Health and Place 58 (2019) 102137

Contents lists available at ScienceDirect

Health & Place

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

Review Essay

Neighbourhood built environment and physical function among mid-to-older aged adults: A systematic review

Jerome N. Rachele[a,*], Takemi Sugiyama[b,c,d], Sasha Davies[e], Venurs H.Y. Loh[f], Gavin Turrell[g], Alison Carver[b], Ester Cerin[b,h]

[a] Melbourne School of Population and Global Health, The University of Melbourne, 207 Bouverie St, Carlton, Victoria, 3011, Australia
[b] Mary MacKillop Institute for Health Research, Australian Catholic University, Australia
[c] Centre for Urban Transitions, Swinburne University of Technology, Melbourne, Australia
[d] Baker Heart & Diabetes Institute, Melbourne, Australia
[e] School of Psychology, Deakin University, Australia
[f] Institute for Physical Activity and Nutrition, School of Exercise and Nutrition, Deakin University, Australia
[g] Healthy Liveable Cities Group, Centre for Urban Research, RMIT University, Melbourne, Australia
[h] School of Public Health, The University of Hong Kong, Hong Kong SAR, China

ABSTRACT

This systematic review included 23 quantitative studies that estimated associations between aspects of the neighbourhood built environment and physical function among adults aged ≥45 years. Findings were analysed according to nine aspects of the neighbourhood built environment: walkability, residential density, street connectivity, land use mix, public transport, pedestrian infrastructure, aesthetics, safety and traffic. Evidence was found for a positive association of pedestrian infrastructure and aesthetics with physical function, while weaker evidence was found for land use mix, and safety from crime and traffic. There was an insufficient number of studies for walkability, residential density, street connectivity and access to public transport.

1. Introduction

Physical function refers to the physical ability to carry out various activities, ranging from self-care (basic activities of daily living (ADL)) to more-vigorous activities that require increasing degrees of mobility, strength, or endurance (Bruce et al., 2009). An individual's physical function declines with age (World Health Organisation, 2002). The trajectory of this decline typically determines the age at which individuals are likely to lose independence in undertaking activities of daily living (e.g., personal care, shopping, and housework). At the population level, loss of function, compounded by the changing age profile (Productivity Commission, 2013), is associated with an increased need for aged care services and an increased likelihood of institutionalisation (Beswick et al., 2008). The rate of decline in functional status is strongly influenced by modifiable individual-level lifestyle factors, such as physical activity (Manini and Pahor, 2009), smoking, diet, and alcohol consumption (Hutchison et al., 2006), and environmental-level factors, such as characteristics of the places in which we live.

The neighbourhood built environment is of particular interest because it plays a key role in ageing in place and healthy ageing (Kerr et al., 2013). Ageing in place is defined as the ability to continue to live in one's own home and community safely, independently, and comfortably, regardless of age, income, or ability level (Centers for Disease Control and Prevention, 2013). Ageing in place has been identified as a major policy goal globally (World Health Organization, 2018). For example, the World Health Organization has a Global Network of Age-friendly Cities and Communities, which seeks to stimulate and enable cities, communities, and other sub-national levels of government around the world to become increasingly age-friendly and, hence, promote ageing in place (World Health Organization, 2018).

The built environment refers to the spatial and functional aspects of the urban form (Rosso et al., 2011). These include characteristics such as residential density, street connectivity, land use mix, pedestrian infrastructure, public transport, aesthetics, and safety (from crime and traffic), which recent systematic reviews have identified as robust correlates of older adults' physical activity (Barnett et al., 2017; Cerin et al., 2017; Van Cauwenberg et al., 2018). It also includes a well-established and frequently-used composite measure of residential density, street connectivity and land use mix – namely, neighbourhood walkability (Frank et al., 2010). Given the evidence of associations between the built environment and health behaviours (McCormack and Shiell,

* Corresponding author.
E-mail addresses: j.rachele@unimelb.edu.au (J.N. Rachele), takemi.sugiyma@acu.edu.au (T. Sugiyama), sasha.davies@deakin.edu.au (S. Davies), venurs.loh@deakin.edu.au (V.H.Y. Loh), gavin.turrell@rmit.edu.au (G. Turrell), alison.carver@acu.edu.au (A. Carver), ester.cerin@acu.edu.au (E. Cerin).

https://doi.org/10.1016/j.healthplace.2019.05.015
Received 18 October 2018; Received in revised form 13 May 2019; Accepted 14 May 2019
1353-8292/

2011; Renalds et al., 2010; Sugiyama et al., 2017), and health behaviours and physical function (Patel et al., 2006; Robinson et al., 2013), it can be postulated that the characteristics of the environments in which people live affect the trajectory of physical function.

While there have been several reviews focusing on the built environment and health-related outcomes among older adults (Chandrabose et al., 2019; Durand et al., 2011; Feng et al., 2010) to date, none have specifically focused on the relationship between the built environment and physical function. For example, Rosso et al. (2011) focused on the urban built environment and specific mobility limitations, an element of physical function defined by impairment or dependence in movement, among older adults (aged 60 years and older); while Levasseur et al. (2015) focused on neighbourhood environmental correlates of mobility and social participation among older adults. Synthesising evidence on the association between the built environment and physical function is an important first step in developing evidence-based urban planning policies that will help ageing populations to maintain their independence and age in place. Therefore, this study systematically reviewed and summarised quantitative research examining associations between the neighbourhood built environment and physical function. This study makes a unique contribution to the literature by providing an improved understanding of the relationship between a wide range of built environment characteristics and physical function among mid-to-older aged adults. In recent systematic reviews, the built environment has been identified as a robust correlate of older adults' physical activity (Barnett et al., 2017; Cerin et al., 2017; Van Cauwenberg et al., 2018). However, as physical activity is not the only lifestyle behaviour impacting on physical function (Robinson et al., 2013), a systematic review of built environment correlates of physical function is needed. As functional decline typically begins in mid-adulthood (Peeters et al., 2013), this review focuses on adults aged 45 years and older.

2. Methods

In July 2018, we searched for English-language peer-reviewed journal articles on the built environment and physical function from all available years in health, sport, nursing, transportation, environmental social sciences, and multi-disciplinary databases. These were: Medline; Embase; Sport-Discus; CIHNAL; Transport Research Information Services (TRIS); UrbanStudies; Environment Complete; PsycInfo; and ScienceDirect. Additionally, a purposive sample of relevant websites was searched for grey literature (Active Living Research and Open Grey). Keyword and phrase searches within titles and abstracts were undertaken. Terms and their variants used to capture the built environment included: objective environment, spatial, neighbourhood, built environment, walkability, streetscape, street connectivity, land use mix, density, geographical information systems (GIS), transport, parks, urban form, and urban planning. Terms and their variants used to capture physical function included: physical function, functioning, impairment, disability, and mobility (see Additional File 1 for full search strategy).

The process for screening and removing records followed the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement (Moher et al., 2009). The search across the eight databases provided 13,498 article references (after removing 1,932 duplicates). These were screened using the following inclusion criteria: 1) included a measurement of the neighbourhood built environment; 2) included a measurement of physical function; 3) involved adult participants 45 years of age or older at any point in the study; and 4) estimated an association between the built environment and physical function, cross-sectionally or longitudinally. Studies reported only qualitative data, referred only to non-adult samples, commentaries, editorials, or literature reviews were removed (Fig. 1). Screening was conducted by SD and AC, with 20% of them independently assessed by VHL (inter-rater agreement = 96.4%). Any disagreement was resolved by discussion. This left 77 potentially eligible articles, each of which was reviewed independently by three authors (SD, AC, and JNR) to confirm which articles met the inclusion criteria. Any disagreement for full text inclusion was resolved by discussion, and further review by VHL. SD and AC manually searched the reference lists of the articles eligible for the review to assess if any had the potential to meet the inclusion criteria. SD and AC reviewed abstracts and, as required, the full text of such articles. A total of 23 articles were included in the final review.

2.1. Data extraction

From the 23 articles, JNR extracted, summarised, and tabulated the following information: author details; study setting, year published, study design (including sample recruitment), sample size, response rate, sample characteristics (gender and age), built environment variables, physical function variables, covariates, and results (associations between the built environment and physical function). AC reviewed all extractions for completeness and accuracy, with any disagreement being discussed. Any relevant missing information was sought from the primary author of the study.

For analytical purposes, environmental variables were classified into categories primarily corresponding to those of the Neighbourhood Environment Walkability Scale (NEWS), the most frequently-used measure of perceived neighbourhood environmental attributes worldwide (Cerin et al., 2013). Environmental variables encompassed: (a) walkability, denoting a composite index including information on access to services/land use mix, residential density, and/or street connectivity; (b) residential density; (c) street connectivity; (d) land use mix and/or access to or availability of services and destinations (shops, food outlets, business/government/institutional/industrial, health and aged-care, religious, park/open space, recreational facilities, and entertainment); (e) public transport (f) pedestrian infrastructure, including pedestrian-friendly features, barriers to walking/cycling, benches/sitting facilities, streetlights, easy access to building entrance, and public toilets; (g) aesthetics and cleanliness/order, including greenery and aesthetically pleasing scenery, and littering/vandalism/decay; (h) safety from crime, including personal safety; and (i) safety from traffic, including motorised traffic volume.

2.2. Coding and quantification of findings

Relationships between the built environment and physical function were categorised as significantly positive, significantly negative, or not statistically significant. Single articles could contribute more than one finding (association) if they had more than one distinct environmental variable and/or outcomes in the same categories, or where the association differed between subgroups. To avoid duplication of data, study findings reported by more than one article were included only if they represented original information. If findings from the same project appeared in more than one article, preference was given to (in order of preference): 1) those that adjusted for self-selection and socio-demographic confounders; 2) those that adjusted for socio-demographic confounders but not adjusted for other environmental variables; 3) those adjusted for socio-demographic confounders and other environmental variables; 4) those unadjusted. Preference was given to adjustment for socio-demographic confounders over adjustment for other environment variables for two reasons. First, there is a higher level of consistency across studies in the selection of socio-demographic confounders than environmental confounders. Second, the confounding effects of socio-demographic characteristics are likely to be more generalisable across geographical locations than those of environmental characteristics. Thus, for a given environmental attribute, the findings from studies with adjustment for socio-demographic characteristics are likely to be more comparable than those from studies with adjustment for environmental characteristics (Gelormino et al., 2015). Following

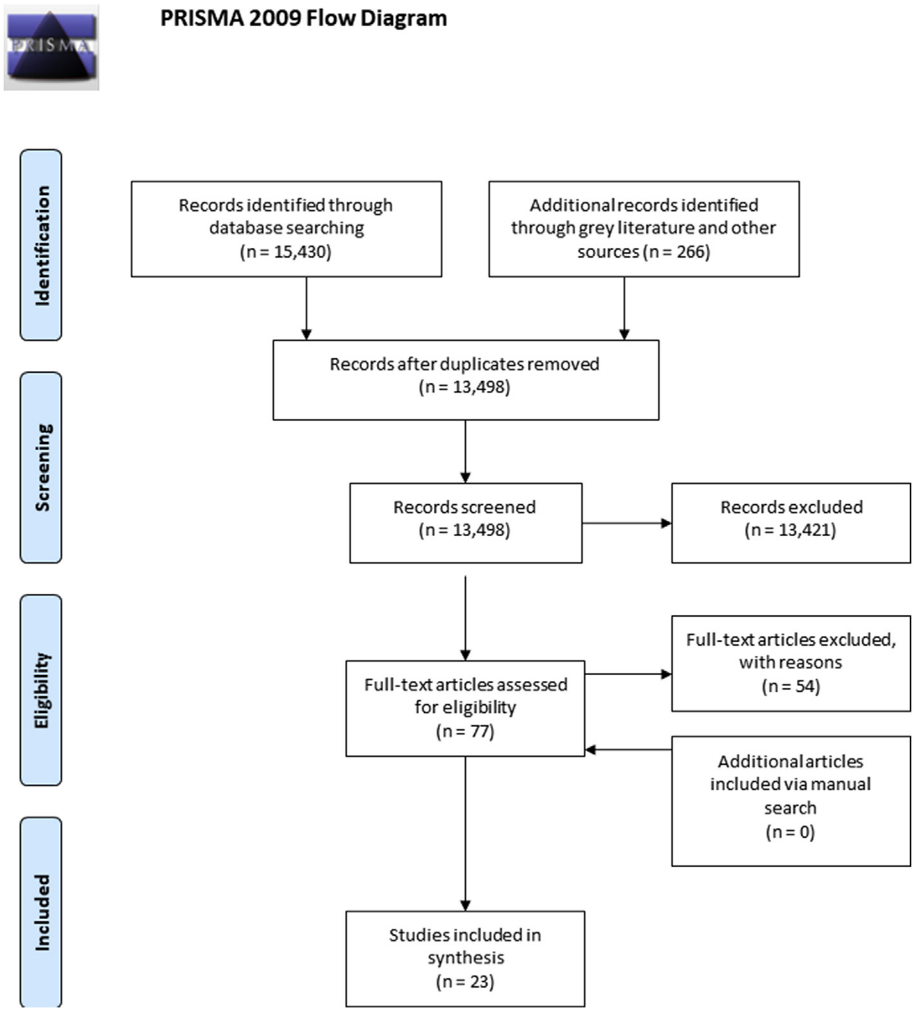

Fig. 1. Summary of results and articles excluded after each phase of study selection.

recent systematic reviews that formulated objective conclusions based on statistical theory (Barnett et al., 2017; Cerin et al., 2017), a threshold of > 50% of significant positive associations with a minimum of five studies was used to define convincing evidence of a positive association between a specific environmental characteristic and physical function.

2.3. Quality assessment

Article quality was assessed using 11 criteria, similar to those used in other systematic reviews of environmental correlates and physical activity (Barnett et al., 2017; Cerin et al., 2017; Van Cauwenberg et al., 2018), and considering other methodological considerations relevant to this research field. These quality criteria and their scores included: 1) study design [score: cross-sectional = 0, longitudinal observational = 1, quasi-experimental = 2]; 2) sample size [n < 100 = 0, n ≥ 100 and n < 300 = 0.5, n ≥ 300 = 1]; 3) stratification of neighbourhoods/study sites or participants by key environmental attributes to maximise variability in exposures and outcomes [yes = 1, no = 0] (Cerin et al., 2010; Kerr et al., 2013); 4) sample shown to be representative of the population or response rate ≥60% [yes = 1, no = 0], and a follow-up response rate ≥60% [yes = 1, no = 0] (Ogilvie et al., 2007); 5) physical function outcome measure shown to be valid or representing commonly-used measure [yes = 1, no = 0] (Ogilvie et al., 2007); 6) adjustment for socio-demographic covariates (at least age, sex, education or similar) [yes = 1, no = 0] (Ogilvie et al., 2007); 7) adjustment for self-selection into neighbourhoods [yes = 1, no = 0] (Ewing and Cervero, 2010); 8) analytical approach accounted for area-level clustering (if appropriate) [yes = 1/3, no = 0] (Cerin, 2010); 9) analytical approach correctly accounted for distributional assumption of physical function outcome [yes = 1/3, no = 0]; 10) analyses conducted and presented correctly (i.e., formal testing of moderators, if applicable; presentation of point estimates and 95% confidence intervals, standard errors and/or p-values) [yes = 1/3, no = 0]; and 11) did not inappropriately categorise continuous environmental exposure [yes = 1, no = 0] (Lamb and White, 2015). Article quality were categorised according to their summed scores into low (0–5.5), moderate (5.6–8.5), and high (8.6–11.0).

3. Results

3.1. Study sample characteristics

The characteristics of the 23 studies identified are presented in Table 1. The majority of studies (n = 14) were conducted in the USA (Balfour and Kaplan, 2002; Beard et al., 2009; Brown et al., 2008; Clarke and George, 2005; Clarke et al., 2008; Clarke, 2014; Freedman et al., 2008; Keysor et al., 2010; Latham and Williams, 2015; Michael et al., 2011; Schootman et al., 2012; Takahashi et al., 2012; White et al., 2010), while only one study was conducted in each of Australia (Byles et al., 2014), UK (Steptoe and Feldman, 2001), Germany (Vogt et al., 2015), Ireland (Walsh and Gannon, 2011), The Netherlands (Etman et al., 2016), Brazil (Nascimento et al., 2018), Finland (Sakari et al., 2017), Japan (Soma et al., 2017) and Sweden (Werngren-Elgström et al., 2008). All studies were published between 2001 and 2018, with

Table 1
Characteristics of included studies[a].

Study	Country	Cities	Design[b]	N	Age (years)[b]	Response rate (%)	Female (%)
Balfour and Kaplan (2002)	USA	> 1	CS	883	M:69.2, SD:8.5, Rg:55+	93	56.6
Beard et al. (2009)	USA	1	CS	937,857	Rg:65+	NA	NA
Brown et al. (2008)	USA	1	LG	273	M:78.5, SD:6.3, Rg:70-100	NA	59
Byles et al. (2014)	Australia	1	CS	202	M:77, Rg:75-79	NA	50.5
Clarke and George (2005)	USA	> 1	CS	4154	M:73.55, SD:6.72	NA	65
Clarke et al. (2008)	USA	1	CS	1195	Rg:45-92	72	56.1
Clarke (2014)	USA	> 1	CS	6578	Rg:65-85+	71.0	56.6
Etman et al. (2016)	Netherlands	1	LG	271	M:74.6, Rg:65+	64.4	49.1
Freedman et al. (2008)	USA	> 1	CS	15,480	Rg:55-85+	86.9	57.1
Keysor et al. (2010)	USA	> 1	CS	479	M:70, SD:4, Rg:65+	89	70
Latham and Williams (2015)	USA	> 1	LG	5922	M:69.8, SD:9.9	71	66.6
Michael et al. (2011)	USA	1	LG	1671	M:71-72, SD:5, Rg:65+	NA	100
Nascimento et al. (2018)	Brazil	1	CS	1190	Rg:60-80+	NA	60.1
Nguyen et al. (2016)	USA	> 1	LG	17957	M:65.7, SD:9.7-9.8	NA	59.3-59.5
Sakari et al. (2017)	Finland	> 1	CS	834	Rg:75-89	NA	60.8-64.3
Schootman et al. (2012)	USA	1	LG	563	M:56.1, SD:4.7, Rg:49-65	76	54.6
Soma et al. (2017)	Japan	1	CS	509	M:72.9-73.7, SD5.1-5.4, Rg:65-86	18	52.9
Steptoe and Feldman (2001)	UK	1	CS	658	M:52, SD:18, Rg:18-94	24	57
Takahashi et al. (2012)	USA	1	CS	53	M:77.02, SD: 4.58, Rg:70-85	48	53
Vogt et al. (2015)	Germany	> 1	CS	1711	M:42.6, SD:2.05, Rg:65+	NA	52
Walsh and Gannon (2011)	Ireland	> 1	LG	3011	Rg:55+	NA	NA
Werngren-Elgström et al. (2008)	Sweden	1	LG	31	Md:79, Rg:75-84	43.0-67.2	58.1
White et al. (2010)	USA	> 1	CS	436	M:70.4, SD:3.9, Rg:65+	81	69

[a] Ranges are provided where two or more subgroups were included in the study.
[b] CS = cross-sectional, LG = longitudinal, M = mean, SD = standard deviation, Md = median, Rg = range.

14 studies (61%) being published after 2010. Sample sizes ranged from 31 to 937,857. Among the 14 studies that reported response rates, the lowest was 18% (Soma et al., 2017) and the highest was 93% (Balfour and Kaplan, 2002). The mean ages of the studies ranged from 42.6 to 78.7 years. Most samples included both men and women, with one study including only women (Michael et al., 2011).

3.2. Study designs

Of the 23 included studies, 15 were cross-sectional (Balfour and Kaplan, 2002; Beard et al., 2009; Byles et al., 2014; Clarke and George, 2005; Clarke et al., 2008; Clarke, 2014; Freedman et al., 2008; Keysor et al., 2010; Nascimento et al., 2018; Sakari et al., 2017; Soma et al., 2017; Steptoe and Feldman, 2001; Takahashi et al., 2012; Vogt et al., 2015; White et al., 2010), while eight were longitudinal (Brown et al., 2008; Etman et al., 2016; Latham and Williams, 2015; Michael et al., 2011; Nguyen et al., 2016; Schootman et al., 2012; Walsh and Gannon, 2011; Werngren-Elgström et al., 2008). No studies employed a quasi-experimental design. The most common number of points of assessments (data collection waves) for longitudinal studies was two (i.e., baseline and follow-up) (Brown et al., 2008; Etman et al., 2016; Latham and Williams, 2015; Schootman et al., 2012; White et al., 2010), while the largest number of points of assessments was eight, conducted biennially over a 14-year period (Michael et al., 2011). Eleven studies (38%) were conducted in multiple cities.

3.3. Article quality

A summary of the quality of included studies is presented Table 2 (detailed findings from the quality assessment of studies are presented in Additional File 2: Supplementary Table 1). Only 4% of studies stratified recruitment on key environment attributes, and 9% adjusted for residential self-selection. Most studies (91%) used outcome measures that were valid or well-established in the field, adjusted for key socio-demographic variables in analyses (87% of studies), and adjusted for clustering where required (96% of studies). Overall, one study (4%) was rated as high quality, nine studies (39%) were rated as moderate, and 13 (57%) were rated as low.

Table 2
Summary of article quality assessment.

Quality assessment score [weight]	% of studies
Cross-sectional [0]	65
Longitudinal study design [1]	35
Quasi-experimental study design [2]	0
Sample size n < 100 [0]	9
Sample size n = 100–299 [1/2]	13
Sample size n > 300 [1]	78
Study areas or participant recruitment stratified by key environmental attributes [1]	4
Response rate ≥60% or sample representative of the population [1]	44
Response rate ≥60% at follow-up [1]	4
Outcomes measure is valid, or well-established in the field [1]	91
Analyses adjusted for key socio-demographic covariates (at least age, sex and education considered) [1]	87
Analyses adjusted for self-selection [1]	9
Analytical approach – adjustment for clustering (if needed) [1/3]	96
Analytical approach – accounting for distributional assumptions [1/3]	61
Analytical approach – analyses conducted and presented correctly [1/3]	100
Did not (inappropriately) categorise continuous environmental exposures [1]	70
Total quality score [theoretical range: 0–11], mean (SD)	5.19 (1.34)

3.4. Measurement

Built environment: For measures of the built environment, 10 studies (Balfour and Kaplan, 2002; Byles et al., 2014; Keysor et al., 2010; Latham and Williams, 2015; Nguyen et al., 2016; Sakari et al., 2017; Steptoe and Feldman, 2001; Walsh and Gannon, 2011; Werngren-Elgström et al., 2008; White et al., 2010) used self-report measures and 13 (Beard et al., 2009; Brown et al., 2008; Clarke and George, 2005; Clarke et al., 2008; Clarke, 2014; Etman et al., 2016; Freedman et al., 2008; Michael et al., 2011; Nascimento et al., 2018; Schootman et al., 2012; Soma et al., 2017; Takahashi et al., 2012; Vogt et al., 2015) used objective measures (e.g., GIS-based measures census data or similar). Most studies assessed some form of land use mix (Beard et al., 2009; Byles et al., 2014; Clarke and George, 2005; Etman et al., 2016; Keysor et al., 2010; Nascimento et al., 2018; Sakari et al., 2017; Soma et al., 2017; Vogt et al., 2015; White et al., 2010) or street connectivity (Freedman et al., 2008; Michael et al., 2011; Schootman et al., 2012); two studies assessed green space (Nascimento et al., 2018; Vogt et al., 2015), while single studies assessed Walk Score (Takahashi et al., 2012), and Neighbourhood Environment Walkability Scale (NEWS) items (Byles et al., 2014). Several studies assessed features related to the participants' home including the home external appearance and building setbacks (Brown et al., 2008; Schootman et al., 2012; Werngren-Elgström et al., 2008). One study (Clarke, 2014) included in-home interviews to assess features around the home (e.g., uneven walking surfaces or broken steps in the area leading up to the home/building). Two studies employed the Home and Community Environment (HACE) survey, which measures a combination of community mobility barriers (e.g., uneven walking area, places to sit and rest, and curbs) and transportation facilities (e.g., public transportation availability, and handicap parking) (Keysor et al., 2010; White et al., 2010). Last, six studies (Balfour and Kaplan, 2002; Clarke et al., 2008; Latham and Williams, 2015; Nguyen et al., 2016; Steptoe and Feldman, 2001; Walsh and Gannon, 2011) measured some form of ‘neighbourhood problems’ or signs of physical disorder such as litter, graffiti or vandalism. Eight of the 10 studies that used a self-report measure of the built environment provided some evidence of instrument validity.

Physical function: Eighteen studies used self-report measures and five used objective measures (e.g., by a clinician, via performing tests). Some studies (n = 7) used a variation of statements pertaining to difficulty performing a range of physical tasks (Balfour and Kaplan, 2002; Clarke and George, 2005; Clarke et al., 2008; Etman et al., 2016; Freedman et al., 2008; Nguyen et al., 2016; Werngren-Elgström et al., 2008), while others used a self-report measure of disability (Beard et al., 2009; Takahashi et al., 2012; Vogt et al., 2015; Walsh and Gannon, 2011), or a version of the Late Life Function and Disability Instrument (Byles et al., 2014; Keysor et al., 2010; White et al., 2010). Of the five studies that measured physical function objectively (Brown et al., 2008; Clarke, 2014; Michael et al., 2011; Nascimento et al., 2018; Soma et al., 2017), four used a measure of gait speed. Three of these (Clarke, 2014; Michael et al., 2011; Soma et al., 2017) also included a chair-stand test. Sixteen of the 18 studies that used a self-report measure of physical function provided some evidence of instrument validity. All five studies (Brown et al., 2008; Clarke, 2014; Michael et al., 2011; Nascimento et al., 2018; Soma et al., 2017) that used objective measures of physical function also used an objective measure of the built environment. However, 10 studies (Balfour and Kaplan, 2002; Byles et al., 2014; Keysor et al., 2010; Latham and Williams, 2015; Nguyen et al., 2016; Sakari et al., 2017; Steptoe and Feldman, 2001; Walsh and Gannon, 2011; Werngren-Elgström et al., 2008; White et al., 2010) used only self-report measures for both physical function and built environment.

The measurement tools used in the included studies are presented in Additional File 3: Supplementary Table 2.

3.5. Associations between the built environment and physical function

A summary of findings from cross-sectional and longitudinal studies is presented in Table 3.

Walkability: In one cross-sectional study examining walkability and physical function, Takahashi et al. (2012) did not find an association between Walk Score and physical function using the Duke Activity Status Index (DASI) among a sample of 53 adults aged 70–85 years.

Residential density: Two cross-sectional studies examined the relationship between residential density and physical function. Freedman et al. (2008) did not find an association between residential density (per square mile calculations of total population and housing units from the US Census) and physical function, and Clarke and George (2005) found no association between housing density, measured as the number of housing units per square mile in each census tract, and lower extremity functional limitations.

Street connectivity: There were six findings across three studies that examined street connectivity and physical function. One cross-sectional study (Freedman et al., 2008) found that higher connectivity (reflected in street design and housing stock age) was associated with a reduced risk of limitations in instrumental activities. Of the two longitudinal studies, Schootman et al. (2012) found that between baseline and three follow-up, participants living in census tracts with the lowest quartile of street connectivity were more likely to develop two or more lower-body functional limitations than those in census tracts with the highest quartile of street connectivity; while Michael et al. (2011) found an association of greater street connectivity with a slower decline in dynamic leg strength only among women who reported walking at baseline.

Land use mix/destinations: There were 29 different findings across 10 studies examining the relationships between land use mix and physical function. Across the nine cross-sectional studies (Beard et al., 2009; Byles et al., 2014; Clarke and George, 2005; Keysor et al., 2010; Nascimento et al., 2018; Sakari et al., 2017; Soma et al., 2017; Vogt et al., 2015; White et al., 2010), some positive associations were found for access to shops, services and transport (Byles et al., 2014; Sakari et al., 2017), and recreational facilities, medical facilities and community centres (Soma et al., 2017), but the large majority of these associations were null. Of the lone longitudinal study, Etman et al. (2016) did not find an association between destinations and physical function.

Public transport: Four cross-sectional studies examined public transport. Balfour and Kaplan (2002) (access to public transport), Keysor et al. (2010) and White et al. (2010) (both examining proximity of services to the home and public transport adaptations) did not find associations between access to public transportation and physical function, while Beard et al. (2009) (access to public transport) found a positive association with physical function.

Pedestrian infrastructure: Eight studies totalling 11 separate findings examined the relationship between pedestrian infrastructure and physical function. Of the five cross-sectional studies, physical function was positively associated with living in neighbourhoods with better street characteristics (Beard et al., 2009) and benches (Sakari et al., 2017). Among the three longitudinal studies, living in blocks marked by low levels of positive front entrance features were 2.7 times more likely to have subsequent poor levels of functioning (Brown et al., 2008); also, environmental features such as uneven or unlit paths were negatively associated with activities of daily living at six and 10 years follow-up (Werngren-Elgström et al., 2008). Null associations were found between streetscape characteristics measured via street audits (e.g., sidewalk, curb cuts) and self-reported difficulty in incidental activities of daily living (Etman et al., 2016).

Aesthetics and cleanliness/order: Eleven studies (17 findings) examined aesthetics and physical function. Of the six cross-sectional studies, some positive associations were found among higher levels of neighbourhood social and physical disorder (e.g., poor lighting, excessive noise, trash and litter) for both self-reported (e.g., Balfour and Kaplan (2002)) and objectively measured exposures (e.g., Beard et al. (2009)), though the majority of associations were null. All five longitudinal studies found positive associations (Etman et al., 2016; Latham and Williams, 2015; Nguyen et al., 2016; Schootman et al., 2012; Walsh and Gannon, 2011), with Walsh and Gannon (2011) reporting significant associations between perceived neighbourhood problems and onset of disability over a seven-year period, and Schootman et al. (2012) finding an association between poor block conditions and increased odds of lower-body functional limitations.

Safety from crime: Eleven studies (15 findings) examined some form of safety from crime and physical function. Of the seven cross-sectional studies, both positive (Beard et al., 2009) and negative (Byles et al., 2014) associations between safety from crime and physical function were found, though most findings were null. Among the four longitudinal studies, Latham and Williams (2015) and Nguyen et al. (2016)

Table 3
Summary of findings by categories of environmental attributes.

	Findings from cross-sectional studies				Findings from longitudinal studies				Overall total	% positive findings
	Positive	Negative	Null	Total	Positive	Negative	Null	Total		
Walkability	0	0	1	1	0	0	0	0	1	0.0%
Residential density	0	0	2	2	0	0	0	0	2	0.0%
Street connectivity	1	0	0	1	1	0	4	5	6	33.3%
Land use mix	6	1	21	28	0	0	1	1	29	20.7%
Public transport access	1	0	4	5	0	0	0	0	5	20.0%
Pedestrian infrastructure	4	2	2	8	2	0	1	3	11	54.5%
Aesthetics	4	0	7	11	6	0	0	6	17	58.8%
Safety from crime[a]	1	1	8	10	3	0	2	5	15	26.7%
Safety from traffic[a]	2	0	5	7	2	0	1	3	10	40.0%
Total	**19**	**4**	**50**	**73**	**14**	**0**	**9**	**23**	**96**	**34.4%**

[a] A positive association indicates higher safety and higher physical function.

found positive associations, while Walsh and Gannon (2011) and Etman et al. (2016) did not find an association between safety from crime and physical function.

Safety from traffic: Seven studies (10 findings) examined safety from traffic and physical function. Of the cross-sectional studies, two Byles et al. (2014) (traffic measured on the Neighbourhood Environment Walkability Scale) and Keysor et al. (2010) (traffic measured as a 'neighbourhood problem') found a positive association, while the remaining studies did not find any association. Of the one longitudinal study, Nguyen et al. (2016) found a positive association.

4. Discussion

The aim of this review was to summarise findings from quantitative studies examining associations between the built environment and physical function of mid-to-older aged adults. Evidence was found for a positive association of pedestrian infrastructure and aesthetics with physical function, while weaker evidence was found for land use mix, and safety from crime and traffic. There was an insufficient number of studies for walkability, residential density, street connectivity and public transport.

This review found evidence of an association of pedestrian infrastructure and aesthetics with physical function. It is noteworthy that pedestrian infrastructure (e.g., provision of footpaths, benches/sitting facilities) and aesthetics (e.g., greenery, littering/vandalism/decay) are among some of the most easily modifiable built environment characteristics, especially when compared to characteristics such as street connectivity, dwelling density or public transport, which may require more drastic changes to the form of a neighbourhood (Stankov et al., 2017). This review suggests that improving these aspects of neighbourhood environments may contribute to residents' physical function (potentially by facilitating their physical activity), and thus promote ageing in place. Further, through the lens of physical activity being a mechanism linking aesthetics and physical function, it is noteworthy that across three recent systematic reviews examining environment and physical activity (active travel (Cerin et al., 2017), total (Barnett et al., 2017), and leisure-time (Van Cauwenberg et al., 2018)), aesthetics was most strongly associated with leisure-time physical activity.

We found weaker evidence for associations of land use mix, safety from crime, and safety from traffic with physical function. One of the possible mechanisms linking land use mix to physical function is the relationship between the built environment and physical activity. Previous systematic reviews and meta-analyses have found associations between the built environment and physical activity among older adults (Barnett et al., 2017; Cerin et al., 2017; Van Cauwenberg et al., 2018). Another possible mechanism could be through dietary behaviours (Robinson et al., 2013). In a systematic review by Larson et al. (2009), better access to supermarkets and other retail stores providing healthy foods were associated with healthier dietary intakes. For example, analysis of the Multi-Ethnic Study of Atherosclerosis (MESA) study found that neighbourhood availability of healthy food, as assessed by greater supermarket density, was consistently positively associated with diet quality (Moore et al., 2008).

For the relationship between safety and physical function, it is possible that the relationships vary between men and women. It is noteworthy that only two studies (Freedman et al., 2008; Soma et al., 2017) conducted additional stratification or sensitivity analysis by gender. Previous evidence suggests that men and women are likely to experience and engage with their local social environments in different ways (Kavanagh et al., 2006). Specifically, women are known to have more concerns about personal safety (Van Dyck et al., 2015), which is likely to influence their physical activity undertaken in the neighbourhood setting (Loh et al., 2018; Wendel-Vos et al., 2007) particularly at night (Bennett et al., 2007). Van Dyck et al. (2013) also found that gender was a significant moderator of an observed linear relationship between self-reported recreational walking and perceived crime and safety, and a curvilinear relationship between physical activity and aesthetics, with women showing stronger associations than men. Features of the built environment (such as parks, transport hubs or distance to shops) are also likely to influence the social environment through encouraging regular social interactions by making destinations safely accessible on foot or by transit (Kerr et al., 2012; Thompson and Kent, 2013). It is therefore not surprising that there are large variations in the findings that appear to be in part dependent on the region the study was conducted. Cities vary widely in their cultural and structural characteristics (such as levels of welfare support, concentration of poverty and ethnic diversity) (Fay-Ramirez, 2014), and local governments shape neighbourhood environments through the planning, implementation, and delivery of services, infrastructure, and policies (Badland et al., 2014).

The findings from this study contribute to the body of knowledge, with policy implications for governments (Bartlett and Carroll, 2011) and advocacy organisations (World Health Organization, 2018) aiming to promote ageing in place by helping middle to older adults to maintain their physical function through environmental initiatives. It is apparent that policy interventions cannot focus solely on individual-level health behaviours; instead, environmental-level change (e.g., improving pedestrian infrastructure or aesthetics) that facilitates the adoption of healthy behaviours will enable integration of these behaviours into daily lifestyle (Sallis et al., 2012). Given that these neighbourhood characteristics are modifiable through policy, these factors are especially attractive targets for policy interventions.

4.1. Strengths and limitations

There are several strengths and limitations that should be considered when interpreting the findings of this review. It should be considered a strength that this review included both peer-reviewed studies and grey literature, which attenuates the likelihood of publication bias. Among this study's limitations, it should be noted that the findings are based on 23 studies, the majority of which were conducted in the United States. Further, there was large variability in both the measures of the built environment and the measures of physical function. We did not exclude or weight study findings based on their individual rigor. This is important to note given that many studies did not provide estimates of the reliability of their built environment or physical function measures. We also did not stratify findings by methods of assessment. Self-report measures of the perceived environment may yield inflated estimates of associations due to reverse causality, whereby people with physical limitations perceiving their neighbourhood as having less desirable built environments. Last, it was beyond the resources of this project to include papers published in languages other than English.

4.2. Recommendations for future research

This systematic review suggests several priorities for future research. First, most studies focused on the individual's neighbourhood environment. More objective measurement of how much time people spend in their neighbourhood (e.g., via GPS monitors), will provide a more accurate assessment of an individual's exposure to each environment characteristic (Hirsch et al., 2016). Second, there is a need for more longitudinal studies with multiple assessments that can permit estimation of temporal precedence in effects (i.e., changes in the objective and perceived environment leading to changes in physical function). Third, greater exploration is needed of the possible mechanisms linking the built environment and physical function. It can be argued that physical activity is a mediator, but it is not clear whether physical activity for exercise or recreation and that for transport are equally relevant. Fourth, there is a need for more studies from multiple locations, especially those with larger variability in environmental exposures. Less than half the studies in this review were from more than one city. Fifth, it is important to note that there were a larger proportion of significant positive findings from longitudinal studies (61%) compared to cross-sectional studies (26%). This may suggest cross-sectional studies looking at functional capacity at one point in time may be less suitable for examining environmental attributes related to physical function. Last, there were less than five studies investigating the associations of walkability, residential density, street connectivity, and public transport with physical function. They are known correlates of residents' walking. Further research is clearly required in these areas to better understand their role in residents' physical function.

Evidence was found for positive associations between pedestrian infrastructure and aesthetics and physical function, weaker evidence for land use mix, and safety from crime and traffic, and a lack of evidence for walkability, residential density, street connectivity and access to public transport. Several priorities for future research have been identified, which offer direction for the field to improve our understanding of the association between the built environment and physical function.

Conflicts of interest

The authors declare they have no actual or potential competing interests.

Acknowledgements

At the time this study was conducted, JNR and VHYL were supported by the NHMRC Centre of Research Excellence in Healthy, Liveable, and Equitable Communities (APP1061404). EC is supported by an ARC Future Fellowship (FT3 #140100085).

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.healthplace.2019.05.015.

References

Badland, H., Whitzman, C., Lowe, M., Davern, M., Aye, L., Butterworth, I., et al., 2014. Urban liveability: emerging lessons from Australia for exploring the potential for indicators to measure the social determinants of health. Soc. Sci. Med. 111, 64–73.
Balfour, J.L., Kaplan, G.A., 2002. Neighborhood environment and loss of physical function in older adults: evidence from the alameda county study. Am. J. Epidemiol. 155, 507–515.
Barnett, D.W., Barnett, A., Nathan, A., Van Cauwenberg, J., Cerin, E., 2017. Built environmental correlates of older adults' total physical activity and walking: a systematic review and meta-analysis. Int. J. Behav. Nutr. Phys. Act. 14, 103.
Bartlett, H., Carroll, M., 2011. Ageing in place down under. Global Ageing 225.
Beard, J.R., Blaney, S., Cerda, M., Frye, V., Lovasi, G.S., Ompad, D., et al., 2009. Neighborhood characteristics and disability in older adults. J. Gerontol. Series B gbn018.
Bennett, G.G., McNeill, L.H., Wolin, K.Y., Duncan, D.T., Puleo, E., Emmons, K.M., 2007. Safe to walk? Neighborhood safety and physical activity among public housing residents. PLoS Med. 4, 1599–1606.
Beswick, A.D., Rees, K., Dieppe, P., Ayis, S., Gooberman-Hill, R., Horwood, J., et al., 2008. Complex interventions to improve physical function and maintain independent living in elderly people: a systematic review and meta-analysis. Lancet 371, 725–735.
Brown, S.C., Mason, C.A., Perrino, T., Lombard, J.L., Martinez, F., Plater-Zyberk, E., et al., 2008. Built environment and physical functioning in hispanic elders: the role of “eyes on the street”. Environ. Health Perspect. 116, 1300.
Bruce, B., Fries, J.F., Ambrosini, D., Lingala, B., Gandek, B., Rose, M., et al., 2009. Better assessment of physical function: item improvement is neglected but essential. Arthritis Res. Ther. 11, 1.
Byles, J.E., Mackenzie, L., Redman, S., Parkinson, L., Leigh, L., Curryer, C., 2014. Supporting housing and neighbourhoods for healthy ageing: findings from the housing and independent living study (hail). Australas. J. Ageing 33, 29–35.
Centers for Disease Control and Prevention, 2013. Healthy Places Terminology: Aging in Place. Centers for Disease Control and Prevention, Atlanta, GA Retrieved from. http://www_cdc_gov/healthyplaces/terminology_htm.
Cerin, E., 2010. Statistical approaches to testing the relationships of the built environment with resident-level physical activity behavior and health outcomes in cross-sectional studies with cluster sampling. J. Plan. Lit 0885412210386229.
Cerin, E., Sit, C.H., Cheung, M-c, Ho, S-y, Lee, L-cJ., Chan, W-m, 2010. Reliable and valid news for Chinese seniors: measuring perceived neighborhood attributes related to walking. Int. J. Behav. Nutr. Phys. Act. 7, 84.
Cerin, E., Conway, T.L., Cain, K.L., Kerr, J., De Bourdeaudhuij, I., Owen, N., et al., 2013. Sharing good news across the world: developing comparable scores across 12 countries for the neighborhood environment walkability scale (news). BMC Public Health 13, 309.
Cerin, E., Nathan, A., Van Cauwenberg, J., Barnett, D.W., Barnett, A., 2017. The neighbourhood physical environment and active travel in older adults: a systematic review and meta-analysis. Int. J. Behav. Nutr. Phys. Act. 14, 15.
Chandrabose, M., Rachele, J., Gunn, L., Kavanagh, A., Owen, N., Turrell, G., et al., 2019. Built environment and cardio-metabolic health: systematic review and meta-analysis of longitudinal studies. Obes. Rev. 20, 41–54.
Clarke, P.J., 2014. The role of the built environment and assistive devices for outdoor mobility in later life. J. Gerontol. Series B 69, S8–S15.
Clarke, P., George, L.K., 2005. The role of the built environment in the disablement process. Am. J. Public Health 95, 1933–1939.
Clarke, P., Ailshire, J.A., Bader, M., Morenoff, J.D., House, J.S., 2008. Mobility disability and the urban built environment. Am. J. Epidemiol. 168, 506–513.
Durand, C.P., Andalib, M., Dunton, G.F., Wolch, J., Pentz, M.A., 2011. A systematic review of built environment factors related to physical activity and obesity risk: implications for smart growth urban planning. Obes. Rev. 12, e173–e182.
Etman, A., Kamphuis, C.B., Pierik, F.H., Burdorf, A., Van Lenthe, F.J., 2016. Residential area characteristics and disabilities among Dutch community-dwelling older adults. Int. J. Health Geogr. 15, 42.
Ewing, R., Cervero, R., 2010. Travel and the built environment: a meta-analysis. J. Am. Plan. Assoc. 76, 265–294.
Fay-Ramirez, S., 2014. The comparative context of collective efficacy: understanding neighbourhood disorganisation and willingness to intervene in seattle and brisbane. Aust. N. Z. J. Criminol 0004865814536707.
Feng, J., Glass, T.A., Curriero, F.C., Stewart, W.F., Schwartz, B.S., 2010. The built environment and obesity: a systematic review of the epidemiologic evidence. Health Place 16, 175–190.
Frank, L.D., Sallis, J.F., Saelens, B.E., Leary, L., Cain, K., Conway, T.L., Hess, P.M., 2010. The development of a walkability index: application to the Neighborhood Quality of Life Study. Brit. J. Sports Med. 44, 924–933.
Freedman, V.A., Grafova, I.B., Schoeni, R.F., Rogowski, J., 2008. Neighborhoods and disability in later life. Soc. Sci. Med. 66, 2253–2267.
Gelormino, E., Melis, G., Marietta, C., Costa, G., 2015. From built environment to health inequalities: an explanatory framework based on evidence. Prev. Med. Rep. 2, 737–745.
Hirsch, J.A., Winters, M., Ashe, M.C., Clarke, P.J., McKay, H.A., 2016. Destinations that older adults experience within their gps activity spaces: relation to objectively

measured physical activity. Environ. Behav. 48, 55–77.
Hutchison, T., Morrison, P., Mikhailovich, K., 2006. A Review of the Literature on Active Ageing. Canberra.
Kavanagh, A.M., Bentley, R., Turrell, G., Broom, D.H., Subramanian, S., 2006. Does gender modify associations between self rated health and the social and economic characteristics of local environments? J. Epidemiol. Community Health 60, 490–495.
Kerr, J., Rosenberg, D., Frank, L., 2012. The role of the built environment in healthy aging community design, physical activity, and health among older adults. J. Plan. Lit. 27, 43–60.
Kerr, J., Sallis, J.F., Owen, N., De Bourdeaudhuij, I., Cerin, E., Sugiyama, T., et al., 2013. Advancing science and policy through a coordinated international study of physical activity and built environments: ipen adult methods. J. Phys. Act. Health 10, 581–601.
Keysor, J.J., Jette, A.M., LaValley, M.P., Lewis, C.E., Torner, J.C., Nevitt, M.C., et al., 2010. Community environmental factors are associated with disability in older adults with functional limitations: the most study. J. Gerontol. Series A 65, 393–399.
Lamb, K.E., White, S.R., 2015. Categorisation of built environment characteristics: the trouble with tertiles. Int. J. Behav. Nutr. Phys. Act. 12, 19.
Larson, N.I., Story, M.T., Nelson, M.C., 2009. Neighborhood environments: disparities in access to healthy foods in the us. Am. J. Prev. Med. 36, 74–81 e10.
Latham, K., Williams, M.M., 2015. Does neighborhood disorder predict recovery from mobility limitation? Findings from the health and retirement study. J. Aging Health 0898264315584328.
Levasseur, M., Généreux, M., Bruneau, J.-F., Vanasse, A., Chabot, É., Beaulac, C., et al., 2015. Importance of proximity to resources, social support, transportation and neighborhood security for mobility and social participation in older adults: results from a scoping study. BMC Public Health 15, 503.
Loh, V.H., Rachele, J.N., Brown, W.J., Ghani, F., Turrell, G., 2018. Neighborhood disadvantage and physical function: the contributions of neighborhood-level perceptions of safety from crime and walking for recreation. J. Phys. Act. Health 15, 553–563.
Manini, T.M., Pahor, M., 2009. Physical activity and maintaining physical function in older adults. Br. J. Sports Med. 43, 28–31.
McCormack, G.R., Shiell, A., 2011. In search of causality: a systematic review of the relationship between the built environment and physical activity among adults. Int. J. Behav. Nutr. Phys. Act. 8, 125.
Michael, Y.L., Gold, R., Perrin, N.A., Hillier, T.A., 2011. Built environment and lower extremity physical performance: prospective findings from the study of osteoporotic fractures in women. J. Aging Health 0898264311412597.
Moher, D., Liberati, A., Tetzlaff, J., Altman, D.G., 2009. Preferred reporting items for systematic reviews and meta-analyses: the prisma statement. Ann. Intern. Med. 151, 264–269.
Moore, L.V., Roux, A.V.D., Nettleton, J.A., Jacobs, D.R., 2008. Associations of the local food environment with diet quality—a comparison of assessments based on surveys and geographic information systems the multi-ethnic study of atherosclerosis. Am. J. Epidemiol. 167, 917–924.
Nascimento, CFd, Duarte, Y.A.O., Lebrao, M.L., Chiavegatto Filho, A.D.P., 2018. Individual and neighborhood factors associated with functional mobility and falls in elderly residents of são paulo, Brazil: a multilevel analysis. J. Aging Health 30, 118–139.
Nguyen, T.T., Rist, P.M., Glymour, M.M., 2016. Are self-reported neighbourhood characteristics associated with onset of functional limitations in older adults with or without memory impairment? J. Epidemiol. Community Health jech-2016-207241.
Ogilvie, D., Foster, C.E., Rothnie, H., Cavill, N., Hamilton, V., Fitzsimons, C.F., et al., 2007. Interventions to promote walking: systematic review. BMJ 334, 1204.
Patel, K.V., Coppin, A.K., Manini, T.M., Lauretani, F., Bandinelli, S., Ferrucci, L., et al., 2006. Midlife physical activity and mobility in older age: the inchianti study. Am. J. Prev. Med. 31, 217–224.
Peeters, G., Dobson, A.J., Deeg, D.J., Brown, W.J., 2013. A life-course perspective on physical functioning in women. Bull. World Health Organ. 91, 661–670.
Productivity Commission, 2013. An Ageing australia: Preparing for the Future. Canberra.
Renalds, A., Smith, T.H., Hale, P.J., 2010. A systematic review of built environment and health. Fam. Community Health 33, 68–78.
Robinson, S.M., Jameson, K.A., Syddall, H.E., Dennison, E.M., Cooper, C., Aihie Sayer, A., et al., 2013. Clustering of lifestyle risk factors and poor physical function in older adults: the hertfordshire cohort study. J. Am. Geriatr. Soc. 61, 1684–1691.
Rosso, A.L., Auchincloss, A.H., Michael, Y.L., 2011. The urban built environment and mobility in older adults: a comprehensive review. J. Aging Res 2011.
Sakari, R., Rantakokko, M., Portegijs, E., Iwarsson, S., Sipilä, S., Viljanen, A., et al., 2017. Do associations between perceived environmental and individual characteristics and walking limitations depend on lower extremity performance level? J. Aging Health 29, 640–656.
Sallis, J.F., Floyd, M.F., Rodríguez, D.A., Saelens, B.E., 2012. Role of built environments in physical activity, obesity, and cardiovascular disease. Circulation 125, 729–737.
Schootman, M., Andresen, E.M., Wolinsky, F.D., Malmstrom, T.K., Miller, J.P., Miller, D.K., 2012. Effect of street connectivity on incidence of lower-body functional limitations among middle-aged african americans. Ann. Epidemiol. 22, 568–574.
Soma, Y., Tsunoda, K., Kitano, N., Jindo, T., Tsuji, T., Saghazadeh, M., et al., 2017. Relationship between built environment attributes and physical function in japanese community-dwelling older adults. Geriatr. Gerontol. Int. 17, 382–390.
Stankov, I., Howard, N.J., Daniel, M., Cargo, M., 2017. Policy, research and residents' perspectives on built environments implicated in heart disease: a concept mapping approach. Int. J. Environ. Res. Public Health 14, 170.
Steptoe, A., Feldman, P.J., 2001. Neighborhood problems as sources of chronic stress: development of a measure of neighborhood problems, and associations with socio-economic status and health. Ann. Behav. Med. 23, 177–185.
Sugiyama, T., Cerin, E., Mridha, M., Koohsari, M.J., Owen, N., 2017. Prospective associations of local destinations and routes with middle-to-older aged adults' walking. Gerontol. 58, 121–129.
Takahashi, P.Y., Baker, M.A., Cha, S., Targonski, P.V., 2012. A cross-sectional survey of the relationship between walking, biking, and the built environment for adults aged over 70 years. Risk Manag. Healthc. Pol. 5, 35.
Thompson, S., Kent, J., 2013. Connecting and strengthening communities in places for health and well-being. Aust. Plan. 1–12.
Van Cauwenberg, J., Nathan, A., Barnett, A., Barnett, D.W., Cerin, E., 2018. Relationships between neighbourhood physical environmental attributes and older adults' leisure-time physical activity: a systematic review and meta-analysis. Sports Med. 48, 1635–1660.
Van Dyck, D., Cerin, E., Conway, T.L., De Bourdeaudhuij, I., Owen, N., Kerr, J., et al., 2013. Perceived neighborhood environmental attributes associated with adults' leisure-time physical activity: findings from Belgium, Australia and the USA. Health Place 19, 59–68.
Van Dyck, D., Cerin, E., De Bourdeaudhuij, I., Salvo, D., Christiansen, L.B., Macfarlane, D., et al., 2015. Moderating effects of age, gender and education on the associations of perceived neighborhood environment attributes with accelerometer-based physical activity: the ipen adult study. Health Place 36, 65–73.
Vogt, S., Mielck, A., Berger, U., Grill, E., Peters, A., Döring, A., et al., 2015. Neighborhood and healthy aging in a German city: distances to green space and senior service centers and their associations with physical constitution, disability, and health-related quality of life. Eur. J. Aging 12, 273–283.
Walsh, K., Gannon, B., 2011. Perceived neighbourhood context, disability onset and old age. J. Socio Econ. 40, 631–636.
Wendel-Vos, W., Droomers, M., Kremers, S., Brug, J., Van Lenthe, F., 2007. Potential environmental determinants of physical activity in adults: a systematic review. Obes. Rev. 8, 425–440.
Werngren-Elgström, M., Carlsson, G., Iwarsson, S., 2008. Changes in person-environmental fit and adl dependence among older Swedish adults. A 10-year follow-up. Aging Clin. Exp. Res. 20, 469–478.
White, D.K., Jette, A.M., Felson, D.T., LaValley, M.P., Lewis, C.E., Torner, J.C., et al., 2010. Are features of the neighborhood environment associated with disability in older adults? Disabil. Rehabil. 32, 639–645.
World Health Organisation, 2002. Active Ageing: A Policy Framework.
World Health Organization, 2018. The Global Network for Age-Friendly Cities and Communities: Looking Back over the Last Decade, Looking Forward to the Next. World Health Organization.