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Zhang, Yufang; Koene, Marijke; Chen, Chen; Wagenaar, Cor; Reijneveld, Sijmen A

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## Review Article

# Associations between the built environment and physical activity in children, adults and older people: A narrative review of reviews

Yufang Zhang<sup>a,b</sup>, Marijke Koene<sup>b</sup>, Chen Chen<sup>c,d,\*</sup>, Cor Wagenaar<sup>b</sup>, Sijmen A. Reijneveld<sup>e</sup>

<sup>a</sup> Management College, Ocean University of China, Qingdao, China

<sup>b</sup> Expertise Center Architecture, Urbanism and Health, Faculty of Arts, University of Groningen, Groningen, the Netherlands

<sup>c</sup> School of International Affairs and Public Administration, Ocean University of China, Qingdao, China

<sup>d</sup> Department of Cultural Geography, Faculty of Spatial Sciences, University of Groningen, Groningen, the Netherlands

<sup>e</sup> Department of Health Sciences, University Medical Center Groningen, University of Groningen, Groningen, the Netherlands

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## ABSTRACT

**Background:** Physical activity is essential for promoting public health, and it is affected by the built environment at population level. Extensive evidence exists on the associations between the built environment and physical activity, but results are inconclusive for different age groups. Therefore, we conducted a narrative review summarizing existing reviews on the associations between the built environment and physical activity for children, adults and older people and synthesized their findings.

**Methods:** We followed the PRISMA 2020 review procedure and searched for systematic reviews published between January 2010 and April 2022 in seven databases (Scopus, Web of Science, Medline, PsycINFO, EMBASE, Socindex and Cochrane Library) using keywords related to the built environment, urban interventions, physical activity and health.

**Results:** The selection process yielded 29 reviews with moderate to high quality. From these reviews, we identified 21 built environment characteristics, several of which were positively related to physical activity. For example, children and older people's physical activity was positively associated with pedestrian-friendly features and general safety. Furthermore, adults and older people's physical activity was positively related to the availability and accessibility of shops/commercial services and parks/open spaces. Lastly, the walkability index was positively associated with physical activity in every age group.

**Conclusion:** Our findings provide valuable information on creating health-promoting urban environments for practitioners. Further research is needed to understand which characteristics make urban environments age friendly for physical activity. Special attention should be paid to less explored promising characteristics such as street lighting and the quality of green spaces.

## 1. Introduction

Physical inactivity is a well-recognized global health challenge, especially in cities (WHO, 2018). Physical inactivity should be prevented, as it is a driving factor for many non-communicable diseases (NCDs), such as diabetes. As such, it is important to understand how the urban environment, also known as the human-made built environment (BE), impacts citizens' physical activity (PA). For example, the 'Healthy Cities' project was initiated by the World Health Organization (WHO) in the 1980s, to promote healthier lifestyles and better health in cities (Mckeown, 1979; WHO, 1994). A major target of this project was to

improve people's PA levels.

In the last two decades, efforts have been made to identify the associations between the urban BE and PA. Several BE characteristics have been explored for their relationship with PA, such as density, diversity, design - these three factors are also known as '3D' (Cervero and Kockelman, 1997), safety (Fonseca et al., 2021), aesthetics (Saelens et al., 2003), and integrated indexes that combine several of these characteristics, such as the walkability index (Clary et al., 2020; Frank et al., 2010). While walking has received much attention as a specific type of PA (Saelens and Handy, 2008), other studies have also investigated combined walking and cycling, or other PA varieties (An et al., 2019;

*Abbreviations:* BE, built environment; PA, physical activity.

\* Corresponding author at: Songling Road 238, Laoshan District, Qingdao, Shandong Province 266000, China.

*E-mail address:* [chendishou@163.com](mailto:chendishou@163.com) (C. Chen).

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Clary et al., 2020). Regarding motivations, studies also assessed PA for recreational and transport purposes separately.

Despite many promising findings on this topic, studies and reviews yield inconclusive results. To some extent this could be explained by the fact that one's behaviors are determined by a host of factors such as the local community, the BE, and the natural environment, as illustrated in the social-ecological model (Barton and Grant, 2006). Another variable that could potentially explain these inconclusive results could be that the BE affects each age-group differently. For instance, a study that allowed to differentiate by age (Ghani et al., 2018) showed that older adults were more sensitive to their neighborhood environment and had less transport-related walking than younger adults.

A suitable and necessary first step to learn more about the potential moderating effect of age is to conduct a review of existing systematic reviews (or an umbrella review; Aromataris et al., 2015). This can help to create a Health-for-All environment, as per WHO (1999). A previous umbrella review on the associations between the urban interventions and physical activity (Zhang et al., 2022a) has shown this method of synthesizing the literature to be suitable for such overarching questions. However, that previous review reported on the impact of specific urban interventions, i.e. with a pre and post-intervention evaluation, rather than on the impacts of general BE characteristics. Moreover, the previous umbrella review did not report results differentiated by age.

To this end, we conducted this narrative review (of reviews) to summarize existing reviews on the associations between the urban BE and PA. Specifically, our aim was to create an up-to-date overview of existing knowledge on 1) what BE characteristics have been studied in association with PA and 2) if these associations differ by distinct age groups (children, adults, and older people). In this study, children and adolescents are aged 17 years and younger (An et al., 2019), occasionally including adolescents aged 18 years (Ding et al., 2011). People aged 18 and older are considered adults (McCormack and Shiell, 2011; Hajna et al., 2015), and people aged  $\geq 65$  years are considered older people (van Cauwenberg et al., 2018).

## 2. Method

### 2.1. Search strategy

The current review followed the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Page et al., 2021). We conducted a search in seven databases, namely Scopus, Web of Science (Core Collection), MEDLINE, PsychINFO, EMBASE, SocIndex, and Cochrane Library, searching for systematic reviews using keywords in the categories built environment, urban intervention, PA and health (see Appendix 1 for our search strategy). We included keywords relating to urban intervention to acknowledge the role of urban design in the field. We restricted the search to reviews that were published between January 2010 and April 2022. In addition to including studies yielded by our systematic search, we also manually searched the reference lists of identified studies for additional review papers.

### 2.2. Selection of reviews

After conducting the search and removing the duplicated studies, two reviewers (YZ and MK) separately screened the titles and abstracts for inclusion in our review. Following this, the full-texts were reviewed independently by the two reviewers for eligibility. When disagreements occurred, the two reviewers first initiated a discussion, and subsequently involved a third party (SR) to reach agreements on the screening results. A review paper was included if it met all the inclusion criteria. Based on the aim of this review, the inclusion criteria are as follows:

- (1) The article is a systematic review/meta-analysis.
- (2) It measures one or multiple aspects of the BE.

- (3) The focus of the outcomes is on PA, including walking behaviors and active travel.
- (4) The setting is urban areas, including natural urban environments such as parks (here, urban settings are defined as geographical spaces characterized by continuous built settlements; Mela, 2014).
- (5) The goal of the review is to find a relationship between the urban BE and PA.

No restrictions were set regarding the language and the types of primary studies included in the reviews.

### 2.3. Data extraction and quality assessment

Research data were extracted by two reviewers (YZ conducted the extraction, while CC further checked) from the reviews that met all the inclusion criteria. A data extraction tool was used for the extraction of author, year of publication, number of included primary studies, location, and the type of review, etc. (Table 1).

We followed the Methodological Quality Checklist (MQC) (Bambra et al., 2009) tool to assess the methodological quality of the included review papers. Based on the seven criteria of this tool, the quality can be scored from zero to seven. We categorized scores as follows: high (6–7), moderate (4–5) and poor (3 and less) (Bambra et al., 2009; Bird et al., 2018). Two reviewers (YZ and CC) conducted the quality assessment independently and then discussed their assessment until consensus was reached.

### 2.4. Data synthesis

Regarding the BE characteristics, we first extracted BE characteristics that were mentioned in any included review. We then listed them all, using the labels as used in the reviews concerned. Next, we combined overlapping labels. These were subsequently grouped into three categories, relating to: destination-, route-, and neighborhood-related characteristics. *Destination-related* characteristics motivate people to go outside and conduct PA. For example, the diversity of shops and the availability of recreation facilities and parks can encourage people to go outside. *Route-related* characteristics include the walking/cycling paths that connect homes and destinations, and related features such as the quality of sidewalks. These are relevant, as they determine how likely it is for people to engage in active travel. Lastly, *neighborhood-related* characteristics relate to the features of a studied area, e.g. density and walkability.

We considered recreational PA, transport PA, and total/non-specified PA as the PA outcome categories based on travel purposes. PA usually refers to daily walking and/or cycling for a variety of utilitarian motives and also sports and performing active recreation activities (WHO, 2019 & 2022; Zhang et al., 2022b). In this review, the term PA refers to all forms of movements including walking and active travel (i.e., walking or cycling for transport; Panter et al., 2008).

The findings for the above-mentioned PA outcome categories were specified per age group: children (including both children and adolescents), adults and older people. Findings that were not specified by age were synthesized to the group of adults (Bancroft et al., 2015; Ding et al., 2018; Hunter et al., 2019; Kärmeniemi et al., 2018; Smith et al., 2017; Tcymbal et al., 2020; and Zhang et al., 2019), as this demographic is the default research group in most cases.

We then coded the associations between the BE characteristics and PA as positive (+), negative (−), or null/mixed (0). A positive association means the improvement of this BE characteristic can improve people's PA levels, while a negative association means the BA characteristic is associated with declined PA levels. Lastly, a null/mixed association yield mixed results for this BE characteristic. When a BE characteristic was found to improve the levels of PA (i.e. either a statistically significant ( $p < 0.05$ ) improvement; Barnett et al., 2017; Cerin

**Table 1**  
Description of the study characteristics of the included reviews ( $N = 29$ ).

	Author	Number of included primary studies	Years of included primary studies	Continent(s)	Study population	Review type
1	An et al. (2019)	20	2006–2017	Asia	C	SR
2	Arango et al. (2013)	15	2006–2012	South America	A	SR
3	Audrey and Batista-Ferrer (2015)	33	1991–2014	North America, Europe, Oceania	C	SR
4	Bancroft et al. (2015)	20	2004–2014	North America	NS	SR
5	Barnett et al. (2017)	100	2000–2016	North America, Europe, Oceania, South America, Asia, Africa	O	MA
6	Cerin et al. (2017)	42	2009–2016	North America, Europe, Oceania, South America, Asia, Africa	O	MA
7	Cleland et al. (2019)	64	2000–2016	North America, Europe, Oceania, South America, Asia	O	SR
8	D'Haese et al. (2015)	65	2003–2014	North America, Europe, Oceania, Asia	C	SR
9	Ding et al. (2011)	103	1993–2009	North America, Europe, Oceania, Asia	C	SR
10	Ding et al. (2018)	23	2002–2017	North America, Europe, Oceania, Asia	NS	SR
11	Eisenberg et al. (2017)	15	2008–2015	North America, Europe, Asia	A	SR
12	Grasser et al. (2013)	34	1997–2010	North America, Europe, Oceania	A	SR
13	Hajna et al. (2015)	6	2009–2014	Europe and Asia	A	MA
14	Hunter et al. (2019)	38	2002–2016	mainly in North America, Europe, Oceania	NS	SR
15	Ikedo et al. (2018)	37	2005–2017	mainly in North America and Oceania	C	SR
16	Jia et al. (2019)	23	2006–2018	North America, Europe, Oceania, Asia	C	MA
17	Kärmeniemi et al. (2018)	51	2003–2015	North America, Europe, Oceania, Asia	NS	SR
18	Lambert et al. (2019)	18	2004–2016	North America, Europe, Oceania	C	SR
19	McCormack and Shiell (2011)	33	NS	North America, Europe, Oceania	A	SR
20	McGrath et al. (2015)	23	2005–2012	North America, Europe, Oceania	C	MA
21	Nordbø et al. (2020)	127	2010–2018	North America, Europe, Oceania, South America, Asia, Africa	C	SR
22	Smith et al. (2017)	28	1979–2015	North America, Europe, Oceania	NS	SR
23	Stappers et al. (2018)	19	2005–2017	North America, Europe, Oceania, South America	A	SR
24	Tcymbal et al. (2020)	36	2007–2020	North America, Europe, Oceania and Asia	NS	SR
25	Terrón-Pérez et al. (2021)	55	1992–2019	North America, Europe, Oceania	C	SR
26	van Cauwenberg et al. (2011)	31	2000–2010	North America, Europe, Oceania, Asia	O	SR
27	van Cauwenberg et al. (2018)	72	NS	North America, Europe, Oceania, South America, Asia, Africa	O	MA
28	Wong et al. (2011)	14	2004–2010	North America, Europe, Oceania, Asia	C	SR
29	Zhang et al. (2019)	25	2008–2016	North America, Europe, Oceania, South America	NS	SR

Note: NS means not specified. C means children and young people, A means adults/the whole population, and O means older people. SR means systematic review and MA means meta-analysis.

et al., 2017; van Cauwenberg et al., 2018, or >66% of the primary studies was attributed to a positive association; Arango et al., 2013), we coded the association as 'positive'. For reviews that already contained a summary table of the associations, we used the summarized evidence provided by the tables. If no such tables were presented, we coded the BE characteristic as positive (+), negative (−), or null/mixed (O), when two-thirds (Arango et al., 2013) of the primary studies showed the results in the same direction. If positive or negative outcomes were reported by less than two-thirds of the primary studies, we coded the characteristic as null/mixed (O). Associations that were identified by only one primary study in the reviews were excluded.

### 2.5. Data reporting

Umbrella reviews built on the findings of included review papers. Since less than one-fourth of the included review papers in our review contain meta-analyses, we reported the associations between BE characteristics and PA for each age group (children, adults and older people) using narrative synthesis. We classified associations as positive (P) when at least half or reviews that studied a specific BE characteristic were coded as positive (review-level evidence), otherwise associations were classified as null/mixed (N) because only positive or null/mixed associations were found in our review (no negative associations).

## 3. Results

The database search resulted in the identification of 2291 review papers; after removing duplicates, 1277 papers remained. A review of titles and abstracts resulted in the remaining of 157 papers, of which all full texts were reviewed. This yielded 29 papers that met the inclusion criteria and were therefore included in our review. The manual search of the reference lists of the included articles did not yield any additional papers; see Fig. 1 for a visual representation of our systematic search.

### 3.1. Characteristics of the included reviews

Among the 29 included reviews, 11 investigated children (and adolescents), 13 focused on adults' PA, and five focused on older people's PA. In every age group, total/non-specified PA was the most explored category, followed by transportation PA.

Most of the primary studies that specified locations, targeted two or more continents, namely North America, Oceania, and Europe. Some also included studies from Africa, Asia and South America (e.g. Barnett et al., 2017; Cerin et al., 2017). Three reviews focused solely on studies from one specific continent, one on Asia (An et al., 2019), one on North America (Bancroft et al., 2015), and one on South America (Arango et al., 2013). The included reviews or meta-analyses mostly identified 15 to 40 articles. The included reviews were published between 2011 and 2021, of which approximately three quarters were published after 2015. All were written in English. Most of the primary studies that were

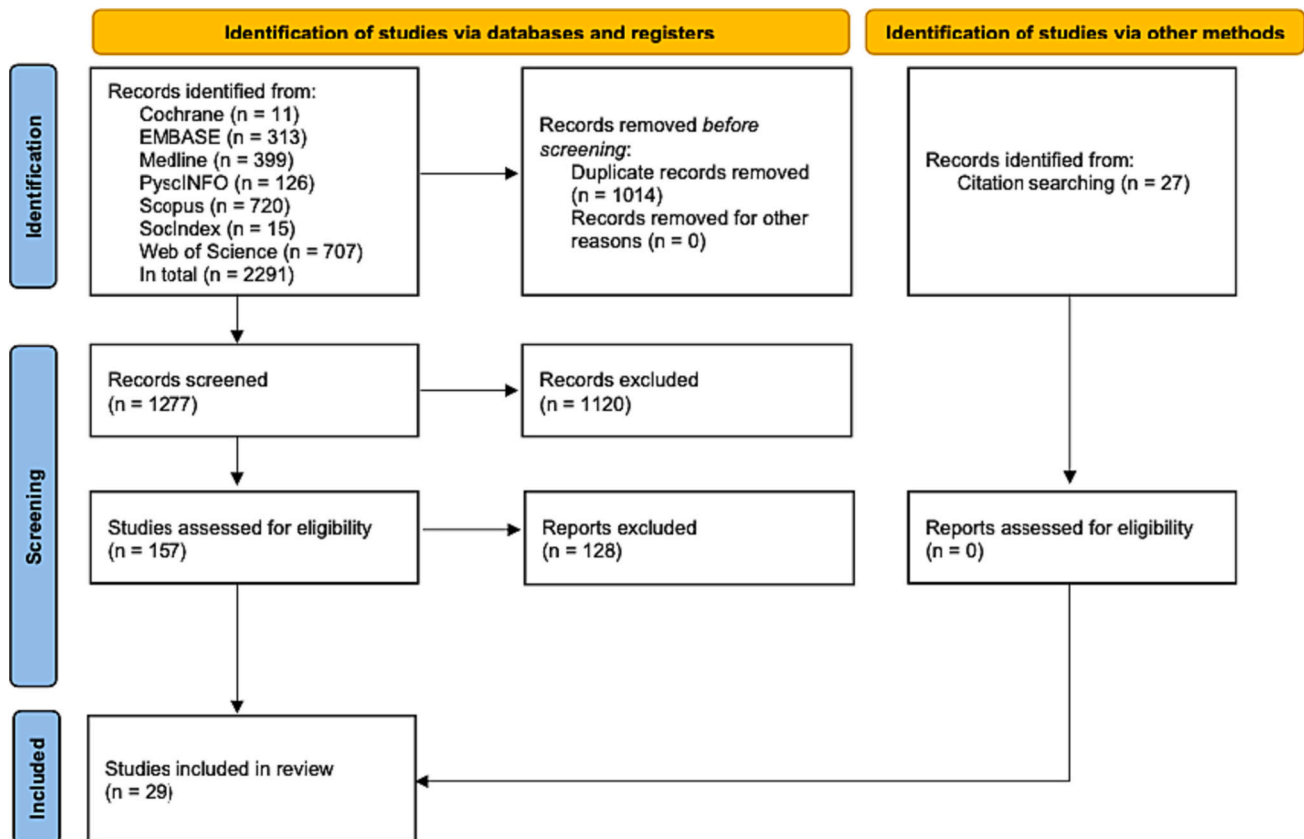


Fig. 1. PRISMA 2020 flow diagram of database search, review process and study selection.

included in the reviews were published in the 21st century, however one primary study was published in 1979. Detailed characteristics of the included papers are shown in Table 1.

Table 2 presents the results of the quality assessment. All included reviews were of moderate to high quality. The reviews with a moderate quality usually performed well with a well-defined question, search strategy, and inclusion criteria, but lacked quality assessment and the involvement of more than one author at each stage of the review process.

### 3.2. Associations between BE characteristics and PA

In total, 21 BE characteristics were identified as being related to PA, and these relationships showed both similarities and differences across age groups. In total, 139 associations were reported, out of which around one-fifth regarded positive associations (29 out of 139). Few characteristics showed a positive relation in every age group. The most explored BE characteristics were land use mix, street connectivity, residential density, availability of parks/open spaces, and walkability index. These BE characteristics were reported by at least 14 (out of 29) of the included reviews. For every age group, more reviews studied the associations between the BE and total or non-specified PA, then recreational and transport PA. The results per age group are presented in the following sections.

#### 3.2.1. Children

Eleven of the included reviews had a focus on the age group of children (An et al., 2019; Audrey and Batista-Ferrer, 2015; D'Haese et al., 2015; Ding et al., 2011; Ikeda et al., 2018; Jia et al., 2019; Lambert et al., 2019; McGrath et al., 2015; Nordbø et al., 2020; Terrón-Pérez et al., 2021; Wong et al., 2011). They addressed 18 BE characteristics and their associations with PA and most revealed null/mixed (N) results

(Table 3a). Specifically, only 9 out of 46 findings on associations were reported as positive.

Positive relationships on total or non-specified PA were only found for the availability and accessibility of sport facilities, the presence of sidewalks, and less distance/time to school/transit. Availability and accessibility to sports facilities, availability and accessibility to parks/open spaces, and pedestrian friendly features were positively related to recreational PA. Crime safety, general safety, and walkability index were positively related to transportation PA. Traffic safety was positively related to transportation PA in one included review, but null/mixed outcomes were shown in two other reviews. Similar results were found for the availability of parks/open spaces (two positive and three null/mixed results for total/non-specified PA).

Five BE characteristics were studied in at least five (out of 11) included reviews for children. These characteristics were: land use mix, the availability and accessibility of parks/open spaces, street connectivity, residential/population density, and walkability index. The availability and accessibility of shops/commercial services, the availability and accessibility of public transit, sidewalk presence, and sidewalk coverage/quality were among the BE characteristics that were less studied.

#### 3.2.2. Adults

Almost half of the included reviews (13 out of 29) collected evidence of associations among adults or non-specified age groups (Arango et al., 2013; Bancroft et al., 2015; Ding et al., 2018; Eisenberg et al., 2017; Grasser et al., 2013; Hajna et al., 2015; Hunter et al., 2019; Kärmeniemi et al., 2018; McCormack and Shiell, 2011; Smith et al., 2017; Stappers et al., 2018; Tcymbal et al., 2020; Zhang et al., 2019); and 18 BE characteristics were measured (Table 3b). Out of 42 identified associations, 10 were found to be positive.

For transportation PA, positive relations were found for land use mix,

**Table 2**  
Results of the quality assessment of the included reviews (N = 29).

	Author (year)	1. Well-defined question	2. Defined search strategy	3. Inclusion criteria stated	4. Primary study designs and number stated	5. Quality assessment conducted	6. Studies were appropriately synthesized	7. More than one author involved in review process	Results of Quality assessment
1	An et al. (2019)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	high
2	Arango et al. (2013)	Yes	Yes	Yes	Yes	Yes	Yes	No	high
3	Audrey and Batista-Ferrer (2015)	Yes	Yes	Yes	Yes	Yes	Yes	No	high
4	Bancroft et al. (2015)	Yes	Yes	Yes	Yes	No	No	No	moderate
5	Barnett et al. (2017)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	high
6	Cerin et al. (2017)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	high
7	Cleland et al. (2019)	Yes	Yes	Yes	Yes	No	No	Yes	moderate
8	D'Haese et al. (2015)	Yes	Yes	Yes	Yes	Yes	Yes	No	high
9	Ding et al. (2011)	Yes	Yes	Yes	No	No	Yes	Yes	moderate
10	Ding et al. (2018)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	high
11	Eisenberg et al. (2017)	Yes	Yes	Yes	No	Yes	Yes	Yes	high
12	Grasser et al. (2013)	Yes	Yes	Yes	No	Yes	Yes	No	moderate
13	Hajna et al. (2015)	Yes	Yes	Yes	Yes	No	No	Yes	moderate
14	Hunter et al. (2019)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	high
15	Ikedo et al. (2018)	Yes	Yes	Yes	Yes	Yes	Yes	No	high
16	Jia et al. (2019)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	high
17	Kärmeniemi et al. (2018)	Yes	Yes	Yes	Yes	Yes	Yes	No	high
18	Lambert et al. (2019)	Yes	Yes	Yes	Yes	Yes	No	Yes	high
19	McCormack and Shiell (2011)	Yes	Yes	Yes	Yes	No	Yes	No	moderate
20	McGrath et al. (2015)	Yes	Yes	Yes	Yes	Yes	Yes	No	high
21	Nordbo et al. (2020)	Yes	Yes	No	Yes	Yes	Yes	No	moderate
22	Smith et al. (2017)	Yes	Yes	Yes	Yes	Yes	Yes	No	high
23	Stappers et al. (2018)	Yes	Yes	Yes	Yes	Yes	Yes	No	high
24	Tcybal et al. (2020)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	high
25	Terrón-Pérez et al. (2021)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	high
26	van Cauwenberg et al. (2011)	Yes	Yes	Yes	Yes	No	Yes	No	moderate
27	van Cauwenberg et al. (2018)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	high
28	Wong et al. (2011)	Yes	Yes	Yes	Yes	No	Yes	No	moderate
29	Zhang et al. (2019)	Yes	Yes	Yes	Yes	Yes	Yes	No	high

Note: Results are summarized as poor quality (0–3 yes), moderate quality (4–5 yes), and high quality (6–7 yes).

the availability and accessibility shops/commercial services, the availability and accessibility of public transit, and aesthetics. For total or non-specified PA, we identified positive relations for land use mix, public transit, availability and accessibility of parks/open spaces, less distance/time to school/transit, neighborhood type and walkability index. Walkability index was also identified as positively related to transportation PA by one of the included reviews, but the results from two other reviews did not support this outcome. No BE characteristic was found to be positively related to recreational PA.

For adults, the most explored BE characteristics were land use mix, availability and accessibility of parks/open spaces, street connectivity, and residential/population density. These BE characteristics were examined by more than five of the included reviews.

### 3.2.3. Older people

For older people, associations were reported on 20 BE characteristics by five reviews (Table 3c) (Barnett et al., 2017; Cerin et al., 2017; Cleland et al., 2019; van Cauwenberg et al., 2011; van Cauwenberg et al., 2018). Out of 51 identified associations, 10 positive associations were reported between the BE and at least one of the three PA categories.

Recreational PA was positively related to general safety. Street connectivity was found positively related to transportation PA. Availability and accessibility of parks/open spaces, pedestrian-friendly features, and walkability index were found positively related to both transportation and total or non-specified PA. The availability and accessibility of shops/commercial services were found to be positively related to total or non-specified PA. Among the 20 reported BE

**Table 3a**

Associations between built environment characteristics and type of children's physical activity (PA): numbers of the reviews that addressed each association and of the reviews that identified a positive association (*N* = 11).

Built environment characteristic		Recreational PA		Transportation PA		Total/non-specified PA	
		Mentioned in review (s)	+	Mentioned in review (s)	+	Mentioned in review (s)	+
Destination-related characteristics	land use mix	8		8, 15, 21, 28		8, 9, 21, 25	
	shops/commercial services*	21		21		21	
	health care services*					25	
	public transit*					8, 9, 20, 25	
	recreational facilities*	8		8		1, 20	<b>1</b>
	sports facilities*	1	<b>1</b>			1, 3, 9, 20, 21	1, 20
Route-related characteristics	parks/open spaces*	18, 21	<b>18</b>	28		20	<b>20</b>
	sidewalk presence					25	
	sidewalk coverage/quality					20, 21	
	pedestrian-friendly features	18, 21	<b>18</b>	21		8, 9	
	infrastructure for walking/cycling	8		8, 15			
	less distance/time to school/transit	8				25	<b>25</b>
	no barriers						
	street connectivity	8, 18, 21		8, 21, 28		8, 9, 16, 20, 21	
	residential/population density	8, 18, 21		8, 21, 28		8, 9, 21	
	general safety	8		8, 15	<b>15</b>	8, 25	
Neighborhood-related characteristics	traffic safety	8, 21		8, 15, 21	15	8, 21	
	crime safety	8		8, 15	<b>15</b>	8, 9, 25	
	aesthetics	8, 21		8, 15, 21		8, 21	
	neighborhood type						
	walkability index	8, 18, 21		8, 15, 21	<b>8, 15</b>	8, 9, 20, 21	

Note: Numbers refer to the included reviews as listed in Table 1.

+ Regards the included reviews that showed a positive association between the built environment characteristic and the type of physical activity (PA). The numbers are shown in **bold** when at least half of the reviews showed a positive association, because they are then considered as a positive association in this review.

\* This regards the availability of or access to that characteristic. Additionally, safety was classified as general safety if it was not specified as traffic or crime related.

**Table 3b**

Associations between built environment characteristics and type of adults' physical activity (PA): numbers of the reviews that addressed each association and of the reviews that identified a positive association (*N* = 13).

		Recreational PA		Transportation PA		Total/non-specified PA	
		Mentioned in review (s)	+	Mentioned in review (s)	+	Mentioned in review (s)	+
Destination-related characteristics	land use mix	17		10, 12, 17, 22	<b>10, 22</b>	17, 19	<b>19</b>
	shops/commercial services*	2		2, 10	<b>10</b>	2, 11	
	health care services*						
	public transit*			10, 24	<b>10, 24</b>	19, 24	<b>24</b>
	recreational facilities*	2		2		2, 19	
	sports facilities*			22		22, 24	
Route-related characteristics	parks/open spaces*	29				4, 14, 17, 24	<b>17, 24</b>
	sidewalk presence					19, 23	
	sidewalk coverage/quality						
	pedestrian-friendly features						
	infrastructure for walking/cycling	17		17, 23		17, 19, 23	19
	less distance/time to school/transit					24	<b>24</b>
	no barriers	17					
	street connectivity	17, 29		10, 12, 17	12	17, 19, 24	
	residential/population density	17, 19		10, 12, 17, 22	12	11, 17	
	general safety	2, 17		17		2, 17	
Neighborhood-related characteristics	traffic safety	2, 29		2		2	
	crime safety	2, 29		2, 10			
	aesthetics	2, 17, 29		10, 17	<b>10</b>	2, 17	
	neighborhood type					19	<b>19</b>
	walkability index	17, 19		17, 19, 22	19	13, 17	<b>13</b>

Note: Numbers refer to the included reviews as listed in Table 1.

+ Regards the included reviews that showed a positive association between the built environment characteristic and the type of physical activity (PA). The numbers are shown in **bold** when at least half of the reviews showed a positive association, because they are then considered as a positive association in this review.

\* This regards the availability of or access to that characteristic. Additionally, safety was classified as general safety if it was not specified as traffic or crime related.

characteristics, three were assessed by all five included reviews: the availability of public transit, residential/population density, and aesthetics. The least studied BE characteristics were sidewalk presence,

pedestrian-friendly features, and less distance/time to transit.

**Table 3c**

Associations between built environment characteristics and type of older people's physical activity (PA): numbers of the reviews that addressed each association and of the reviews that identified a positive association (N = 5).

		Recreational PA		Transportation PA		Total/non-specified PA	
		Mentioned in review (s)	+	Mentioned in review (s)	+	Mentioned in review (s)	+
Destination-related characteristics	land use mix	7, 27	27	7, 26		5, 7, 26, 27	5
	shops/commercial services*	26, 27				5, 27	5
	health care services*	27				5, 27	
	public transit*	7, 26, 27		6, 7, 26	6	5, 6, 27	5, 6
	recreational facilities*	7, 26, 27		7		5, 7, 26, 27	5, 27
	sports facilities*	27				27	
	parks/open spaces*	27		6	6	5, 6, 27	5, 6, 27
Route-related characteristics	sidewalk presence	27				27	
	sidewalk coverage/quality	7		7		5, 7	
	pedestrian-friendly features			6	6	6	6
	infrastructure for walking/cycling	26, 27		26		5, 26, 27	5
	less distance/time to school/transit					5	
	no barriers	7, 27		7		5, 7	5
	street connectivity	26, 27		6, 26	6	5, 6, 27	6
Neighborhood-related characteristics	residential/ population density	7, 26, 27		6, 7, 26	6	5, 6, 7, 27	5, 6
	general safety	26, 27	27	27		27	27
	traffic safety	26, 27		6, 26		5, 6, 26, 27	
	crime safety	26, 27		26		5, 26, 27	5
	aesthetics	7, 26, 27	27	6, 7, 26		5, 6, 7, 26	5
	neighborhood type						
	walkability index	7, 26, 27	27	7, 26	7, 26	5, 7, 26, 27	5, 7

Note: Numbers refer to the included reviews as listed in Table 1.

+ Regards the included reviews that showed a positive association between the built environment characteristic and the type of physical activity (PA). The numbers are shown in bold when at least half of the reviews showed a positive association, because they are then considered as a positive association in this review.

\* This regards the availability of or access to that characteristic. Additionally, safety was classified as general safety if it was not specified as traffic or crime related.

## 4. Discussion

### 4.1. Main findings

This review found 21 BE characteristics that have been studied regarding their associations with PA. Few similarities in the positive associations were found across all three age groups of children, adults and older people. Regarding types for PA, few positive associations with recreational PA were found. For adults, positive associations were only found with transportation and total PA. For children and older people, they were also found in recreational PA.

The results of our review revealed rather weak associations between BE characteristics and PA; research on most BE characteristics yielded mixed/null relationships with PA regardless of whether they were recreational or transportation oriented. We may speculate that isolating one specific BE characteristic out of its social and local context can result in misleading results, since people's behavior is affected by many factors. Notoriously absent in the reviewed articles are drawings, maps and diagrams, which are indispensable to address BE characteristics at the level of precision that is a condition sine qua non for studies on the BE.

Nevertheless, several of the identified positive relationships overlapped across age groups (either recreational, transportation or total/non-specified PA). For example, for children and older people's PA, we found positive associations of pedestrian-friendly features and general safety of a neighborhood. The availability and accessibility of shops/commercial services and the availability and accessibility of parks/open spaces were found positively related to adults' and older people's PA. Despite not being for the same PA outcomes across all age groups, the walkability index was positively related to every age group.

We found that most of the associations differed by age group. However, we also identified a number of similarities. For example, adults and older people shared some common BE characteristics in the destination and neighborhood categories (i.e., the availability and accessibility of parks/open spaces, and the walkability index) that

positively related to total/non-specified PA. Furthermore, we found relatively many route-related BE characteristics to have a positive impact for both children and older adults, more than for adults. This suggests that it is promising to include these characteristics in the design of walking/cycling environments for children and older people.

For children, the included reviews (Lambert et al., 2019; McGrath et al., 2015; Terrón-Pérez et al., 2021) reported positive relationships mostly in the route-related category, revealing the importance of sidewalks for children's PA. This viewpoint has also been reported in a recent systematic review, which identified an association between sidewalks and increased PA (Wei et al., 2021). This might be because travel to school is a big part of children's daily PA, and whether there is a good sidewalk connecting their home and school has a big influence on their choices for active travel.

The results of this review also suggest that BE characteristics indeed often have varied associations with different types of PA per age group. This is supported by the BE characteristic of the availability and accessibility of shops/commercial services, which was found positively related to transportation PA for adults, and total/non-specified PA for older people, but not to any type of PA for children. Another example is the availability and accessibility of parks and open spaces. The findings showed positive associations with transportation and total/non-specified PA for older people, total/non-specified PA for adults, and recreational PA for children. This can be caused by the different motives for PA among the different age groups. Or, possibly, it is related to the uneven amount of included reviews for each group, which causes some characteristics to be better explored in one age group than in others.

The findings of this review add further insights into the frequently studied BE characteristic walkability index (Frank et al., 2010), revealing that this characteristic may not be positively related to children's PA. Walkability, which integrates density, land use mix, street connectivity, and sometimes other indicators (Frank et al., 2010), was found positively related to the total PA levels of adults and older people. However, the review showed no impact on children's total/non-specified



PA. Four included reviews that focused on children found mixed/null associations (D'Haese et al., 2015; Ding et al., 2011; McGrath et al., 2015; Nordbø et al., 2020). Possibly, this is the case because we considered a variety of movements, rather than only walking, as PA outcomes, whereas walkability is more closely related to walking behaviors. Another explanation is that children's PA is closely related to general safety, and this is often overlooked in studies about walkability (Frank et al., 2010).

#### 4.2. Strengths and limitations

A strength of this review is that it covers broad evidence from several research fields (transportation, urban planning and public health), rather than being limited to one specific field. Another strength is that our review compares different age groups, which adds evidence to create a Health-for-All environment.

This review also has some limitations. Some included reviews did not clarify the age groups and the evidence was then synthesized to the group of adults/unspecified. Also, the number of included reviews focusing on each age group is unevenly divided. Moreover, we grouped walking behaviors and active travel under the heading PA, though by definition they are not the exact same PA forms.

#### 4.3. Implications for future research and practice

Our findings can provide useful information for creating health-promoting urban environments. Several BE characteristics that are positively related to people's PA can be applied by urban designers and policymakers to increase PA levels. Especially the characteristics that were positively associated with PA in two or more age groups are of interest in this regard, as they can promote the PA of a broader group of people. Examples of such BE characteristics are the availability and accessibility of shops/commercial services, the availability and accessibility of park/open spaces, and the walkability of an area. Furthermore, our findings can be used to improve PA in the neighborhoods that house a specific group of people, e.g. neighborhoods that are designed especially for older people. Practitioners should then focus more on the BE characteristics that can effectively promote PA in this age group. Lastly, quite some BE characteristics showed similar (null/mixed) results across all age groups, which has quite some importance for urban design and planning.

A traditional meta-analysis was not possible for the current review due to a lack of data for this in the included reviews. Therefore, we recommend future reviews to synthesize estimates of effect sizes for age groups. Furthermore, we suggest more research on a number of potential BE characteristics. For instance, street lighting was found to significantly promote all forms of walking behavior for older people in one included review (Cleland et al., 2019). Moreover, another review (Zhang et al., 2022c) found the quality of green spaces to have more impact than its quantity regarding health-related outcomes. However, various BE characteristics have been insufficiently studied and therefore require additional study. A next step would be to integrate transportation, urban design, public health and other related fields in order to untangle the mixed results found for associations between the BE and PA.

We also suggest that future research should be conducted in less-studied regions such as Asia and Africa. Geographical and cultural differences could lead to different results, and future umbrella reviews should take this into account. Furthermore, our results indicate a paucity in review studies focusing on older people, despite the fact that this population in particular could benefit from a supportive BE. As such, future research on the association between the BE and PA should focus more on this age group.

## 5. Conclusion

This review provides an up-to-date overview of the associations

between the BE and PA for children, adults and older people. We found 21 studied BE characteristics in reviews of the past 12 years. Although the majority of BE characteristics showed mixed/null results, several were positively related to people's PA. Regarding the reported positive relationships, however, different associations between BE and PA were found for distinct age groups (children, adults, and older people). Few characteristics showed a positive relation in every age group, even when taking all types of PA into account. Nonetheless, the positive relationships in a particular age group, or occasionally in more groups, can help practitioners in developing urban environments that promote health by increasing PA.

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## CRediT authorship contribution statement

**Yufang Zhang:** Writing – review & editing, Writing – original draft, Conceptualization, Methodology. **Marijke Koene:** Writing – review & editing, Data curation. **Chen Chen:** Writing – review & editing, Data curation. **Cor Wagenaar:** Supervision, Funding acquisition. **Sijmen A. Reijneveld:** Writing – review & editing, Supervision.

## Declaration of competing interest

None.

## Data availability

Data will be made available on request.

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## Appendix A. Supplementary data

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