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Measures of walkability in the pediatric population: a qualitative review of the literature

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Parole chiave: Walkability, salute urbana, revisione, misurazioni, popolazione pediatrica

Abstract

Context. *Sedentary lifestyle is spreading among children living in urban settings. Recent studies in urban health investigated the effects of built environment on children's physical activity, focusing on the concept of "walkability", an index of how much an area is conducive to walking and active transportation. We decided to browse the literature in order to review all possible tools and methods by which walkability has been evaluated and measured.*

Methods. *We conducted a qualitative review of the literature in agreement with PRISMA guidelines, searching three medical databases for papers published between January 1994 and July 2017. Inclusion criteria were: primary studies, population ≤18 years and exposure variable as an assessment of walkability or built environment.*

Results. *We retrieved 1,702 articles and included 195 of them in the final review. Most of the studies were cross-sectional (n=188, 96.4%). We identified two possible approaches and four main tools to address walkability measurement. A subjective method approach was used in 71 studies (36.4%), an objective method in 87 (44.6%). Only 37 studies (19.0%) used both. Main tools were survey (n=70, 35.9%), Geographic Information System (GIS) (n=64, 32.8%), street audits (n=11, 5.6%) and Walk-score™ (n=3, 1.5%). Forty-six studies (23.4%) used mixed methods. Environmental variables' assessment and definition was found to vary greatly by method of choice*

Conclusions. *We found a high degree of heterogeneity regarding methods and measurements of walkability. A standard approach regarding tools and environmental variables' choice and definition will be advisable in order to allow comparisons among studies. Also, more longitudinal studies are needed.*

Introduction

Physical inactivity among children and adolescents is considered a major public health problem, being an important determinant of chronic disease. A sedentary lifestyle can significantly increase the risk of developing serious medical conditions, such as type 2 diabetes, cardiovascular disease, obesity and cancer (1). World Health Organization's (WHO) guidelines recommend at least 60 minutes of daily moderate to vigorous physical activity (PA) (2), however it is estimated that 80% of the adolescents aged 11-17 years in 105 countries of the world do not achieve the target of recommended PA (3). This proportion varies according to sex, with girls being less active than boys (84% vs 78% not meeting the target) in all WHO regions. The prevalence of physical inactivity is higher in upper-middle income countries and lower in lower-middle income countries

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(4). This deficiency in the PA domain is not just attributable to a lack of exercise or sport activities: WHO warns that PA is not the same as sports, but it includes any bodily movement that uses energy, so comprising also playing, walking, biking, dancing and many other activities (5). The reason for such a level of inactivity should therefore be linked to the spread of a sedentary lifestyle throughout all daily activities, which has determined a decreasing trend in children's PA levels in the last decades (6). Active transport in particular has seriously declined among the youth. In the U.S. the percentage of children actively commuting to school decreased from 48% in 1969 to 13% in 2009 (7), despite the available evidence showing the benefits of active transport on health outcomes (8-11).

Several factors are implicated in influencing active transport and global PA levels in a community, including individual factors, social factors and environmental factors (12). The relevance of environmental factors, particularly those related to the built environment, is growing since the number of persons living in urban settings is rapidly increasing. In 2015, 54% of the world's population lived in urban areas and this proportion is expected to rise to 70% by 2050 (13, 14). Urbanization is thought to reshape global health issues, with a shift towards non-communicable diseases and accidental injuries, mainly due to lifestyle changes, air quality and pollution, working and living conditions (15, 16). Children and adolescents are even more prone than adults to the effects of built environment, since they have less autonomy and independent mobility and are less likely to be able to leave the home-neighborhood boundaries (17-20).

WHO suggests that developing urban environments supportive of PA and active transport would be a key strategy to face global sedentary habits (4, 21). In order to obtain that, however, specific environmental factors influencing PA levels must be identified and then effectively defined and measured. Recent studies in urban health did focus on the concept of "walkability". This term has been used to define the degree to which an area's built environment is conducive to walking and active transportation. Evidence shows a correlation between high walkable areas and higher levels of active transportation among resident children (22). Evidence available is only from cross-sectional studies, while longitudinal studies are still scarce, so limiting the possibility to draw causal and timing inference. Different tools and methods can be used to assess the built environment and some authors have identified the lack of standard definitions and measures as one major flaw on this topic. The consistency of association between the built environment and PA was found to vary mostly according to the method of choice (23). Moreover, since many environmental factors are potentially able to influence walking and active transport, it is not clear which walkability variables should be considered for the assessment. Lack of standards and shared methods makes a synthesis of findings from different sources unlikely. Finally, it is important to consider that standards should not be universal, but subgroup-specific, since individual populations can have specific needs based on their socio-economic and demographic characteristics (24).

The aim of this study is to systematically review the scientific literature, in order to browse and describe all possible methods and tools that have been used to measure walkability in a pediatric population, as well as the environmental variables assessed.

Methods

A qualitative review of the scientific literature was performed to retrieve all published studies assessing walkability and targeting the pediatric population. The study protocol was designed in accordance with

PRISMA guidelines (25) and registered on FigShare (26). The following databases were searched: Medline, Embase and Cochrane Library. Hand-searching and snowballing (27) searching were also performed. The following search-strings were used to perform the PubMed search: "*(walkability OR walkable OR "built environment") AND (child OR children OR childhood OR boy OR boys OR girl OR girls OR pupil* OR young* OR youth OR adolescent* OR boyhood)*". Similar strings were constructed to browse Embase and Cochrane Library databases. Inclusion criteria were: primary studies written in English or Italian languages, study population ≤18 years and exposure variable as a multidimensional measurement of walkability or built environment.

Exclusion criteria were: secondary literature (systematic or narrative reviews, guidelines and protocols) and studies written in languages other than Italian or English. In addition, since we considered walkability as a multidimensional concept, we excluded all studies which only measured the built environment according to a single dimension (for example studies only focusing on greenspaces). The search was conducted for papers published from January 1994 to July 2017.

Potentially eligible studies were independently identified from abstracts and titles by two reviewers (AU, GR); full-texts of relevant studies were assessed for inclusion and their reference lists were searched for additional studies. Any disagreement was primarily resolved through discussion. If consensus was not reached, an opinion of a third author (DG) was requested.

Data extraction for each study was also performed independently by two reviewers (AU, GR) and checked by a third one (DG). Information on country, study design, study population, independent variables, outcomes and tools used for the assessment of the built environment was recorded. Collected data were analyzed and presented through descriptive statistics using Microsoft EXCEL 2013 and Stata Statistical Software, Release 13.

Environmental variables

Environmental variables assessed for each study were identified and then grouped in nine categories. The categories were defined in accordance with the *walkability framework* proposed by Zuniga-Teran (28). They represent nine interrelated and interdependent neighborhood design categories, including: connectivity, land-use, density, traffic safety, surveillance, parking, experience, community and greenspaces. The interrelation among categories means that each design element can potentially fit in more than one category. Each category, in turn, can encompass multiple variables related to the same field. A brief description of each category follows.

Connectivity reflects the directness of possible walking routes. It can be measured through the density of street intersections in an area, with higher intersection density meaning higher connectivity. It also includes other design elements such as the availability of an adequate transit system and the absence of barriers (gated communities, *cul-de-sacs*, rivers, fences, freeways, railway lines, etc). *Land-use* refers to the proximity to different land uses (residential, commercial, industrial) in the same area. It is usually considered with respect to the distance and access to services as destinations of walking. Bus stops and transit stations are also considered destinations that encourage walking, since they provide the opportunity to reach other neighborhoods without using the car. *Density* refers both to residential density and retail density. *Traffic safety* refers to the availability of infrastructures needed to make walking safe from traffic risks (sidewalks, traffic lights, crosswalks, bike-lanes, traffic calming treatments, etc). *Surveillance* is the street-evident viewing capacity within buildings. This is thought to be a crime deterrent, since people tend to feel safer when what happens in the street is easily visible from surrounding buildings. Design elements for this category include: windows at pedestrian level, building entries at short distances, balconies oriented towards the street, appropriate street lighting, etc. *Parking* refers to the availability, size and location of parking lots in an area. More parking lots facilitate car use, decrease walkability, and *vice versa*. *Experience* include all design elements which may affect how people feel while walking, regarding streetscape, esthetics, thermal comfort, way-finding, slope, noise and stray animals. *Greenspaces* pertain to proximity and access to urban green areas such as parks, courtyards and similar. *Community* includes all design elements that encourage activities that may lead to social interactions and increase the sense of community.

Environmental variables for each study were attributed to one or more categories, independently from the tool or the definition used to measure them. The choice of attribution was made autonomously by the two reviewers (AU, GR), with the judgment of a third one (DG) in case of discordance.

Results

A total of 1,702 potentially relevant papers were retrieved (Fig. 1), 1,116 from Medline, 2 from Cochrane Library, 500 from Embase, 84 from hand-search. 1,298 were excluded after removing duplicates and screening for title and abstract, 209 were excluded after full-text reading for not meeting the inclusion criteria. 195 articles were therefore included in the final review (references in the Appendix).

Most of the studies were cross-sectional (n=188, 96.4%) and just a few had a cohort design (n=7, 3.6%). The study settings were: USA (n=94, 48.2%), European countries (n=50, 25.6%), Australia (n=23, 11.8%), Canada (n=20, 10.3%), Asian countries (n=5, 2.6%) and other countries (n=3, 1.5%). Sample sizes ranged from 52 to 94,997 (mean=2,891.2). Age ranged from 0 to 18 years. Most of the studies were focused on school children aged 6-12 years (n=160, 82.1%) rather than adolescents aged 13-18 years (n=116, 59.5%) or pre-school children aged 0-5 years (n=35, 17.9%). 103 (52.8%) studies targeted more than one age range.

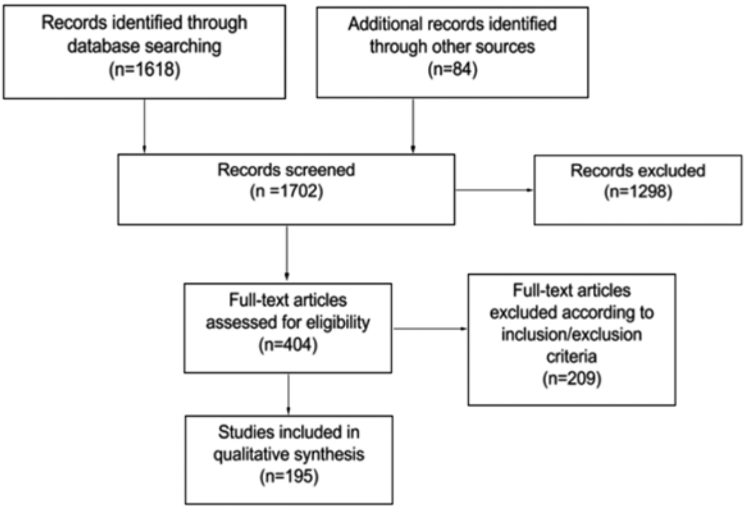

Figure 1 - Flow diagram for article identification and selection process

Table 1 - Included studies by type of measurement and tool.

Type of measurement	GIS	Survey	Audit	Walk-Score	Map drawing	Mixed methods	Total
Objective	64	0	11	3	0	9	87
Subjective	0	70	0	0	1	0	71
Both	0	0	0	0	0	37	37
Total	64	70	11	3	1	46	195

The measured outcomes were grouped in 5 categories: PA (n=130, 66.7%), including both self-reported and objectively measured PA, independently from the purpose for doing it (leisure time, active transport, etc.); mode of transport to school or to other destinations (n=38, 19.5%); Body Mass Index (BMI) and derivative measures (n=37, 19.0%); diet and eating behaviors (n=6, 3.1%); other (n=13, 6.7%). The "other" category included different clinical outcomes such as metabolic syndrome, insulin resistance index (HOMA-IR), lung function, cardiovascular fitness and time spent outdoor.

Tools for the assessment of the built environment were classified as subjective or objective. Subjective tools included survey and map drawing, accounting for 71 studies (36.4%). Objective methods included Geographic Information Systems (GIS), street audits and Walk-score™ (29). Studies applying these methods were 87 (44.6%). Subjective and objective methods could be combined and used together in the same study, as happened in 37 (19.0%) studies.

Survey was the most used method (n=70, 35.9%), followed by GIS (n=64, 32.8%), street audits (n=11, 5.6%), Walk-score™ (n=3, 1.5%) and map-drawing (n=1, 0.5%).

46 studies (23.6%) used mixed-methods, combining two or more of the previously discussed methods (Table 1).

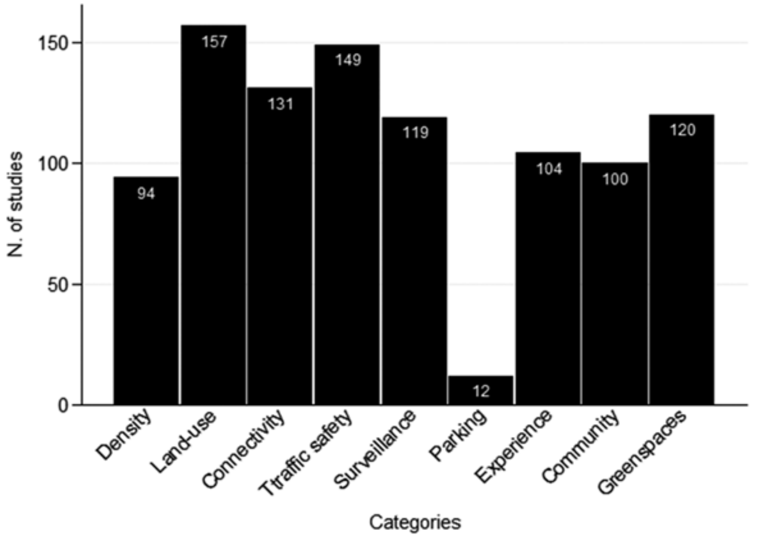

Figure 2 - Frequencies of environmental variables categories

Environmental variables' assessment was not homogeneous among the studies. Figure 2 shows the frequency distribution of the nine previously defined categories across the studies.

The most frequently used categories were: *land-use* (n=157, 80.5%) and *traffic safety* (n=149, 76.4%). *Parking* was the less frequently used (n=12, 6.2%). Since studies assessing only one category were excluded, each study could overall assess from two to nine categories. The mean number of categories for each study was 5.1 ± 2.1. A total of 5 (2.6%) studies included all nine categories, while 22 (11.3%) included only 2 of them. Table 2 shows how the mean number of categories included varied in accordance with the type of measurement or the tool used. Studies that only relied on objective methods tended to include less categories than studies using subjective or mixed methods. Street audit was the tool associated with the highest number of categories.

We also investigated how the inclusion of each category could vary according to the tool of measurement chosen. Table 3 shows the frequency distribution of categories across different tools. *Density*, *land-use* and *connectivity* were more frequently assessed using GIS. *Traffic safety* and *surveillance* were more frequently measured using surveys. *Parking*, *experience*, *greenspaces* and *community* were assessed with higher frequencies through street audit.

Table 2 - Mean number of categories included by tools and type of measurement.

	n. of categories (mean ± SD)
Type of measurement	
Objective	4.5 ± 2.1
Subjective	5.4 ± 2.0
Both	5.6 ± 1.9
Tool	
GIS	4.0 ± 1.6
Survey	5.4 ± 2.0
Audit	6.4 ± 2.2
Walk-score	2
Map drawing	5
Mixed methods	5.8 ± 2.1

Discussion

Our findings suggest that measuring and quantifying walkability are not standardized and clear processes. We found a high degree of heterogeneity in the applied methods. The first methodological discrepancy could be found in the choice between subjective and objective methods. Subjective methods (like surveys and interviews) do not directly assess the built environment but tend to focus on residents' perceptions about the built environment surrounding them. Objective methods, instead, focus on quantitative measures of built environment, which can be realized directly or indirectly. Objective

Table 3 - Frequency distribution of categories' assessment by tool of choice.

	GIS (n=64)	Survey (n=70)	Audit (n=11)	Mixed methods (n=46)
Density	45 (70.3%)	23 (32.9%)	5 (45.4%)	21 (45.6%)
Land use	55 (85.9%)	51 (72.9%)	9 (81.8%)	38 (82.6%)
Connectivity	55 (85.9%)	31 (44.3%)	9 (81.8%)	32 (69.6%)
Traffic safety	28 (43.7%)	69 (98.6%)	10 (90.9%)	42 (91.3%)
Surveillance	13 (20.3%)	66 (94.3%)	4 (36.4%)	36 (78.3%)
Parking	0 (0.0%)	2 (2.9%)	6 (54.5%)	4 (8.7%)
Experience	10 (15.6%)	51 (72.9%)	10 (90.9%)	32 (69.6%)
Community	15 (23.4%)	47 (67.1%)	8 (72.7%)	29 (63.0%)
Greenspaces	38 (59.4%)	39 (55.7%)	9 (81.8%)	33 (71.7%)

and subjective may seem two alternative approaches that allow the evaluation of the same entities, but they indeed are not. In fact, studies applying different approaches tend to include qualitatively and quantitatively different categories of environmental variables, making these approaches more complementary than alternative. Even when assessing the same variables, literature warns that concordance between subjective and objective measures can be variable (30). Perceptions are not simply proxies for objective measures, and the two can be differently associated with PA. This distinction is important to rigorously collect data. Both approaches should be used in the same study in order to have a more complete information and to reduce the impact of measurement mode. On the other side, literature suggests that urban health intervention, aimed at improving lifestyles, can be addressed both to change the built environment or to change perceptions (31, 32). Whatever the side on which intervention is targeted, both perceptions and reality have to be known and any potential discrepancy between them needs to be monitored (33). Deep knowledge of objective environment and residents' perceptions can also be useful in order to plan specific interventions for subpopulations qualified either by their neighborhood's characteristics or their beliefs about them (30, 34). Despite the remarkable potentialities of using a mixed methods approach, this only turns out to happen in less than one fifth of the cases in our sample of papers.

A second, and deeper discrepancy, addresses the tool used for the measurement of environmental variables. We identified four major instruments: GIS, survey, street audit and Walk-score™. Over 75% of the studies used only one tool to assess the built environment, while about 25% combined two or more methods. Different tools measured different variables or the same variable in different ways. In our study sample, the average number of categories included in each study varied in accordance with the tool used. Street audit was the tool that, on average, allowed to include more categories. The categories were not evenly distributed across the studies applying different tools, as if each tool was more suitable to evaluate some categories and less suitable for others. For example, we observed that density or land-use were more easily assessed using GIS whilst traffic safety and surveillance were more frequently assessed through surveys.

All the instruments we identified had specific defining characteristics in each study. In this way, each tool also represented a source of heterogeneity by itself, given the existence of many possible variants, the only exception being Walk-score™ with its fixed algorithm.

Brownson et al (35) described the characteristics of a large number of surveys available for the measurement of the perceived built environment. Accordingly, we also identified many kinds of surveys, the most commonly used being the Neighborhood Environment Walkability Scale (NEWS) (36). Surveys could vary for a number of questions, variables assessed and administration mode and this is known to influence psychometric and measurement properties (35). Direct comparison among studies using different types of surveys are made difficult because of this.

Audits are tools that allow systematic, direct and in-person observation of the built environment. Through audits, presence or absence of specific design elements are recorded in a standardized form. As it was the case for surveys, also many kinds of audits were found to be used in our sample and they could vary significantly depending on how many features were evaluated and in which degree of detail. Potentially audits were able to provide more information than other methods and were particularly fit to evaluate categories that could only be assessed by direct observation. However audit also represents the most time-consuming approach among the ones identified and that is probably the reason it was used in a minority of studies.

GIS is a method that measures the built environment deriving from pre-existing data sources with some spatial reference. GIS is less time consuming than audits and is useful to collect information from neighborhoods in a large dispersed area (37). On the other hand, not all kinds of data are recorded and available for GIS analysis. This probably explains why, in our sample, GIS was more frequently used than audit but it included, on average, less categories. GIS-based measures also are very dependent on the specific definition used to describe the variables assessed. A large degree of variability was found due to operationalization of measures, and this causes GIS-based studies to be particularly difficult to compare (35). Validity and reliability of GIS-based measures are strongly influenced by the accuracy and completeness of data sources and by the geographic scale at which measures are aggregated (38-41). Moreover the use of GIS requires adequately trained staff in order to match the planned variables with the available data (38).

Finally, Walk-score™ is a relatively recent web-based measurement tool, freely accessible and easy to use. The walkability score, ranging from 0 to 100, is calculated automatically using an algorithm that takes into account two main elements: proximity of amenities and street connectivity. Walk-score™ has been increasingly used in recent years, mainly because of its favorable characteristics and public availability. Walk-score™ was validated and related to other objective measures of walkability (42-44) as well as to walking behaviours (45, 46). Some authors, however, have also highlighted some limitations of Walk-score™ mainly due to not considering some important elements as traffic, esthetics, road conditions and subjective perceptions of residents (47, 48). Moreover Walk-score™ was found to be positively correlated with neighborhood-level crime (48). Our study confirmed that Walk-score™ was the tool that included fewer categories. Also, it was only used in 4 of the studies included in our review, suggesting that even if Walk-score™ has been largely used in studies regarding adults, more studies are expected in the pediatric field.

Other tools, besides those presented in this review, are available for the measurement of walkability, although they were not tested in relation to children health (49, 50). Children are known to have different attitudes than adults towards walking, given their partial lack of autonomy and independent mobility and their own subjective perceptions about their home-neighborhood environment. While new tools keep being developed, flexibility could be a particularly desirable feature, in order to allow the inclusion/exclusion or the relative weighting of different variables, in accordance with the specific needs and characteristics of the pediatric population.

As tools and measure need refinement in order to advance walkability research, also the study design represents a major issue of concern. Most of the available literature is of cross-sectional nature. Longitudinal research will strongly contribute to future improvements.

Limitations of the study

The main limitation of our study was that only medical literature was browsed for review. Urban health, though, is a field of study growing at the intersection of different disciplines such as public health, architecture and city planning. A more integrated approach would be advisable for future research. We exposed some important sources of heterogeneity in the scope of walkability assessment but many others are still to be studied in deep. Areas that still need more evaluation are the geographical scale applied, the operationalization of variables' definitions and a more detailed partition of specific subgroups.

Conclusions

Walkability is a very complex construct and needs a wide range of variables to be fully described. Different approaches have been used to measure walkability in relation to different aspects of pediatric health. The dichotomy between subjective and objective methods cannot probably be solved, rather a bimodal approach is strongly recommended. Many tools are available, each one with its *pros* and *cons*. Choice of the specific tool should be based on the characteristics of the local setting and on the knowledge of which dimensions could be more relevant for children. A standardized approach will be strongly advisable in future studies, to achieve comparable results and advance research on this topic. It is of paramount importance to reach a shared consensus between researchers on which variables are to be included in the analysis and how to reach shared definitions. Variables' definitions should be tool-specific and also population-specific, coherent with children's socio-demographic, perceptual and clinical characteristics. Future research should also move towards longitudinal study design.

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AU, AR and MPF conceived and designed the study. AR, GR carried out the review, acquired, analyzed, and interpreted the data. AU checked data extractions. AR and DG drafted the manuscript, which was critically revised for important intellectual content by all authors. AU and DG carried out the statistical analysis. DG supervised the study. All authors have read and approved the final manuscript. AU is guarantor and had full access to all the data and takes responsibility for the integrity of the data and the accuracy of the data analysis.

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Riassunto

Metodi di misurazione della walkability per la popolazione pediatrica: una revisione qualitativa della letteratura

Contesto. La sedentarietà sta aumentando tra i giovani che vivono negli spazi urbani. Recenti studi sull'urban health hanno indagato gli effetti di un ambiente urbano sull'attività fisica dei ragazzi, focalizzandosi sul concetto di "*walkability*", un indicatore di come una determinata area può essere utilizzata per camminare e per il trasporto attivo. Abbiamo quindi condotto una ricerca della letteratura con lo scopo di cercare gli strumenti e i metodi tramite i quali viene misurata la *walkability*.

Metodi. Abbiamo condotto una revisione qualitativa della letteratura, in accordo con le linee guida PRISMA, su tre database sanitari, includendo studi pubblicati tra Gennaio 1994 e Luglio 2017. I criteri di inclusione erano: studi primari, popolazione con età ≤18 anni e un'esposizione suscettibile di valutazione della *walkability* o dell'ambiente costruito.

Risultati. Su 1702 articoli consultati ne abbiamo inclusi 195 nella revisione finale. La maggior parte degli studi erano cross-sectional (n=188 96,4%). Abbiamo individuato due metodiche e quattro strumenti principali per la misurazione della *walkability*. Un approccio metodologico di natura soggettiva è stato utilizzato in 71 studi (36,4%), un metodo oggettivo in 87 (44,6%). Solo 37 studi (19%) li hanno utilizzati entrambi. Gli strumenti erano per lo più questionari (n=70 35,9%), Sistema Informativo Geografico (GSI) (n=64 32,8%), audit stradale (n=11 5.6%) e Walk-score™ (n=3 1,5%). 46 studi (23,4%) utilizzavano metodi misti. La valutazione e la definizione delle variabili ambientali variavano in maniera importante in base alla metodica utilizzata.

Conclusioni. Abbiamo trovato un alto grado di eterogeneità circa i metodi di misurazione della *walkability*. Un approccio standard circa la definizione delle variabili ambientali e della scelta degli stumenti metodologici sarà quindi richiesto al fine di poter eseguire una comparazione tra i vari studi. Inoltre sono necessari più studi di natura longitudinale.

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APPENDIX

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