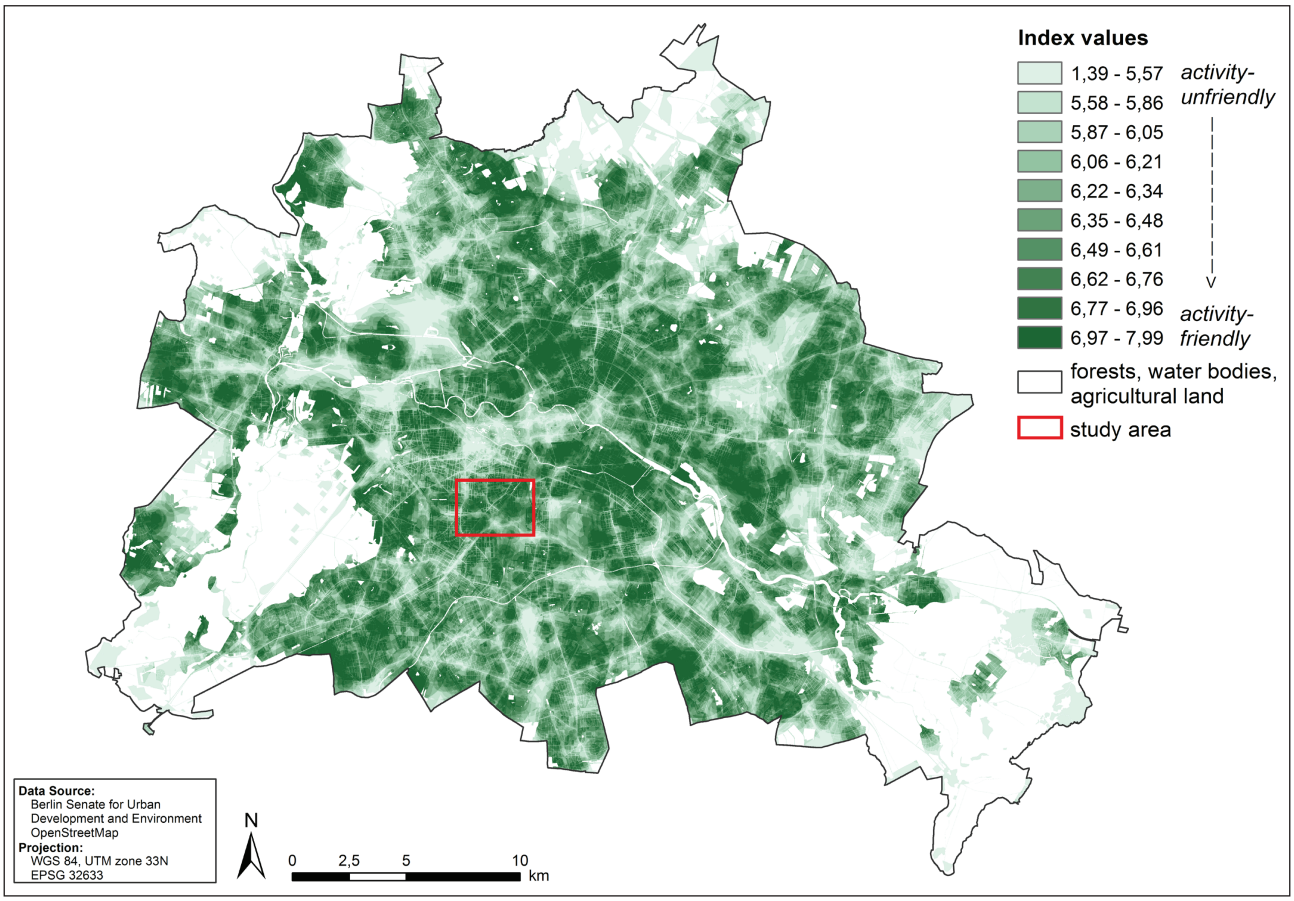

Fig. 3 Activity friendliness of Berlin for children. Source: Own elaboration

4. Discussion

4.1 Key results

Revising the two aims of this paper, we can state that the distance to parks and playgrounds and the access to private gardens or yards were identified as the most prominent environmental factors for assessing the friendliness of urban environments in terms of encouraging children to be active. Besides these factors, a wide range of influential factors were identified in terms of traffic, the social environment and spatial planning. Mainly factors that supported physical activity but also three limiting factors (distance to main streets, density of accidents involving pedestrians, distance to casinos, night clubs and erotic shops) were identified. The factor-based index that was developed enables a spatial assessment of the friendliness of the study area in terms of encouraging children to be active.

4.2 Comparison with previous research

When compared with previous walkability studies, we found that the main factors are confirmed, although some of the factors are contradictory and other factors are additional. Our data suggests that low intersection density has a positive effect on the activity patterns of children, contrary to the classical walkability index (*Frank* et al. 2010). The interviewed parents perceived their children's way to school safer with less crossings accepting short detours. *Gose* et al. (2013) confirm that high connectivity is associated with high traffic volumes and potentially dangerous crossings. Contrarily, high intersection density was assessed as being activity-friendly in previous studies (*Bringolf-Isler* et al. 2014; *Buck* et al. 2015; *Gose* et al. 2013), because many potential destinations can be reached within walking distance with no detours.

Following our study results, mixed land use was considered to be activity-friendly, since distances to destinations such as schools, supermarkets or sports grounds are short. This contradicts the aspect that

less mixed neighborhoods, in particular residential areas with traffic-calmed streets, cul-de-sacs and private gardens or yards, can also support how active children are (*Buck* et al. 2015). But besides the factor of mixed land use in our study, living areas were mapped as activity-friendly because of other factors, such as the proximity to traffic-calmed streets and buildings with yards or gardens.

In our study, parents mentioned that if they thought streets were safe, they would allow their children to act independently in their environment. Perceived road safety in this respect was operationalized through a combination of factors: low intersection density, proximity to traffic-calmed streets, large distance to main streets. This finding corresponds with previous studies from *Buck* et al. (2015) and *Gose* et al. (2013). In particular, crossings perceived as unsafe within the study area were related to a high number of accidents involving pedestrians, therefore accident density was added.

In our interviews children and parents reported previously known places of physical activity, such as parks and playgrounds as already addressed by *Buck* et al. (2015) and *Bringolf-Isler* et al. (2014), but they additionally mentioned sports grounds and private yards and gardens. This supports the assumption of *Veitch* et al. (2006) that most physical activity takes place in private spaces, which parents perceive as enclosed and secure.

In contrast to previous studies by *Gose* et al. (2013) and *Bringolf-Isler* et al. (2014), our study did not operationalize the social environment through the socio-economic status of each planning unit. Neither parents nor children described the socio-economic status within the study areas as a factor that supported or limited activity. Rather, certain factors that had not been considered in previous studies such as cleanliness and facilities that frighten children such as erotic shops were mentioned by parents and children and included in our final index.

Certain factors that were perceived to be important for activity friendliness for children in our interviews could not be included because of unavailable spatial data in this study: secure pedestrian crossings and a low traffic density, which were described by the parents interviewed as relevant factors for pursuing an active means of getting to school, as well as the temporary meeting points of adolescents, homeless people, alcoholics or drug addicts, which were also an important limiting factor because children and parents perceived these places as frightening and tried to avoid them. These factors should be analyzed and considered in further studies.

4.3 Strengths and limitations

The index allows for area-wide and comparable assessments. We provide a transferable method which builds upon individually perceived and objectively measured factors to describe the activity friendliness of urban environments for active transport, free play and the sports of children. The combination of qualitative surveyed factors that support and limit activity and their quantification into an index has not yet been applied in earlier studies. Our index supports and corresponds to the perspective that subjectively perceived and objectively measured environmental factors affect the activity patterns of children (*Bringolf-Isler* 2014; *Hawkins* and *Law* 2006).

Certain limitations remain. The multicollinearity of several factors (e.g. long distance to main roads and short distance to traffic-calmed streets) has not been considered to obtain the diversity of reported activity-friendly factors by children and parents. Our integrated approach, covering the wide range of activity patterns of children, leads to spatial data conflicts, e.g. notable in the compared index values of parks and housing areas. Population density and backyards are spatially measurable only at housing areas, which is why those spaces were overrated. The exclusion of some factors (e.g. traffic density) limits our result, which might be worth considering for future studies (e.g. traffic census at selected crossings). Moreover, factor classification and weighting based on qualitative interviews are determined by the authors, but can of course be adjusted for other case studies. Focusing on a specific target group of nine- to ten-year-old children in only one study area in Berlin represents subjective perceptions and the reported physical activity of a limited number of children and parents. The dependency on the selected study area where the interviews were conducted is a further limitation. Reported factors can be overrated, underrepresented or missing depending on the study area characteristics. Local conditions of our study area in Berlin impacting our index are e.g. the housing structure from the Gründerzeit period with private outdoor spaces (backyards), a relatively high density of erotic

shops at Martin-Luther-Straße, a wide variety of recreational outdoor facilities (e.g. parks, public sportsgrounds). At the same time, the local setting allowed a very detailed and in-depth insight into the supporting and limiting factors of the urban environment. The Berlin-wide assessment shows certain limitations of transferability. Individual factors, such as population density and neighborhood facilities, predominate and factors, such as access to larger green and blue areas, e.g. forests, are clearly underestimated. Therefore, future research should provide comparable survey data for other areas in Berlin and other cities. In the transformation process from qualitative interviews to a quantifiable index, uncertainties arise. Future studies could include an additional validation tracking or measurement of the actual physical activity, e.g. with accelerometers (*Buck* et al. 2015; *Oliver* et al. 2016; *Uys* et al. 2016) to generate additional robust results.

5. Conclusion

This study that assesses activity friendliness for children in urban environments is a promising approach, which combines qualitative with quantitative methods. Qualitative interviews enabled very detailed factors to be considered that support and limit activity, whereas the quantitative index created a general and comparable but still fine-grained evaluation of activity friendliness for children. Interviewing both children and parents helped not only to investigate the children's perspective with partially diffuse wishes and concerns (e.g. fear of the dark), but also included parents as educators and potential decision-makers (e.g. deciding where children are allowed to spend their time).

The calculated CAI illustrates the integrated approach, which focuses on residential environment as well as evaluates the daily mobility and recreational activities of children. Complex physical activity patterns of children, mainly consisting of active transport, moderate to vigorous playing and sports, can be covered with this approach. Not only objectively measurable facilities within the neighborhood, but also perceived characteristics (e.g. safety) and the social perspective have to be obtained in further research approaches. This study has been applied in one area of Berlin and therefore needs individual modifications for transferring it to other parts of the city or other cities. Additional adjustments are required for other study populations (e.g. adolescents). Nevertheless, the index is only applicable to urban areas. Further research in other environments is needed to test for the applicability in other settings.

Our findings provide important information for urban decision-makers from urban planning and development to prevent a growing physical inactivity of children considering the association with neighborhood characteristics. Preventative health programs can benefit from the environmental perspective on factors that support and limit activity as well as their spatial distribution in urban areas.

References

Abley, S. 2005: Walkability. Scoping paper. – Online available at: http://www.levelofservice.com/walkability-research.pdf– accessed 13/06/2017

Amt für Statistik Berlin Brandenburg (AfS) 2014: Einwohnerregister [dataset]. – Online available at: www.statistik-berlin-brandenburg.de – accessed 27/07/2015

Babb, C., M.I. Burke and *P. Tranter* 2011: Developing neighbourhood 'walkability' indices for children's active transport. – World Planning Schools Congress 2011: Planning in an era of uncertainty and transformation, Perth. – Online available at: http://www98.griffith.edu.au/dspace/bitstream/handle/10072/42793/75058_1.pdf?sequence=1– accessed 13/06/2017

Bringolf-Isler, *B*. 2014: Auswirkungen der Walkability auf Kinder und Jugendliche. – In: *Buksch, J.* and *S. Schneider* (eds.): Walkability. Das Handbuch zur Bewegungsförderung in der Kommune. – Bern: 207-216

Bringolf-Isler, *B*., *L. Grize*, *U. Mäder, N. Ruch*, *F.H. Sennhauser* and *C. Braun-Fahrländer* 2010: Built environment, parents' perception, and children's vigorous outdoor play. – Preventive Medicine **50** (5-6): 251-256, – doi: 10.1016/j.ypmed.2010.03.008

Bringolf-Isler, *B*., *S. Kriemler,* U. Mäder, *A. Dössegger, H. Hofmann, J.J. Puder* and *C. Braun-Fahrländer* 2014: Relationship between the objectively-assessed neighborhood area and activity behavior in Swiss youth. – Preventive Medicine Reports **1**: 14-20, – doi: 10.1016/j.pmedr.2014.09.001

Buck, C., H. Pohlabeln, I. Huybrechts, I. De Bourdeaudhuij, Y. Pitsiladis, L. Reisch and *I. Pigeot* 2011: Development and application of a moveability index to quantify possibilities for physical activity in the built environment of children. – Health & Place **17** (6): 1191-1201, – doi: 10.1016/j.healthplace.2011.08.011

Buck, C., T. Tkaczick, Y. Pitsiladis, I. De Bourdehaudhuij, L. Reisch, W. Ahrens and *I. Pigeot* 2015: Objective Measures

of the Built Environment and Physical Activity in Children: From Walkability to Moveability. – Journal of Urban Health **92** (1): 24-38, – doi: 10.1007/s11524-014-9915-2

Cervero, R. and *K. Kockelman* 1997: Travel demand and the 3Ds: Density, diversity, and design. – Transportation Research Part D: Transport and Environment **2** (3): 199-219, – doi: 10.1016/S1361-9209(97)00009-6

Davison, K.K. and *C.T. Lawson* 2006: Do attributes in the physical environment influence children's physical activity? A review of the literature. – The International Journal of Behavioral Nutrition and Physical Activity **3** (19), – doi: 10.1186/1479-5868-3-19

De Bourdeaudhuij, I., M. Verloigne, L. Maes, W. Van Lippevelde, M.J. Chinapaw, S.J. Te Velde, Y. Manios, O. Androutsos, E. Kovacs, A. Dossegger and *J. Brug* 2013: Associations of physical activity and sedentary time with weight and weight status among 10- to 12-year-old boys and girls in Europe: a cluster analysis within the ENERGY project. – Pediatr Obes **8** (5): 367-375, – doi: 10.1111/j.2047-6310.2012.00117.x

Dessing, D., S.I. de Vries, G. Hegeman, E. Verhagen, W. van Mechelen and *F.H. Pierik* 2016: Children's route choice during active transportation to school: difference between shortest and actual route. – International Journal of Behavioral Nutrition and Physical Activity **13** (1): 48-58, – doi: 10.1186/s12966-016-0373-y

Ding, D., J.F. Sallis, J. Kerr, S. Lee and *D.E. Rosenberg* 2011: Neighborhood Environment and Physical Activity Among Youth: A Review. – American Journal of Preventive Medicine **41** (4): 442-455, – doi: 10.1016/j.amepre.2011.06.036

Dobesova, Z. and *T. Krivka* 2012: Walkability Index in the Urban Planning: A Case Study in Olomouc City. – In: *J. Burian* (ed.): Advances in Spatial Planning. – Rijeka: 179-196. – Online available at: https://www.intechopen.com/books/advances-in-spatial-planning/walkability-index-in-the-urban-planning-a-case-study-in-olomouc-city, – doi:10.5772/33747

Frank, L.D., J.F. Sallis, B.E. Saelens, L. Leary, K. Cain, T.L. Conway and *P.M. Hess* 2010: The Development of a Walkability Index. Application to the Neighborhood Quality of Life Study. – British Journal of Sports Medicine **44**: 924-933, – doi: 10.1136/bjsm.2009.058701

Giles-Corti, B., S.F. Kelty, S.R. Zubrick and *K.P. Villanueva* 2009: Encouraging walking for transport and physical activity in children and adolescents: how important is the built environment? – Sports Med **39** (12): 995-1009, – doi: 10.2165/11319620-000000000-00000

Giles-Corti, B., G. Wood, T. Pikora, V. Learnihan, M. Bulsara, K. Van Niel, A. Timperio, G. McCormack and *K. Villanueva* 2011: School site and the potential to walk to school: the impact of street connectivity and traffic exposure in school neighborhoods. – Health & Place **17** (2): 545-550, – doi: 10.1016/j.healthplace.2010.12.011

Gose, M., S. Plachta-Danielzik, B. Willié, M. Johannsen, B. Landsberg and *M.J. Müller* 2013: Longitudinal Influences of Neighbourhood Built and Social Environment on Children's Weight Status. – International Journal of Environmental Research and Public Health **10** (10): 5083-5096, – doi: 10.3390/ijerph10105083

Graf, C., B. Koch, S. Dordel and *R. Jaeschke* 2009: Die aid-Bewegungspyramide für Kinder. – Rheinbach

Hawkins, S.S. and *C. Law* 2006: A review of risk factors for overweight in preschool children: A policy perspective. – International Journal of Pediatric Obesity **1** (4): 195-209, – doi: 10.1080/17477160600943351

Holt, N.L., J.C. Spence, Z.L. Sehn and *N. Cutumisu* 2008: Neighborhood and developmental differences in children's perceptions of opportunities for play and physical activity. – Health & Place **14** (1): 2-14, – doi: 10.1016/j.healthplace.2007.03.002

Lakes, T., M. Brückner and *A. Krämer* 2014: Development of an environmental justice index to determine socio-economic disparities of noise pollution and green space in residential areas in Berlin. – Journal of Environmental Planning and Management **57** (4): 538-556, – doi: 10.1080/09640568.2012.755461

Mackett, R., D. Banister, M. Batty, D. Einon, B. Brown, Y. Gong, K. Kitazawa, S. Marshall and *J. Paskins* 2007: Final report on 'Children's Activities, Perceptions And Behaviour in the Local Environment (CAPABLE)'. – London

Oliver, M., J. McPhee, P. Carroll, E. Ikeda, S. Mavoa, L. Mackay, R.A. Kearns, M. Kytta, L. Asiasiga, N. Garrett, J. Lin, R. Mackett, C. Zinn, H. Moewaka Barnes, V. Egli, K. Prendergast and *K. Witten* 2016: Neighbourhoods for Active Kids: study protocol for a cross-sectional examination of neighbourhood features and children's physical activity, active travel, independent mobility and body size. – BMJ Open **6**, – doi: 10.1136/bmjopen-2016-013377

OpenStreetMap (OSM) 2015: [dataset] – Online available at: www.openstreetmap.de – accessed 27/07/2015

Polizei Berlin 2015: Sonderuntersuchung 'Fußgängerverkehrsunfälle' in Berlin. – Berlin

Rahman, T., R.A. Cushing and *R.J. Jackson* 2011: Contributions of built environment to childhood obesity. – Mt Sinai J Med **78** (1): 49-57, – doi: 10.1002/msj.20235

Rattan, A., A. Campese and *C. Eden* 2012: Modeling walkability. Automating analysis so it is easily repeated. –Arcuser Winter 2012, 30-33. – Online available at: http://www.esri.com/news/arcuser/0112/files/walkability.pdf – accessed 13/06/2017

Reyer, M., S. Fina, S. Siedentop and *W. Schlicht* 2014: Walkability is Only Part of the Story: Walking for Transportation in Stuttgart, Germany. – International Journal of

Environmental Research and Public Health **11** (6): 5849-5865, – doi: 10.3390/ijerph110605849

Robert Koch-Institut 2014: Die Gesundheit von Kindern und Jugendlichen in Deutschland 2013. – Berlin

Sallis, J.F., R.B. Cervero, W. Ascher, K.A. Henderson, M.K. Kraft and *J. Kerr* 2006: An ecological approach to creating active living communities. – Annual Review of Public Health **27** (1): 297-322, – doi: 10.1146/annurev.publhealth.27.021405.102100

Senatsverwaltung für Stadtentwicklung und Umwelt Berlin (SenStadtUm) 2013: Monitoring Soziale Stadtentwicklung Berlin 2013. – Berlin

Senatsverwaltung für Stadtentwicklung und Umwelt Berlin (SenStadtUm) 2015: Geodienste – Downloaddienst (WFS) [dataset]. – Online available at: http://www.stadtentwicklung.berlin.de/geoinformation/geodateninfrastruktur/de/geodienste/wfs.shtml – accessed 27/07/2015

Senatsverwaltung für Wirtschaft, Technologie und Forschung Berlin (SenWTF) 2015: Berlin Open Data [dataset]. – Online available at: www.daten.berlin.de – accessed 27/07/2015

Spence, J.C., N. Cutumisu, J. Edwards and *J. Evans* 2008: Influence of neighbourhood design and access to facilities on overweight among preschool children. – International Journal of Pediatric Obesity **3** (2): 109-116, – doi: 10.1080/17477160701875007

Timperio, A., D. Crawford, A. Telford and *J. Salmon* 2004: Perceptions about the local neighborhood and walking and cycling among children. – Preventive Medicine **38** (1): 39-47, – doi: 10.1016/j.ypmed.2003.09.026

Uys, M., S.T. Broyles, C.E. Draper, S. Hendricks, D. Rae, N. Naidoo, P.T. Katzmarzyk and *E.V. Lambert* 2016: Perceived and objective neighborhood support for outside of school physical activity in South African children. – BMC Public Health **16** (1): 462-470, – doi: 10.1186/s12889-016-2860-0

Veitch, J., S. Bagley, K. Ball and *J. Salmon* 2006: Where do children usually play? A qualitative study of parents' perceptions of influences on children's active free-play. – Health & Place **12** (4): 383-393, – doi: 10.1016/j.healthplace.2005.02.009

Wheeler, B.W., A.R. Cooper, A.S. Page and *R. Jago* 2010: Greenspace and children's physical activity: A GPS/GIS analysis of the PEACH project. – Preventive Medicine **51** (2): 148-152, – doi: 10.1016/j.ypmed.2010.06.001

Whitzman, C., V. Romero, M.J. Duncan, C. Curtis, T. Paul and *M.I. Burke* 2007: Links Between Children's Independent Mobility, Active Transport, Physical Activity and Obesity. – In: *Waters, E., B. Swinburn, J. Seidell* and *R. Uauy* (eds.): Preventing Childhood Obesity. Evidence, Policy, and Practice. – Oxford, UK: 105-112