Master's Thesis

The influence of the built environment on walking among urban, community-dwelling older adults in the United States: A systematic review and thematic synthesis

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ABSTRACT

Background and Purpose: Driven by changing demographics, cultural shifts, and improvements in healthcare, the older adult population (≥65 years) in the United States (U.S.) is growing at a rapid and unprecedented rate. Simultaneously, the U.S, is becoming increasingly urbanized, with projections indicating that 87% of the U.S. population will live in urban centers by 2050. The convergence of an urbanizing and aging population necessitates a focus on aligning the urban environment with the needs of older adults. Among these needs is continued physical activity (PA) throughout older adulthood, yet despite the numerous physical, mental, and social benefits, the majority of older adults fail to meet recommended PA guidelines.

Objectives: To investigate the influence of the outdoor built environment on walking behaviors among urban, community-dwelling older adults (≥65 years) in the U.S. and to analyze results with reference to implications for designing and improving communities to support active living for this population.

Methods: A systematic review was conducted following PRISMA guidelines. Eight databases were searched for articles published 2011-2016 using search terms related to features of built environment, older adults, and walking. A total of 3254 abstracts were reviewed for eligibility, of which 17 studies fit all inclusion criteria. The final study set underwent quality appraisal, followed by data extraction, analysis, and thematic synthesis.

Results: Findings suggest that older adults engage in PA for two primary purposes, leisure or transport, and that unique aspects of the built environment support or act as a barrier to each type of walking. Macroscale components of walkability (e.g., land use mix, street connectivity, and population density) were consistently and positively associated with transport walking, whereas microscale elements, such as aesthetics, pedestrian infrastructure, and crossing characteristics, were more commonly associated with leisure walking.

Conclusions: Results support multiple associations between the built environment and walking behavior among older adults. This review furthers the current evidence regarding how macro and microscale features of the built environment can act upon older adults to support or discourage walking. While this area of research is growing, numerous gaps in the literature were identified. Future research is needed to improve the generalizability of findings to better inform future interventions and policies that support this population.

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INTRODUCTION

Statement of the Problem

Driven by changing demographics, cultural shifts, and improvements in healthcare, the older adult population (≥65 years) in the United States (U.S.) is growing at a rapid and unprecedented rate.[1] Estimates project a doubling of the U.S. older adult population from 2010-2050, rising from 13% (40.2 million) to 20% (88.5 million) of the population by 2050.[2] Additionally, age demographics within the population of older adults are undergoing a substantial shift. Most notably, the population categorized as oldest-old (≥85 years), is expected to increase from 14% of the population over 65 to over 21% by 2050.[2] Simultaneously, the U.S. is becoming increasing urbanized, with projections indicating that 87% of the U.S. population will live in urban centers by 2050 compared to 81% in 2014.[3] The convergence of an urbanizing and aging population necessitates a focus on aligning the urban environment with the specific health needs and challenges faced by older adults.[4]

Among these needs is continued physical activity (PA) throughout the life course. Despite physical activity's profound impact on health and wellbeing, the majority of older adults fail to meet the U.S. Department of Health and Human Services (DHHS) recommended guidelines for daily PA.[5] This lack in activity has serious health and social consequences, as sedentary older adults are significantly more likely to experience adverse, long-term health problems, reduced quality of life, and earlier loss of functional independence.[6,7] Further complicating and underscoring the significance of this problem are the unique physical challenges and changes older adults face as they age: 42% of adults over 65 currently report having a health condition or disability, and 28.3% of those 65-74 years and 47% of those 75 and over report limitations in physical functioning.[7,8] These numbers are only expected to increase in the coming years as the current population of middle-age adults shift into older adulthood.[8] Due to the prevalence of chronic health issues, sedentary behavior, and the continued growth of this population, the health care costs associated with older adults are projected to escalate at an alarming and unsustainable rate.[6,7]

Given these rising concerns, it is imperative to better understand the features of the built environment that influence PA behaviors among older adults. Prior research studying the relationship between the built environment and older adult PA indicates that a range of characteristics, such as population density, land use mix, pedestrian streetscape features, and perceptions of neighborhood quality and safety, can significantly facilitate or act as a barrier to PA.[9] By identifying and further understanding the diverse array of features that shape PA behavior, communities can be better designed to support the unique needs of older adults, and in doing so, the built environment can be used as a key resource to help support successful aging, long-term health, and functional independence among this growing and vulnerable population. Although past reviews have explored this topic, no known work has systematically investigated the recently published (2011-2016) quantitative and qualitative literature on the relationship between the built environment and PA among urban, community-dwelling older adults in the U.S. The purpose of this paper is to systematically review the latest evidence on this topic and contribute to the greater understanding of the diverse environmental factors that influence PA among the urban, community-dwelling older adult population.

Background

Physical Activity and Older Adults

Engagement in regular PA is an essential component of healthy aging. PA confers a range of valuable health benefits for older adults, including: prevention of obesity, type 2 diabetes, cardiovascular disease, osteoporosis, chronic obstructive pulmonary disease, high cholesterol, high blood pressure, and certain cancers;[6] reduction in the rates of functional decline; preservation of muscle, bone mass, and healthy body weight; improvements in glucose control, cardiovascular health, balance, and stability;[7] and treatment of certain forms of chronic pain.[6] Beyond these physical health effects, exercise provides numerous mental and cognitive health benefits, such as reduced rates of depression and anxiety, higher ratings of quality of life, improved cognitive functioning, and reduced Alzheimer's risk.[5,6] Additionally, PA is associated with decreased risk of falls, maintenance of physical functioning, and recovery from functional limitations, all of which are important factors that contribute to continued independent living. In order to experience these and other substantial health benefits associated with PA, the U.S. DHHS recommends that older adults engage in 150 minutes of moderate-intensity aerobic activity or 75 minutes of vigorous-intensity aerobic activity per week, complemented by muscle-strengthening activities.[10]

Among community-dwelling older adults, engagement in PA is a critical facilitator of successful aging-in-place and reduces the likelihood of experiencing the costly health complications linked to sedentary living.[6] Furthermore, maintenance of physical ability and independence helps prevent the associated financial and emotional challenges of relocation to a nursing home, assisted living, or other long-term care facility.[11] Yet with increasing age, the percentage of older adults who are inactive gradually rises: 35% of adults 65-74 years, 47% of those 75-84 years, and 64% of those 85 and above report recent PA.[12] Simultaneously, the percentage of older adults meeting DHHS guidelines steadily declines with age: only 42% of those 65-74 years, 31% of those 75-84 years, and 18% of those 85 years and older meet the recommended PA levels.[12] The majority of older adults not only fail to meet the DHHS guidelines, but they are largely sedentary, with adults over 70 years averaging less than 10 minutes of accelerometer derived moderate-to-vigorous physical activity (MVPA) per day.[7] This decrease in PA, rise in sedentary behavior, and the associated negative health effects highlights a major challenge facing the older adult population and the U.S. health system.

Walking and Older Adults

Among the many types of physical activity, walking is cited as a highly beneficial, accessible, low-risk, and low-cost activity that most older adults can engage in year-round and across multiple settings.[10] For adults over 65 years, walking for a period of at least 10 minutes counts towards daily MVPA.[10] Walking serves diverse purposes, such as leisure-time exercise or transportation. Even among older adults with mobility limitations or disabilities, walking is possible with the aid of assistive devices, such as walkers or canes.[13] Due to these many factors, outdoor walking is the primary source of PA among older adults, and is the most frequently cited activity among those who meet the DHHS PA guidelines.[13,14]

Further supporting the low-risk nature of this exercise, past research examining rates of injury among older walkers and joggers found that only 5% of walkers, as compared to 57% of joggers, experienced a lower extremity injury over a 12 week period.[15] Studies examining walking specifically have identified the clear health benefits of walking among this population, such as decreased risk of depression, osteoarthritis, colon cancer, hypertension, and dementia.[10] Jointly, this research indicates that regular engagement in walking reduces risk for a myriad of diseases, improves strength and flexibility, and provides relief from arthritis related discomfort.[10] As such, walking serves as a preventative measure to keep older adults within their community and outside of an institutionalized environment.[10] However, similar to PA engagement, older adults engaging in walking as a form of PA decreases with increasing age: 59% among those 65-

74 years, 49% of those 75-84 years, and 41% of those 85 years or older report recent walking.[12] Understanding the environmental factors that contribute to the marked decrease in walking is therefore essential in developing communities that encourage and facilitate this health-promoting behavior.

The Built Environment and Older Adults

Although the causes of this widespread trend of physical inactivity are multifaceted, a key factor contributing to sedentary behavior is the physical environment in which older adults live and spend their time.[7] Due to lifestyle changes and transitions, older adults are highly susceptible to the influence of the built environment.[16] Notably, this period of the life course is marked by departure from the labor force, with 73.8% of adults 65-74 years and 92% of adults over 75 years no longer participating in the workforce.[17] Upon retirement, individuals are more likely to spend the majority of their time in the proximal area surrounding their place of residence, and as a result, the neighborhood environment has greater opportunities to exert influence on behavior.[16]

Older adults experience many concerns in regards to ability to age-in-place and maintain residence in their communities safely, comfortably, and independently throughout older adulthood. Among these concerns is the fear of isolation or inability to function independently due to loss of driving status, especially for older adults residing in auto-dependent settings.[6] Many communities lack the features that support mobility and independent community living among non-driving older adults, thus creating barriers to active living and the maintenance of functional independence. Additionally, despite its inherently low risk nature and copious benefits, numerous age-related changes increase both the perceived and realized risks of walking for older adults. For example, deterioration of visual acuity, which effects the sharpness with which an individual perceives objects at a distance, puts older adults at higher risk of misinterpreting the distance between themselves and oncoming traffic.[18] When compared to younger pedestrians, older adults are significantly more likely to accept a smaller gap in traffic when crossing the road.[18] Furthermore, due to reduced mobility, older pedestrians are limited in their ability to react quickly to avoid immediate danger of oncoming vehicles, cyclists, or other rapidly-moving objects.[18] This reduced mobility impacts the speed at which older adults are able to cross the road, putting them at increased risk even at timed-intersections, as automated timers may not provide sufficient time for those with slower walking gaits.[18]

These vulnerabilities, as well the high likelihood of pre-existing, underlying health conditions or frailty, contribute to older adults being at increased risk of experiencing severe pedestrian injuries or fatalities.[18,19] The U.S. fatality rate for pedestrians over 75 years is higher than any other age group, at 2.28 per 100,000.[18] Regardless of intersection type (i.e., signalized or unsignalized), older pedestrians have a higher probability of severe injuries.[19] Unsignalized intersections, however, are particularly problematic. In 62% of pedestrian crashes at unsignalized intersections, older pedestrians were associated with a higher probability of severe injuries compared to all other age groups.[19] Additionally, past research has identified higher risks of pedestrian crashes in areas with a larger proportion of older adult residents.[20]

Considering the growth of the aging population and its particular safety needs and concerns, communities need to be planned with both older adult safety and accessibility in mind. Features of the built environment, such as sidewalk quality, street crossing amenities, and perceptions of traffic safety, may significantly impact the ability of older adults to interact with their surrounding community. Despite the numerous health benefits conferred through PA engagement, the sustainable, affordable, and safe nature of walking, and the high need for older adults to maintain mobility and independence as they age, the built environment factors that encourage and shape walking behavior among this population are not fully understood. It is essential, therefore, to understand these variables, as they can be used to inform urban planners, developers, city transportation officials, and public health departments how to design healthy communities and implement effective interventions to the built environment that encourage active living throughout the lifespan.

REVIEW AIMS

The objective of this review is to investigate the influence of the neighborhood built environment on walking behaviors among urban, community-dwelling older adults living in the U.S. While the built environment can also refer to the indoor home environment, this review will focus exclusively on the neighborhood features and qualities that surrounding an individual's residence, with a specific focus on macroscale (e.g., land use mix, street connectivity, population density) and microscale (e.g., sidewalk design, street crossing features, aesthetics) environmental features. The specific aims of this review are to:

1. Identify recurring patterns and features of the built environment that influence walking behavior among urban, community-dwelling older adults in the U.S. (≥65 years).
2. Compare findings across studies and identify features of built environment that are most influential on the walking behaviors of this population.
3. Identify gaps in the literature, directions for future research, and areas for intervention that would hold the greatest promise to influence this population's walking behaviors.

METHODS

Query Development and Search Strategy

A systematic literature review was conducted guided by the principles of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement.[21] The following electronic databases were searched for relevant literature: AgeLine, Abstracts in Social Gerontology, Public Administration Abstracts, PubMed, Social Sciences Full Text, Social Work Abstracts, The Journal of Planning Literature, and Urban Studies Abstracts.

Search terms and search query were developed from a scoping review of existing empirical studies and theoretical commentary resulting in: (1) a list of relevant terminology and Medical Subject Headings (MeSH terms) used in past reference databases; (2) synonyms for terminology (e.g., population density and residential density); and (3) greater depth of knowledge regarding how relevant topics have been addressed in the literature. Additionally, past systematic reviews relating to this topic helped inform the search query development for this review. Identified terms were searched in PubMed to determine how they are used and defined in the literature, thus allowing the list of terms to be refined further. Once the final list of terms was determined, the search query was built out methodically to ensure it captured the full range of studies relevant to addressing the aims of this review.

Selected databases were searched using the following search terms: ("land use mix" OR "street connectivity" OR "residential density" OR "street scale" OR "built environment" OR "walkability" OR "population density" OR "environmental design") AND ("walking" OR "walk") AND ("aged" OR "older adult"). The search was then restricted to research published within the last five years (July 2011- July 2016) in order to capture the most recent body of research and build upon previously published reviews that reported on literature from 2011 and earlier (e.g., Kerr et al[22], Moran et al[5], and Yen et al[23]).

Literature Review

Phase One

A total of 3254 records were identified through database searching. All titles and abstracts were reviewed in Phase One for eligibility based on the following predetermined inclusion and exclusion criteria: (1) Participants were community-dwelling older adults (mean age ≥65 years) living in urban areas (central city and the surrounding metropolitan region) in the U.S.; (2) The study explored the outdoor built environment (exposure) and its impact on participants' PA behavior specific to walking (outcome); (3) Study population was not focused on older adults with a specified pre-existing health condition (e.g., diabetes, obesity, mobility disability); (4) Study was published in the past 5 years (July 2011-July 2016); and (5) Study was available in English. Studies using qualitative as well as quantitative methods were included. Based on the information available from the title and abstract, 65 studies met eligibility criteria and moved on to Phase Two of the literature review.

Phase Two

The selected 65 studies underwent full-text evaluation in Phase Two. Seventeen (17) studies met all inclusion criteria and 48 were excluded. Common reasons for removal included: insufficient fit with this review's exposure and outcome of interest; study location outside of the U.S. or in a non-urban location; study focus on older adults with mobility disabilities or other health conditions (e.g., diabetes, obesity); and inappropriate age or lack of transparency regarding participant age distribution. For example, some articles focused on older adults ≥60 years without providing mean age, thus preventing verification as to whether mean age was greater than or under 65 years. Commonly, studies recruited a range of adult age categories (including ≥65), yet provided only aggregated results rather than a breakdown by age. Other studies were excluded as they focused on indoor built environments, such as malls, or on the built environment of adults living in long-term care, such as nursing homes or assisted living facilities. Studies exploring mixed ages or neighborhood types (i.e., not exclusively urban) were included only if results were clearly differentiated between groups. The seventeen studies that passed Phase Two review were reexamined to ensure fit, all seventeen were approved for inclusion in the final set of literature.

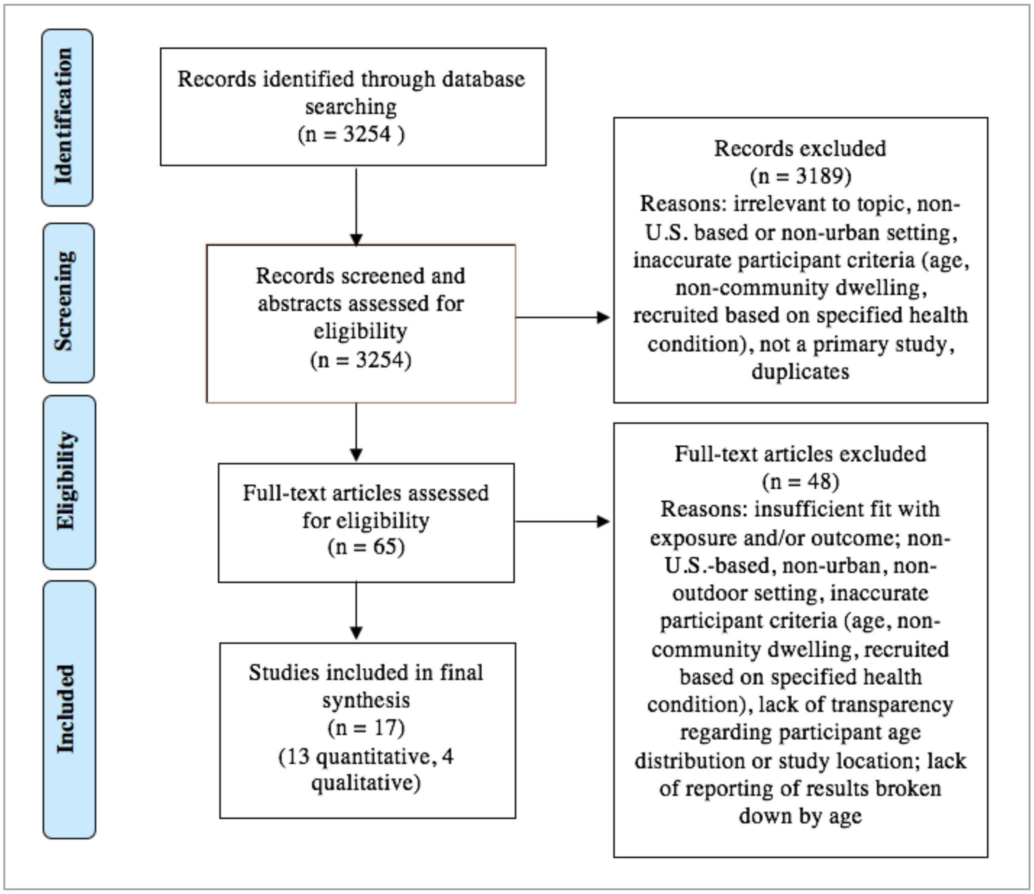

Table 1: PRISMA Flow Diagram

Quality Assurance

To evaluate the methodological rigor of the included research and whether it may have shaped findings, a quality assurance analysis was performed on both the quantitative and qualitative literature. The final 13 quantitative studies were carefully reviewed using an adapted Newcastle-Ottawa Quality Assessment Scale (NOS) for use with observational research. This adaptation was developed by Herzog et al[24] for use in a systematic review comprised of primarily cross-sectional literature, and has been adopted successfully by others.[25] Using the adapted NOS, the following criteria were assessed for each of the thirteen (13) quantitative studies: (1) Selection: representativeness of the sample, sample size, non-respondents, ascertainment of the exposure; (2) Comparability: controlling for confounding variables; (3) Outcome: assessment of the outcome; use of statistical tests. No eligible articles were excluded from content analysis due to methodological issues, though some were identified as weaker than others. *See **Appendix I** for an outline of the NOS protocol and **Appendix II** for the quality assurance rating of all quantitative studies included in this review.*

The four qualitative studies were appraised using a quality assurance checklist developed by Mays and Pope.[26] While there is less consensus and considerable debate on how methods and quality can be assessed in qualitative research,[26] this checklist was selected due to its use in prior syntheses of qualitative research[27-29] and its endorsement from the Cochrane Collaboration Qualitative Methods Group.[30] A primary concern in quality assessment of qualitative research is that it is not possible or suitable to judge qualitative research using conventional criteria such as reliability, validity, and generalizability.[26,29] Mays and Pope[26] attest that quality can be assessed using these broad concepts, however, it is necessary to operationalize these terms differently for the distinct goals and approaches of qualitative research. Past research has noted that the Mays and Pope checklist is suitable for qualitative research assessment due to its clarity, simplicity, and thorough approach to critical appraisal without being excessively prescriptive.[29] These considerations were deemed appropriate for this review. The checklist is comprised of questions regarding relevance, context clarity, design, sampling, data collection, data analysis, and reflexivity.[29] While certain studies were more transparent about methodological processes or results, none were deemed uniformly poor or excluded based on critical appraisal using the Mays Pope criteria. *See **Appendix III** for further details regarding the Mays and Pope checklist and assessment of the four qualitative studies used in this review.*

Data Extraction and Analysis

Data extraction was completed systematically in order to obtain an overview of each study's methodological characteristics and results. General characteristics and methods were extracted first, including: study design, purpose, setting (city, state, and region), sample size, sample age, exposure and outcome measurement, and variables that were controlled for in analysis (e.g., socioeconomic status (SES), gender, or marital status). Next, relevant results were extracted through multiple, careful examinations of the Tables, Results, and Discussion sections of each article. Extracted findings were then grouped together based on similarity, from which themes and subthemes emerged. Within each theme and subtheme, findings were grouped based on quantitative or qualitative methodology. Study results that were not relevant to this review's research question were not included in the data extraction or analysis.

RESULTS

Topics, Settings, and Methodologies of Reviewed Literature

General characteristics

In total, 17 studies met inclusion criteria: 13 quantitative and 4 qualitative. The majority of quantitative studies were conducted in either the Northwest (n=8) or Mid-Atlantic (n=8) regions of the U.S., followed by the West (n=4), Northeast (n=3), and Midwest (n=1), and eight studies occurred across either two (n=5) or three (n=3) states. The four qualitative studies were each conducted in a different region: Northwest, West, Midwest, and Northeast. No studies were conducted in the Southwest, Southeast, or the non-contiguous states (Alaska and Hawaii). Most studies included both men and women (n=15), with the exception of three quantitative studies that focused on women only.

Methodological characteristics of reviewed quantitative studies

All quantiative studies used a cross-sectional (n=11) or longitudinal approach (n=2). The two longitudinal studies (Ding et al[31], King et al[32]) involved measurement of study variables at two time points taken six months apart. The reviewed literature recruited a range of sample sizes (≤100 (n=1), 100-500 (n=3), 500-1000 (n=5), 1000-5000 (n=2), >5000 (n=2)) and there were varied approaches to participant recruitment and data collection. Studies collected data for both neighborhood features and PA outcomes using either a combination of objective measurement and survey or interview self-report (n=9), or self-report only (n=4). **Table 2** includes a summary of the methodological characteristics of all reviewed quantitative studies.

The majority of quantitative studies used Geographic Information System (GIS) software to analyze and objectively measure features of the built environment known to be related to PA behavior (n=8). For example, four studies used GIS to develop a walkability index for a 500 meter buffer around each participant's home based on residential density, retail floor area ratio, intersection density, and land use mix.[33-36] In a comparable approach, two studies explored population, intersection, and facility density within 800 and 1200 meters of the participant’s home.[37,38] King et al[32] used GIS-measured built environment variables (residential density, retail floor area ratio, intersection density, and land use mix) as well as income data to categorize neighborhoods based on walkability and income. Similarly, Siu et al[39] used GIS to conduct a cluster analysis of geographic units in Portland, OR. Objective measures of transit access, land use mix, intersection density, and population density were then aggregated to develop six unique urban forms (central city, city periphery, suburb, urban fringe with poor commercial access, urban fringe with poor park access, and satellite city) which were used to define different regions of the metro area.[39]

	Number of Studies	Reference Number
GENERAL		
U.S. Region		
Northwest	8	16,31-35,39,40
Mid-Atlantic	8	16,31-35,37,38
West	4	35,37,38,41
Northeast	3	37,38,42
Midwest	1	43
Southwest or Southeast	0	
Gender		
Men and women	10	16,31-35,40-43
Women only	3	37-39
METHODS		
Study Design		
Cross-sectional	12	16,33-35,37-43
Longitudinal	2	31,32
Sample size		
n≤100	1	42
100<n≤500	3	35,40,43
500<n≤1000	5	16,31-34
1000<n≤5000	2	39,41
n>5000	2	37,38
Exposure Data Collection		
Geographic Information Systems (GIS)	4	32,37-39
Self-report (SR)	4	16,41-43
Environmental audit (EA)	1	40
GIS and SR	3	31,33,34
GIS and EA	1	35
Outcome Data Collection		
Accelerometer and SR	7	16,31-35,40
SR only	6	37-39,41-43
All Data Collection		
Mixed (Objective and SR)	10	16,31-35,37-40
SR Only	3	41-43
Objective only	0	

Table 2: General and methodological characteristics of quantitative literature

Four studies combined GIS-derived measurement with a non-objective measure, such as self-reported perceptions of the neighborhood (n=3) or an environmental audit (n=1).[31,33-35] Self-reported perceptions were measured using the Neighborhood Environment Walkability Scale (NEWS), a validated scale that assesses participant perceptions of a neighborhood's urban form and recreation-oriented variables.[16] The environmental audit was conducted using the Microscale Audit of Pedestrian Streetscapes (MAPS) tool, which measures streetscape characteristics (e.g., street design, transit stops, sidewalk qualities, street crossing amenities, and features related to aesthetics) for a 0.25 mile route from the participant's home towards pre-selected non-residential destinations.[35] All studies using only self-report methods focused on measuring perceptions of the built environment using NEWS (n=3),[16,42,43] with the exception of the work from Li and colleagues[41], which did not specify the measure used for assessing the built environment. Lastly, Sallis et al[40] conducted the only study in this review that employed environmental audit alone, using MAPS and its shortened version, MAPS-Mini.

To measure PA, seven studies combined objective, accelerometer measured PA with self-report. All studies used Actigraph accelerometers, which are the most widely used brand in PA research[44] and are reliable and valid measures of PA in the older adult population.[33] Accelerometers are used to measure overall moderate or vigorous physical activity (MVPA), which among older adults is predominantly made up of walking for transport or leisure.[44] They are considered the ideal measurement tool for PA in older adults, as they are simple to use, require no input from the participant during the collection period, and eliminate bias associated with subjective recall of past PA via self-report questionnaires, a task that can be particularly problematic for older adults due to declines in memory recall.[44] Within the studies included in this review, accelerometers were worn for a range of 5-7 days, with a valid day serving as a minimum of 8-10 hours of continuous wear.[33] Self-reported PA was assessed using the Community Healthy Activities Model Program for Seniors (CHAMPS) survey, a validated measure among older adults. CHAMPS tasks participants with recalling activities performed over the previous four weeks, such as walking for errands, leisure, or transport.[16]

Combining these two measurement strategies is ideal for capturing the range of walking behavior among older adults. Prior literature has identified that older adults engage in two primary types of PA, walking for transportation (i.e., to a specified location) and leisure (i.e., for recreation or relaxation), and that unique factors of the built environment shape engagement in each type of walking.[45] By measuring overall moderate-to-vigorous PA, accelerometers are instrumental in gathering an accurate, general understanding of PA engagement. However, they are not able to capture the type, purpose, or motivation behind walking behavior, thereby highlighting the need to compliment objective measurements with self-report data.[45]

Among the seven studies that measured PA using self-report, two used previously validated measures that sought to determine walking over the previous seven days. Gallagher and colleagues[43] used items from the Neighborhood Physical Activity Questionnaire, whereas Maisel[42] used selections of the International Physical Activity Questionnaire. Three studies did not report use of a specific measurement tool, however, they asked participants standard questions about recent PA engagement (e.g., total number of blocks walked daily; frequency/total duration of walking in the past week). Alternatively, two studies sought to determine if participants met the U.S. DHHS recommendation of 150 min/week of walking by measuring the average time per week participants engaged in difference types of PA over the past year and assigning a metabolic equivalence task (MET) value for walking based on pace.[37,38]

Methodological characteristics of reviewed qualitative studies

Three of the four qualitative studies used exclusively qualitative methods, including photovoice (n=2)[46,47] and semi-structured interviews (n=1)[14], and one study used mixed-methods. [48] All were cross-sectional designs. The photovoice studies involved participants describing photographs they took for the purposes of depicting perceived facilitators or barriers to PA engagement.[46,47] The one semi-structured interview study looked at built environment factors that influence older adults' fear of falling, as well as their ability and motivation to engage in outdoor PA.[14] The fourth qualitative study used a mixed-methods approach by combining quantitative neighborhood audits with qualitative in-person interviews and walk-alongs (i.e., an interview conducted while the participant walked through the neighborhood on a pre-determined route).[48] While all four studies differed slightly in study aims, each produced data that described environmental facilitators and barriers to PA. **Table 3** provides a summary of all general and methodological characteristics of the four qualitative studies included in this review.

	Number of Studies	Reference Number
GENERAL		
U.S. Region		
Northwest	1	47
West	1	46
Northeast	1	14
Midwest	1	48
Mid-Atlantic, Southwest, Southeast	0	
METHODS		
Study Design		
Qualitative	3	14,47,48
Mixed-Methods	1	48
Data Collection Method		
Semi-structured interviews	2	14,48
Photovoice	2	46,47
Walk-along	1	48
Sample Size		
n≤20	1	14
20<n≤30	1	46
30<n≤40	2	47,48

Table 3: General and methodological characteristics of qualitative literature

Built Environment Features Identified in the Reviewed Literature

The following sections outline the seven primary constructs that emerged from the data: (1) Residential and Population Density, (2) Walkability, (3) Neighborhood Land Composition, (4) Street Network Composition, (5) Pedestrian Infrastructure, (6) Safety, and (7) Environmental Appeal and Conditions. Both the quantitative and qualitative studies covered environmental variables within two broad categories, macroscale features and microscale features. Macroscale features consist of the broader structural features that comprise an environment and its overall walkability index, such as population and residential density, street connectivity, and land use mix.[35] Conversely, microscale features make up the finer details that more directly shape the pedestrian experience and environment, such as aesthetics, sidewalk quality and design, and street crossing amenities.[35] Macroscale-oriented themes are described first, followed by microscale themes, however, many themes included cross-over between the two general categories. **Table 4** summarizes all the broad built environment constructs identified within the body of reviewed literature, the specific built environment features examined, and the findings regarding the association between these characteristics and walking PA among older adults.

Table 4: General and Specific Built Environment Features Studied and Associations with Physical Activity Findings

General Built Environment Characteristic	Specific Built Environment Features	Physical Activity Related Findings	Relevant Studies
Residential and Population Density	Residential and population density	High population or residential density consistently associated with increased likelihood of overall, leisure, and transport walking. Positive effect of residential density on walking particularly strong when combined with other walkability features (e.g., land use mix, street connectivity).	Adams[16], Gallagher[43], Siu[39], Tamura[37], Troped[38]
Walkability	Walkability index	High walkability emerged as a key facilitator of overall PA. High walkability particularly supportive for older adults with mobility limitations; supportive for those who lack or have given up driving-status; supportive in helping older adults overcome perceived barriers to PA. Walkability positively associated with walking for both transport and leisure. Walkability had stronger association with walking for transport compared to walking for leisure. Interactions affecting leisure walking more related to walking infrastructure (e.g., access to facilities, aesthetics) as opposed to macroscale walkability index.	Adams[16], Carlson[34], Ding[31], King[32]
Street Network Composition	Street connectivity and intersection density	Overall street connectivity (e.g., limited cul-de-sacs, short block lengths, presence of four-way intersections) and greater intersection density positively associated with walking.	Maisel[42], Siu[39], Tamura[37], Troped[38]
Neighborhood Land Composition	Land use and access to daily destinations	Increased walking associated with heterogeneous neighborhood destinations (restaurants, entertainment, shops, and services), especially those with utilitarian, recreational, or social component, such as services (e.g., post office), shops (e.g., grocery store), facilities (e.g., library), and PA facilities (e.g., recreation center, gym).	Adams[16], Bracy[33], *Buman*[46], Cain[35], Carlson[34], *Chaudhury*[47], *Chippendale*[14], Ding[31], Gallagher[43], King[32], Siu[39], Tamura[37], Troped[38]
	Parks and outdoor recreational spaces	Abundant opportunities to rest along walking trails or paths helped facilitate park use. Barriers to park use include concerns about lack of safe paths, public restrooms, or places to rest; fear of being too isolated or vulnerable to crime. Lack of overall perceptions of safety in parks as compared to indoor recreational facilities or commercial areas.	*Buman*[46], *Chaudhury*[47], *Chippendale*[14] Li[41], Siu[39]

General Built Environment Characteristic	Specific Built Environment Features	Physical Activity Related Findings	Relevant Studies
	Public and motorized transport	Availability of convenient, consistent public transit system encouraged neighborhood walking. Presence or availability of motor vehicle parking not influential on active living.	*Buman*[46], *Chaudhury*[47], *Chippendale*[14]
Pedestrian Infrastructure	Sidewalk presence, quality, and design	Facilitators of PA included sidewalk continuity; presence of smooth, wide, spacious, and well-maintained sidewalks; buffer between the sidewalk and street; presence of curbs cuts and benches. Barriers to PA included uneven or slippery surfaces (e.g., cobblestone, brick, tile, grates), cracks, obstructions, lack of ramps, insufficient maintenance or snow/ice removal.	*Buman*[46], *Chaudhury*[47], *Chippendale*[14], Gallagher[43], Sallis[40]
	Crosswalk presence, quality, and design	Features supporting PA included crosswalk markings, wide crossings, ramped curbs, crossing signals (e.g., walk, countdown, and/or audible signals), and other pedestrian protections or aids (e.g., protected refuge islands, curb extensions). Barriers to PA included inoperable/broken crosswalks and lack of midblock crossing opportunities.	*Buman*[46], Cain[35], *Chaudhury*[47], *Chippendale*[14], Sallis[40]
	Presence and quality of street lighting	Presence of street lights provided support for PA by increasing perceptions of safety and security, improving visibility of sidewalk obstructions, vehicles, cyclists and other non-motorized transport, and reducing fear of falling.	*Buman*[46], *Chaudhury*[47], *Chippendale*[14], Sallis[40]
	Wayfinding strategies, aids, and cues	Presence of clear street signs, numbers of buildings, block numbers, advance street signs, clear and logical street labeling conventions (e.g., numbered grid system), transit stops, railroad tracks, landmarks, and other individuals to ask for help were all supportive of engagement in walking in both familiar and unfamiliar neighborhoods.	*Marquez*[48]
Safety and Comfort	Street safety	Increased perceptions of street safety encouraged PA. Facilitators of street safety included elevators for subway access, benches for resting, kneeling buses, fences/railings to hold for support, and timed crossings. Fear of traffic related injuries was a barrier to PA. Fears regarding street safety were enhanced by busy streets, high traffic volume and speed, unsafe intersections and crosswalks, dangerous or impatient drivers, poor visibility, and being struck by non-motorized transport (e.g., cyclists, skateboarders).	*Buman*[46], *Chaudhury*[47], *Chippendale*[14], Li[41], Maisel[42]

General Built Environment Characteristic	Specific Built Environment Features	Physical Activity Related Findings	Relevant Studies
	Perceived safety and crime	Perception of safety from crime encouraged walking within the neighborhood. Safety perceptions improved by presence of other people/pedestrians. Perception of unsafe environment, fears of personal safety, and difficulty with wayfinding discouraged engagement in PA and contributed to concerns about leaving home, especially at night. Perceptions of unsafe environment enhanced by presence of crime, graffiti, and vandalism.	*Buman*[46], *Chaudhury*[47], *Chippendale*[14], Gallagher[43], Li[41], Maisel[42], *Marquez*[48]
Environmental Appeal and Conditions	Aesthetics	Positive aesthetics facilitated engagement in PA, including presence of street trees and well-maintained green spaces; plantings, flowers, or gardens; attractive scenery, views, landscaping, or architecture; settings that promoted connectivity to nature; and absence of broken glass, litter, graffiti.	*Buman*[46], Carlson[34], *Chippendale*[14], Maisel[42], Sallis[40]
	Weather	Pleasant, temperate weather motivated walking. Walking was discouraged by unpleasant weather or environmental conditions, such as high heat, humidity, cold, snow, or pollution, as well as seasonal changes in daylight (e.g., early darkness in winter).	*Chippendale*[14], Gallagher[43]

Note: Italics indicate qualitative study.

Residential and Population Density

Residential and population density are macroscale measures of the built environment that emerged as influential variables within the literature. Typically, residential density measures the concentration dwelling units per square kilometer (or other unit of measurement), whereas population density captures the average number of persons per square kilometer of an area. While eight studies in the final set objectively measured either neighborhood residential density (n=5) or population density (n=3) using GIS methods to analyze census and land use data, three articles omitted explicit discussion of results relating to this variable. This lack of reporting was likely due to population/residential density's role as a component of the overall walkability index in an area. As such, some studies reported only the impact of walkability on PA behavior, rather than for each subcomponent of the walkability index. However, five studies did explicitly address the effect of population or residential density on PA. Adams and colleagues[17] found that residentially dense neighborhoods, when combined with other walkability features (e.g., land use mix diversity, access to amenities, and street connectivity), were associated with the best overall PA outcomes, including highest engagement in transport and leisure walking compared to all neighborhood profiles examined. Conversely, neighborhoods characterized by low residential density (among other walkability variables), were associated with the poorest PA performance.[16]

A number of studies looked at gender specific effects of residential density. Gallagher et al[43] examined gender differences in walking behavior among older adults, finding that walking for transport and total neighborhood walking were influenced by neighborhood density for men, yet not for women. Despite disparities emerging in walking behaviors by gender in areas of varying residential densities, this research found no significant gender differences in perception of neighborhood density.[43] Research examining the effects of population density on older women found that participants were more likely to walk for exercise and transport in neighborhoods characterized by high population density compared to women living in lower population density areas.[39] Additionally, living in an area of higher population density was significantly associated with older women who met the DHHS recommended minimum PA levels via walking.[38] Tamura et al's[37] study exploring spatial clusters of PA in Massachusetts and California, found that population density was significantly associated with areas of high physical activity. Women living in higher density neighborhoods, especially those in the 90.1-95th and 95.1-100th percentiles of population density, had significantly greater odds of meeting the DHHS recommended minimum PA levels via walking.[37] Among women in these areas of higher population density, living in a neighborhood that also had high facility density (in particular, services, cultural and educational, and recreational facilities) resulted in an even higher likelihood of meeting PA recommendations.[37] These results are explained in part by Siu et al's[39] findings that areas of high population density were often supported by characteristics associated with high walkability, such as high street connectivity and convenient access to amenities, especially transit and commercial areas. These findings did not hold true, however, in areas with lower population density and high density of facilities, indicating that a relatively high level of population density may be needed for facility access to support walking behavior among older women, as these environments may be low walkable environments lacking in key supportive infrastructure.[37]

Walkability

A neighborhood's walkability is an aggregate of macroscale variables that are commonly associated with a greater prevalence of PA, such as high residential density, mixed land use, and a well-connected street pattern (i.e., street connectivity).[16] Eight studies used GIS analysis of census, land use, transportation, and other publicly available place-based data, to develop an objective score of overall walkability surrounding participants' place of residence. Other studies relied on participant self-report of walkability using the Neighborhood Environment Walkability Scale (NEWS), a validated survey based measure that was adapted for an older adult population and explores the urban landscape and variables that effect recreation in an individual's environment.[16] While some research broke down walkability and explored the relationships between its subcomponents and PA, five research articles analyzed walkability as a summary measure. Within these findings, two patterns emerged in regard to walkability's effect on unique types of walking behavior, as well as on older adults with different limitations: *1. Effect on type of walking; 2. Effect on those with mobility limitations.*

1. Effect on type of walking

Neighborhood walkability emerged as a key driver of overall PA.[16,32,34] Research by Carlson et al[34] exploring GIS-derived walkability indices found positive associations between neighborhood walkability and accelerometer measured MVPA ($p<.01$). Additionally, older adults residing in objectively measured higher walkability areas experienced fewer perceived barriers to PA engagement.[34] Using comparable methods, King et al[32] identified similar findings, with older adults living in higher walkability neighborhoods averaging 69.4 minutes/week of MVPA, compared to 52.2 minutes/week in lower walkability neighborhoods. Although these numbers are only 17.2 minutes/week apart, they reveal a 33% disparity in PA minutes/week between high and low walkability neighborhoods. Considering the already low levels of PA engagement among older adults, this difference is especially concerning, as overtime it could result in significant disparities in the maintenance of physical abilities, functional independence, and quality of life.[32]

King and colleagues[32] also found interactions between walkability and neighborhood income levels. Despite most older adults failing to meet the DHHS recommended >150 minutes/week of MVPA regardless of neighborhood, those residing in higher walkability/higher income neighborhoods had a significantly greater likelihood of meeting recommendations (17.8%), as to compared high walkability/low income neighborhoods (8.6%).[32] However, when comparing neighborhoods of similar income levels, researchers found significant differences between high and low walkability. Among high income neighborhoods, high walkability was associated with a 6.5% higher rate of residents meeting PA guidelines compared to residents in high income but low walkability neighborhoods (17.8% of residents compared to 11.2%).[32] In lower income neighborhoods a similar effect was observed, with 4.7% of residents meeting guidelines in high compared to low walkability neighborhoods (8.6% of residents compared to 3.9%).[32] Regardless of these disparities, most older adults engaged in insufficient amounts exercise. Even in high walkability areas, participants averaged less than 20 minutes/week, highlighting that walkability alone is not a sufficiently powerful motivator for PA among this population.[32]

In addition to having an impact on walking and overall MVPA, neighborhoods characterized by high walkability were significantly associated with the most favorable outcomes in terms of transport and leisure PA.[16] For example, Carlson et al[33] examined associations between objectively measured walkability and subjectively defined barriers to PA, separately and jointly. They found that individuals living in high walkability neighborhoods who had few perceived environmental barriers to PA engaged in 58 minutes/week of transport walking.[34] By comparison, those living in neighborhoods of low walkability with high perceived barriers to PA spent on average almost 50% fewer minutes walking for transport, with only 28 minutes/week.[34] This finding was corroborated by King and colleagues, who found a significant, positive relationship (p<.001) between objectively measured neighborhood walkability and the average number of minutes/week spent walking for transport.[32] Notably, interactions related to walking for transport were more related to walkability, whereas interactions related to leisure walking tended to be related to walking infrastructure, such as sidewalk quality, access to parks, or neighborhood aesthetics.[34] Despite this finding, research exploring GIS-measured walkability found a positive association between neighborhood walkability and walking for leisure (p<.05), highlighting the positive influence walkability can have across all types of walking behavior.[34]

2. Effect on older adults with mobility limitations

The effect of neighborhood walkability held its influence even among older adults with different types of limitations, such as physical impairment or driving status.[31,32] In a multi-city study, King and colleagues[31] found that regardless of physical limitations, older adults living in lower walkability neighborhoods had low rates of walking for transport (e.g. to complete errands or travel outside the home). However, in comparison, older adults across all physical ability levels exhibited a greater range of PA behavior in high walkability neighborhoods. Notably, the most mobility impaired older adults living in high walkability neighborhoods reported transport activity similar to those who were less impaired but living in a low walkable area.[32] These findings suggest that the incorporation of walkable design may allow residents across the spectrum of mobility impairment to optimize their ability to participate in walking transport activity.[32] This finding underscores the ways in which the built environment can support all older adults (regardless of mobility level) in increasing PA. Even brief amounts PA, such as short errands within the neighborhood are significant, as they helps facilitate and support the continued independence necessary for successful aging-in-place and maintained quality of life.[32]

Ding et al[35] examined neighborhood walkability effects on PA by driving status. Among older adults who differed based on driving status (i.e., current driver or non-driver), attributes of the neighborhood environment exhibited similar influence on transport walking.[36] This finding highlights the importance of walkable, activity-friendly neighborhoods to encourage PA and facilitate walking among all older adults.[36] An interesting distinction arose in regards to where driving and non-driving older adults chose to live: non-driving older adults were significantly more likely to live in neighborhoods with activity-friendly environmental features compared to their driving counterparts.[36] However, because this finding arose from cross-sectional research, temporal order cannot be determined between driving status and residing in a highly walkable neighborhood. It is not known, therefore, whether older adults gave up driving and subsequently relocated to a walkable neighborhoods, or if due to living in a pedestrian-friendly, non-automobile reliant environment, they stopped driving.[36]

Street Network Composition

The street network composition, and in particular, street connectivity and intersection density, emerged as a link between the neighborhood environment and PA behavior among older adults. Street connectivity describes the ease of travel between different points based on street design, such as limited cul-de-sacs, short block lengths, or the presence of four-way intersections.[42] Notably, street connectivity is among the variables that commonly make up GIS-measured walkability. Similar to other variables that comprised walkability in this review (e.g., residential/population density, land use mix), street connectivity was not consistently discussed as a unique variable, but rather, was analyzed as part of overall walkability.

Despite this limitation, street connectivity was discussed in the set of reviewed articles. Maisel[42] explored the relationship between perceptions of street connectivity and PA, finding a small, positive correlation ($r=.25$; $p<.01$) between older adults with positive perceptions of street connectivity and job walking (i.e., walking that occurs while engaging in paid or unpaid work, such as volunteering), transportation walking, and total weekly walking. Additionally, research looking at the influence of objectively-measured street connectivity on PA behavior of older women found that those living in neighborhoods characterized by high street connectivity were more likely to walk for leisure and transport.[39] Similar results were found in a study by Tamura et al[37] comparing measurements of intersection density with walking behavior. Study results indicate that that women living in neighborhoods with a density in the range of >2-11 intersections/km had an 18% greater odds of meeting DHHS daily recommendations for PA (>150 minutes/week) compared to neighborhoods with <2 intersections/km.[37]

Neighborhood Land Composition

Neighborhood land use, and in particular, the presence of diverse destinations and amenities, was referenced throughout the studies reviewed as a driver of PA. Three specific features of land use composition emerged as important: *1. Land use and access to daily destinations; 2. Parks and outdoor recreational spaces; 3. Public transit and motorized transport.*

1. Land use and access to daily destinations

Neighborhood land use and the availability of non-residential, daily destinations emerged as a key facilitator of older adults' PA behavior. Land use mix, a GIS-measured component of an area's overall walkability index, was frequently references in the literature, however, similar to other walkability measures it was less often analyzed as a unique variable.[16,31-35,39] Cain and colleagues[35] were among the few studies that described land use mix as a stand-alone variable, finding that it significantly influenced older adults' engagement in objectively measured MVPA.[35] More commonly, however, the studies in this review focused on the specific types and density of destinations in a neighborhood, both of which played a key role as facilitators of PA. Cain et al[35] found a positive relationship between that the presence of heterogeneous neighborhood destinations and walking behavior, especially restaurants, entertainment, shops, and services (e.g., banks). It is likely that these destinations elicited positive results due to their role in providing a specific motivation to leave one's residence and thus offering a context for PA engagement.[23,35]

Multiple studies explored the effects of destinations on women only. A study from Siu and colleagues[39] looked at the relationship between different urban forms and walking among older women.[39] Neighborhoods characterized as urban fringe with poor commercial access ranked lowest among six different types of urban forms in terms of median number of daily blocks walked.[39] In contrast, older women living in high walkable neighborhoods with convenient access to amenities (especially public transit and commercial areas), were most likely to walk for both exercise and transport.[39] Across all neighborhood types, access to any destination, especially commercial areas, was beneficial in terms of PA engagement.[39] Additional research conducted specifically with older women supports the exercise-promoting nature of facilities in the neighborhood. Troped et al[38] found that facility density was significantly associated with greater odds of meeting DHHS PA recommendations for walking, even when adjusted for the participant's age, race, ethnicity, education, BMI, walking limitations, smoking status, preference for staying indoors, and number of years at current address (an indication of neighborhood familiarity). Among the eight facility types examined (retail, services, cultural/education, physical activity, restaurants, fast-food, grocery stores, convenience stores), the presence of service (e.g., post office) and/or physical activity (e.g., gym or recreation center) facilities was most associated with meeting PA recommendations.[38]

Services may provide a particular motivation for PA, as each additional service facility/km of road was associated with a 53% higher odds of meeting PA recommendations.[38] Density of PA facilities was associated with a 91% greater odds of meeting walking recommendations when adjusted for age, however, this finding was greatly attenuated when adjusted for all previously listed potential confounders.[38] This finding is likely due to the financial barriers associated with access or membership to PA facilities.

Other research supports the value of facility density for older women: Tamura et al[36] found that among women living in areas with high population density, density of services, as well as cultural, educational, and PA facilities had the strongest, positive relationship with walking outcomes.[37] Additional findings compliment this research. Using the NEWS self-report measure of neighborhood environment, Gallagher and colleagues[40] investigated the impact of destinations on walking behavior by gender.[43] For women, reporting destinations within walking distance was associated with both increased walking for transportation and total neighborhood walking, with a friend's house cited as the most common destination.[43] Men, however, were slightly more likely to report the presence of destinations within walking distance compared to women.[43]

Findings from the qualitative research reviewed provides additional evidence for the PA facilitating role of amenities and destinations. Buman et al's study[46] of individuals across five low-income housing sites found supermajority consensus (≥67% of residents referring to a built environment variable) regarding the importance of attractive amenities and destinations (e.g., shops, restaurants, and public services) in supporting active living. Using photovoice methods to document neighborhood-based facilitators and barriers to PA, Chaudhury and colleagues[47] found that accessible amenities with either a utilitarian, recreational, or social component (e.g., bank, grocery store, post office, mall, library, gym, recreation center) were most supportive of older adult PA.[47] Other qualitative research using semi-structured interviews found that stores for browsing or shopping, street fairs, and farmers markets were all activity promoting destinations.[14] Additionally, for some older adults, the incentive of potential social interaction (either informal or formal) at a destination served as a motivator for PA.[14]

2. Parks and outdoor recreational spaces

The quantitative studies reviewed presented mixed support for park access as a facilitator of PA. Both Maisel[41] and Siu et al[39] found that access to parks can encourage PA among older adults. However, the same study from Siu and colleagues[39] found that park access was not as impactful on PA behavior compared to other amenities. For example, in urban fringe areas, daily walking was more positively impacted by access to commercial areas compared to parks, suggesting that living close to a commercial area might play a stronger role in promoting or encouraging walking compared to proximity to a park.[39]

Across the qualitative studies reviewed, green spaces, public gardens, urban trails, and walking paths emerged as a PA promoting destinations.[14,46] Older adults described suitable, safe walking paths,[14,46] walking trails along blue spaces (e.g., river, lake),[14] and ample opportunities to rest[14] as key facilitators to PA. A cited barrier to park utilization was poor access, and older adults in higher density areas may rely on other neighborhood-based outlets for PA engagement instead of seeking out parks.[47] Interestingly, those residing in low density areas more commonly referenced seeking out parks or beaches to engage in PA compared to higher density areas, possibly due to the less supportive walking infrastructure associated with low density environments.[47]

3. Public and motorized transit

The specific issue of public transportation was explicitly discussed only by the qualitative studies. Within the qualitative studies reviewed, public transportation emerged as a present but not commonly cited variable influencing PA engagement as compared to shops, services, parks, or other amenities. Overall, residing in higher density neighborhoods was associated with a more positive outlook on the public transit system, and when perceived as accessible and convenient, public transit was described as a PA motivating amenity in the community.[47] Older adults reported that the availability of public transit as an alternative form of mobility encouraged PA, as it served a backup/safety-net in case of becoming tired on longer walks.[14] The same study reported that some older adults found unreliable public transit to also be a facilitator of PA, as lack of reliability encouraged walking to a destination rather than riding transit.[14] While the presence of transit generally encouraged PA, features of the transit stations themselves were cited as barriers, such as steps down to the subway, the absence of an elevator or escalator, and concerns about wet floors, open grates, or tiled walkways.[14]

Older adults living in more residentially dense neighborhoods discussed that it was often more convenient to walk or use public transit rather than drive, as compared to lower density areas where car ownership was both more common and less burdensome.[47] Similarly, participants across three different neighborhoods in Buman et al's[46] study agreed that access to parking was not an influential variable on active living, underscoring older adults' preference for engaging in physical activity within the confines of their neighborhood, rather than needing to drive elsewhere to do so.

Pedestrian Infrastructure

Pedestrian infrastructure, a microscale characteristic of the built environment, played a key role in encouraging PA across studies, with four specific features emerging: *1. Sidewalk presence, quality, and design; 2. Street crossing amenities and support; 3. Presence and quality of street lighting; 4. Wayfinding strategies, aids, and cues.*

1. Sidewalk presence, quality, and design

Sidewalk presence, quality, and design addresses the presence, continuity, and maintenance of the sidewalk network throughout a neighborhood, as well as more granular aspects of sidewalk design, such as ramped curbs, surface quality, and width. Across multiple cross-sectional studies, significant associations were found between walking for transport or leisure and different sidewalk variables, including: sidewalk presence or absence,[40,43,47] specific design elements such as presence of a buffer between the sidewalk and street, curbs cuts, and benches,[40] and sufficient sidewalk width and continuity (i.e., lack of abrupt endings).[47] Among older women, Gallagher and colleagues[43] found that the perception of one's ability to overcome barriers to PA (including the ability to navigate obstacles on the sidewalk and maintain balance) significantly influenced confidence in the ability to walk throughout the neighborhood for sustained periods of time.

Sidewalk presence emerged as a common theme within the qualitative studies reviewed, and there were multiple areas of convergence between the qualitative and quantitative findings. Poor sidewalk quality and design was repeatedly referred to as a barrier to PA, and common barriers included uneven surfaces or slippery (e.g., cobblestones, brick), cracks in the sidewalk, and other obstructions that could be tripping hazards.[14,46,47] A lack of suitable sidewalk infrastructure for those with a wheelchair, walker, or other mobility disability (e.g., curb cuts or ramps) was raised as a concern.[46] Chippendale and Boltz[14] examined the relationship between the built environment, fear of falling (FOF), and PA behavior in qualitative interviews with older adults in three urban neighborhoods. Participants identified numerous structural factors that impacted FOF, which in turn, shaped PA engagement, including: uneven walking surfaces on sidewalks (e.g., uneven grates, brick surfaces, embedded decorative stones), inadequate maintenance (e.g., cracked sidewalks, potholes, pools of rainwater, delayed snow and ice clearance), presence of curbs, and sidewalk obstructions.[14]

In contrast, several studies identified facilitators to PA, such as paved, flat, smooth, wide, continuous, and well-maintained walking surfaces, as well as curb cuts, convenient routes, and benches spaced consistently throughout the neighborhood.[14,46] In particular, seating or benches were viewed as a valuable but often limited resource. Having a safe place to rest was referred to as a key feature that helped create a more comfortable and supportive environment, especially given the mobility needs and limitations of many older adults.[47,14] Other sidewalk features that were emphasized as facilitators included the importance of railings, handrails, ramps, safe stairs, and water fountains, and that blocked access to handrails created a barrier to safely navigating stairs or steep areas in parks or other areas of neighborhood.[14,47]

2. Street crossing amenities and support

Due to age-related changes in physical, auditory, and visual acuity, older adults are more likely to experience difficulty in safely navigating street crossings.[18] This review revealed that the presence of high-quality street crossings serves as an important environmental facilitator of PA.[35,40] Cain et al's[35] cross-sectional research identified a significant relationship between objectively measured PA and positive crossing characteristics, such as crosswalk markings, wide crossings, curb cuts, crossing signals (e.g., walk, countdown, and/or audible signals), and other pedestrian protections or aids (e.g., protected refuge islands, curb extensions). These findings were supported by research from Sallis and colleagues[40], which identified a significant relationship between active transport (i.e., walking as a form of transportation) and the presence of microscale crossing amenities, such as crosswalks, curb cuts, and crossing signals.

Qualitatively, older adults reported crosswalk limitations, such as inoperable or broken signals and motorists not stopping at the crosswalk, to be a major barrier to PA engagement.[46] Additionally, on longer blocks, older adults reported a lack of midblock crossing opportunities to be a barrier to engaging in PA within the neighborhood.[14] Conversely, the presence of safe crosswalks was reported as a common facilitator of PA.[46] Concerns about the ability to safely cross streets emerged repeatedly across both the quantitative and qualitative literature,[14,35,40,46,47] and the findings in this review suggest that negative or a lack of crossing amenities can have serious and detrimental effects on PA engagement. Conversely, the presence of positive crossing characteristics may provide relief from crossing anxieties or fears, and as such encourage and facilitate increased engagement in PA.

3. Presence and quality of street lighting

Street lights play a critical role in cultivating feelings of safety and security during activity that takes place at dawn, dusk, or nighttime.[40] Lighting was not commonly addressed across the quantitative literature, with the exception of Sallis and colleagues[40], who found significant associations between walking for transport and the presence of street lights. Qualitatively, however, the presence of lighting mitigated major concerns affecting older adult PA engagement, including reducing fears of falling and increasing visibility of cyclists and sidewalk obstructions.[14,47] An exception to these findings was one qualitative study that did not identify lighting conditions as an important facilitator to PA.[46] However, this may have been a reflection of study methods, as data collection using photovoice was conducted exclusively in daytime, thus potentially biasing responses.[46] The researchers do suggest that older adults may simply avoid going out in the dark, and that well-lit streets might not be a powerful enough facilitator to encourage evening PA.[46]

4. Wayfinding strategies, aids, and cues

Supportive wayfinding is key to enabling older adults with a range of functional, cognitive, and sensory abilities to remain mobile and engaged in the community. Despite its value, wayfinding was explicitly addressed by only one study in this review.[48] Using exploratory mixed-methods, Marquez et al[48] looked specifically at the wayfinding strategies older adults employ when walking in their neighborhood, and the ways in which the presence of wayfinding aids impact PA engagement. Infrastructure that was identified as a wayfinding aid or cue included the presence of clear street signs, numbers on buildings, block numbers, advance street signs, clear and logical street labeling conventions (e.g., numbered grid system), transit stops, railroad tracks, and landmarks.[48] Landmarks, such as a cathedral or prominent community building, were the most frequently cited facilitator of wayfinding, as they provided orientation and a frame of reference.[48] In terms of determining a safe walking route and general wayfinding support, older adults commonly employed the help of known individuals such as friends, as well as highly regarded trusted officials, such as transit workers or police officers.[48] Major barriers to wayfinding included a lack of landmarks, missing street signs, confusing street naming systems or alignments, and distractions (e.g., acoustic distractions, such as loud train noises). Notably, few older adults identified mobile phones, GPS, or other technological resources as sources of wayfinding information.[48] This finding underscores the need for supportive infrastructure to help non-technology oriented older adults engage in active living by navigating the community with comfort and ease.

Safety

Across both the quantitative and qualitative literature, perceptions of safety within the community arose as a common theme that shaped walking behavior among older adults, with two main safety-related constructs: *1. Street safety; 2. Perceived safety and crime.*

1. Street safety

Concerns about and perceptions of street or traffic safety emerged as variables that influenced PA behavior. Quantitatively, Maisel's[42] cross-sectional study found that perceptions of traffic safety were correlated with both job walking and total weekly walking, and that greater safety concerns were associated with reduced PA engagement. The impact of street safety concerns on PA engagement surfaced more frequently across the qualitative literature, including personal safety fears (e.g., being hit by a vehicle), busy streets, high traffic volume and speed, unsafe intersections and crosswalks, dangerous or impatient drivers, drivers ignoring traffic laws, and poor visibility.[47,46] Additionally, difficulty or dangers securing a taxi at night was discussed as a concern that prevented older adults from wanting to go out in the evening.[14] Neighborhoods with higher population density elicited a greater volume of concerns, an expected finding given the heavier traffic patterns found in dense neighborhoods.[47] Outside of cars, getting struck by cyclists, skateboarders, and other forms of non-motorized transport was a concern among older adults, with some expressing more worry about cyclists than motorists.[14] Certain aspects of the social environment promoted feelings of increased safety, such as communication from drivers that it was safe to cross (e.g., waving to cross the street) or the presence of crossing guards and other officials.[14] The presence of select built structures also increased feelings of safety, including: elevators to access the subway, benches for resting, kneeling buses, fences or railings to hold for support, timed crossings that indicated the amount of time remaining to cross, and flashing crosswalks that calmed traffic and made older adults feel more secure in crossing streets without signaled crossings.[47,14]

2. Perceived safety and crime

The influence of perceptions of safety and crime was explored across both the quantitative and qualitative studies. Maisel[42] found that older adults with more positive perceptions of crime safety reported greater total weekly walking compared to those with more negative perceptions. Additionally, concerns about crime safety were correlated (however, weakly) with both recreational and total weekly walking.[42] Gallagher and colleagues[43] found that perception of neighborhood crime significantly influenced walking duration. Li et al's[41] study of walking behaviors among older Asian adults found that perceptions of safety were significantly related to walking, most notably among Filipino-American older adults.

Perceptions of safety were commonly discussed in the qualitative literature, with older adults expressing a preference for crime free environments that cultivated a strong sense of physical safety and psychological security.[47,46] Higher density neighborhoods provoked greater feelings of negativity in relation to safety and security, with older adults reporting issues such as feeling unsafe, as well as concerned about the presence of crime, graffiti, and vandalism.[47] Safety and vulnerability also emerged as a factor influencing the ability to orient oneself and feel comfortable walking around an unfamiliar place.[48] Some older adults described increased perceptions of safety corresponding to the presence of other people.[14] For example, busy, rather than isolated, neighborhoods encouraged PA by not only enhancing perceptions of safety, but by also helping older adults feel more secure in navigating the environment, as it increased the likelihood that trustworthy, helpful individuals may be able to assist them in case they became lost or disoriented.[48] Fear of personal safety was commonly reported as a barrier to leaving home in the evening, as some older adults felt particularly vulnerable and feared they may be targeted due to their older appearance.[14]

Environmental Conditions and Appeal

The sensory appeal, perceived attractiveness, and environmental conditions of the neighborhood were commonly explored as variables influencing PA behavior. Two main constructs surfaced within the reviewed studies, *1. Aesthetics; 2. Weather and environmental conditions*.

1. Aesthetics

Quantitatively, interactions emerged between objectively-measured PA, aesthetics (e.g., presence of street trees, attractive landscaping, views, buildings, or homes), barriers to PA (e.g., discomfort when walking, time constraints), and social support (e.g., having family or friends to walk with or provide encouragement to do PA).[34] Among participants with few self-reported barriers to PA, high ratings of aesthetics accounted for 30 additional min/week of MVPA compared to low ratings for aesthetics.[34] For participants with more barriers, high compared to low ratings of aesthetics accounted for 18 fewer min/week of MVPA.[34] Additionally, the combinations of low aesthetics/low social support and high esthetics/high social support were found to be explanatory variable combinations for the minutes per week older adults spent walking for leisure.[34] Supporting this finding, Maisel[42] found that aesthetics were significantly correlated with recreation (i.e., leisure) walking, however, they were unrelated to job or transportation walking. Similarly, Sallis et al[40] concluded that both aesthetics and social characteristics were largely unrelated to active transport in older adults. Aesthetics surfaced as an influential variable in the qualitative literature as well. Positive aesthetics, such as the presence of trees, flowers, and attractive scenery, were cited as common facilitators to PA.[46] Similarly, appealing architecture, well maintained green spaces, water views, and settings that promote connectivity to nature were all mentioned as factors that help facilitate walking and exercise among older adults.[14]

2. Weather and environmental conditions

Weather as an environmental condition was mentioned as a negative influence and barrier to engagement in PA. The perception of weather as a barrier to PA, as well as a variable shaping an individual's self-efficacy to engage in PA engagement, was found to be significant, especially among older women.[43] When faced with perceived environmental barriers, including inclement weather, older women were significantly less confident in their ability to walk in their neighborhood both overall and for increasing durations, as compared to older men.[43] However, older men with low self-efficacy for PA engagement were less likely to report walking in the face of similar environmental barriers.[43] Additionally, within the qualitative literature, insufficient sidewalk and street maintenance related to weather (e.g., lack of snow, ice, or slush removal, pools of rainwater on sidewalks or street corners) was cited as a key barrier to PA engagement.[14]

DISCUSSION

Synthesis of Results

The studies included in this review further the evidence regarding the ways in which walking behaviors of older adults are shaped by the built environment and in particular, the neighborhood surrounding one's place of residence. The seventeen studies reviewed revealed seven major built environment features associated with older adult's physical activity: (1) Residential and Population Density, (2) Walkability, (3) Street Network Composition, (4) Neighborhood Land Composition, (5) Pedestrian Infrastructure, (6) Safety, and (7) Environmental Appeal and Conditions. Within each major construct, various sub-constructs provided more granular level details regarding the built environment and its impact on physical activity. Overall, this review supports the previously identified relationship between the micro and macroscale features that commonly comprise high walkable neighborhoods, such as high population density, land use mix, street connectivity, aesthetics, and perceptions of safety, and overall engagement in PA.[49] All studies included in this review referred to all or a combination of macro and microscale features, with findings suggesting that variables in both categories play an influential role in shaping PA behavior.

Many findings from this review were corroborated by past reviews investigating the relationship between older adult PA and the built environment. In regards to street connectivity, findings are consistent with evidence summarized in a prior review by Haselwandter and colleagues[7], who found that street density and connectivity was significantly associated with the number of blocks walked among women ≥65 years. Similarly, multiple reviews support findings associated to land use mix. Quantitative studies included in reviews by Haselwander et al[7] and Yen et al[23] indicate positive associations between PA and neighborhood access to commercial and retail businesses,[23] grocery stores,[23] and recreation facilities (e.g., indoor gyms, facilities with treadmills).[7] Moran et al's[5] systematic review of qualitative literature supports these findings as well, with access to daily destinations, such as shops (e.g., grocery store), services (e.g., post office), and other facilities (e.g., library, senior center) emerging as a key theme across literature reviewed from 1996-2012.

In regards to access to parks and outdoor recreational spaces, past reviews supports the mixed findings in this present review. Earlier studies reviewed by Haselwandter et al[7] provide support for park proximity as a facilitator for PA. However, Kerr and colleagues[6] note that park proximity and/or density has shown an inconsistent association with PA in past literature, and of the recent studies included in their review, two found positive associations, while four noted a lack of association. A possible interpretation of these findings is that many parks may be inappropriate or unappealing destinations for older adults due to a lack of safe paths, public restrooms, or places for rest.[6] Additionally, older adults may avoid going to parks that are not consistently trafficked by others, as the isolation may increase perceptions of vulnerability to crime or injury in the case of a fall.[6] In comparison, recreation facilities were cited as a preferred, safe, and more supportive environment for PA.[6] The review by Moran et al[5] supports these mixed perspectives on parks, with findings indicating that although parks can serve as motivators for PA, older adults were also averse to isolated parks or trails due to low visibility and increased fear of crime, and generally preferred PA engagement in commercial areas or recreational facilities.

The value of microscale features of pedestrian infrastructure in facilitating walking among older adults is supported by earlier literature. Moran and colleagues[5] found that the presence, usability, and comfort (i.e., sheltered from inclement weather) of benches and seating areas played a role in facilitating PA within qualitative studies reviewed.[5] Additionally, Kerr et al's[6] narrative review discussed the value provided by street crossing amenities, the challenges posed from insufficient presence of crossing aids (e.g., unsignaled intersections, large crossing distances), and the impact these features have on PA behavior. Notably, however, because of the relatively new focus on microscale features in this area of research, past findings in regards to the microscale environment were not commonly addressed in review articles of earlier literature.

Older adult concerns about safety, as well as the effect of these concerns on neighborhood walking, were also substantiated in prior studies summarized in past reviews. In terms of street safety, the presence of sidewalks and light rather than heavy traffic has been previously associated with increased perceptions of safety and greater engagement in PA in older adults.[7] The association between perceived safety from crime and older adult mobility is also supported by prior studies included in systematic reviews and summary discussions of the relevant literature.[5-7,23] Yen et al[23] commented that while mixed land use may provide an important contextual influence for PA, its presence alone may not be a sufficient motivator for PA if the perception of safety and security within the environment is insufficient. Certain stores such as retail liquor sales, as well as the presence (or absence) of other pedestrians may enhance the perception of high neighborhood crime, and in turn, prevent older adults from engaging in outdoor activity.[23] Kerr and colleagues[6] offered an interesting perspective: the authors surmise that safety influences walking depending on the purpose of the activity. For example, regardless of perceptions of safety, older adults may walk for transport due to necessity, cost, or convenience.[6] In contrast, perceived safety of the environment may significantly influence leisure and recreational walking, thereby underscoring the role of perceptions of safety and security as an influential mechanism in older adults' decisions about PA engagement.[6,23]

This review's findings regarding the importance of positive aesthetics, weather, and environmental conditions were also consistent with findings based on earlier studies. Previous research has found links between increased older adult mobility and the perceived attractiveness of the neighborhood, an absence of negative features (e.g., litter, broken glass, graffiti) and an abundance of positive characteristics, (e.g., trees, plantings, gardens, or other greenery, pleasant scenery or views, and attractive architecture) – all of which were found to affect PA among older adults in the more recent studies reviewed in the present paper.[5-7,22,23] Prior studies also support and complement findings regarding the challenges of weather, noting inclement (e.g., rain, snow) or extreme (temperature, humidity, sun exposure) weather, seasonal challenges (e.g., early darkness), and environmental quality (e.g., polluted areas, traffic exhaust and noise) as serious barriers to PA engagement.[5,7]

Overall, the thirteen quantitative and four qualitative studies included in this review offered unique contributions and findings. The qualitative research in particular added greater depth to the research on microscale features, with each of the four included studies exploring the subtle aspects of the built environment that shape older adult PA perceptions and behaviors. Unearthing the nuances regarding how even small variables influence this population is instrumental to effective design and implementation of built environment interventions. While features such as well-maintained sidewalks or consistent curb cuts may seem minute, this population experiences unique barriers to and fears regarding PA, and features that encourage even incremental improvements in regular walking can have major benefits for aging individuals, especially considering the widespread inactivity among this population.[42] Benches, for example, need to be not only present, but consistently spaced, abundant (especially in areas with hills), and usable for older adults (e.g., easy to sit on, sheltered).[5] Additionally, many microscale characteristics can be modified at lower costs and in a shorter time-frame (e.g., repairing sidewalks, improving street crossing design) as compared to the major costs and barriers associated with reconfiguration of macroscale features.[35]

Within the quantitative literature, the greater proportion of studies focused on the macroscale-oriented features of the built environment, such as walkability, land use mix, and street connectivity. The lack of quantitative focus on microscale features was likely due to three factors: (1) limitations in the ability of GIS to measure microscale features, (2) the high cost of quantitatively assessing microscale features of the built environment through environmental audits, and (3) the relatively new nature of microscale-focused research, as it has not been studied to the same depth as macroscale features. For example, the Microscale Audit of Pedestrian Streetscapes (MAPS), a leading in-person audit tool designed for fine-grained examination of the built environment, was released only in 2012.[50] Two studies included in this review made use of the MAPS tool (Cain et al; Sallis et al),[35,40] both of which provided quantitative substantiation to the extensive discussion of microscale features apparent in the qualitative literature. The addition of the MAPS tool also highlights a promising methodological finding from this review. Previous reviews on this topic have suggested that a limitation of this area of research was the lack of consistent and validated measures that allowed for cross-study comparisons.[51] Findings from this review suggests that researchers in this field are beginning to employ comparable, validated built environment and PA measurement scales and tools, such as MAPS[35,40], NEWS[16,42,43], CHAMPS[16,31-35,40], GIS[32,37-39], and Actigraph accelerometers.[16,31-35,40]

Research conducted prior to this review suggests that older adults engage in two primary types of PA, walking for transportation (e.g., for errands) and leisure (e.g., for recreation), and that distinct factors of the built environment shape engagement in each type of walking.[45] The findings of this review further support this claim, with the reviewed literature revealing unique environmental qualities that encourage each type of walking. The variable most prominently impacting transport walking was overall walkability, suggesting that the basic necessities of walkable environments may be sufficient in encouraging active transport among older adults. For example, the well-connected streets, mixed land use, and high residential density needed to support a walkable neighborhood may cultivate an environment in which it is possible or even more convenient to engage in active transport. These findings were supported by a recent systematic review and meta-analysis of studies in multiple countries exploring neighborhood correlates with active transport.[52] From this review, Cerin and colleagues[52] concluded that there was very strong and consistent evidence supporting a positive association between objectively measured walkability and walking for transport.

Leisure walking, however, was most influenced by aesthetics, amenities, safety, and access to facilities. This contrast between leisure and transport walking underscores the influence of a pleasant and comfortable atmosphere on older adult decisions to engage in PA for pleasure rather than necessity or errands. Even if a neighborhood is highly walkable in the conventional, macroscale-defined sense, older adults may avoid non-necessary walking if the environment makes them feel unsafe or vulnerable (i.e., high perceived crime, broken sidewalks, insufficient crossing amenities, inadequate snow or ice removal), or is aesthetically unappealing (i.e., litter, graffiti, lack of street trees or plantings). Kerr and colleagues[6] postulate that this is likely because transport walking frequently occurs out of convenience, cost, or necessity, whereas leisure walking is typical carried out as pleasurable activity. Despite these findings, walkable environments that encourage transport-oriented PA are still of high value, as they may help facilitate the daily, routine forms of walking that typically require less of the planning, scheduling, and motivation required for leisure activity engagement.[32]

Overall, the findings from recent studies included in the present review, as well as results from earlier studies conducted in the U.S. and other countries, suggest that although numerous areas of possible intervention may support older adult PA, in order to achieve the greatest effect across all domains of PA, improvements need to be made to both macro- and micro-oriented features. For example, the presence of amenities alone is not sufficient to encourage PA, as it is critical to also consider how older adults can actively and safely travel to these destinations (e.g., are the sidewalks high quality and continuous? Can older adults cross the street safely? Are the streets well connected and easy to navigate?). The results of this review also highlight how environmental interventions should focus on addressing the unique needs of older adults, and that changes to the built environment need to focus on variables that will most encourage and motivate PA given these particular needs. For example, prioritizing safety concerns within the neighborhood through traffic calming measures (e.g., reducing speed limits in pedestrian areas), increasing time allocated to pedestrians at signalized crossings, installing pedestrian refuge islands on wide streets, and repairing broken curbs, may cumulatively have a stronger effect on supporting older adult PA compared to adding bike paths or providing parking at a local park.[18,42]

Gaps in the Literature and Directions for Future Research

Based on this review's assessment of the past and current state of the literature, it is clear that the study of the relationship between the physical environment and PA in older adults is on the rise. The first review on this topic, published in 2004, included only six studies all based on self-report data.[53] Over the past decade, the research on this topic has become increasingly robust and sophisticated as PA tracking technology through accelerometers and geospatial mapping programs have advanced. For example, a 2012 review of studies published from 2000-2010 found that only 2/33 articles (7%) used accelerometers.[6] By comparison, 7/17 studies (41%) in this review of studies published 2011-2016 used accelerometers, highlighting how tracking technology has become more integrated into this area of public health research. Despite these advances, this review identified a few noteworthy gaps in the literature and identified areas in need of future study: *(1) Participant diversity; (2) Geographic diversity; (3) Age representation; (4) Wayfinding; (5) Climate change; (6) Naturally occurring retirement communities*.

1. Participant diversity

On average, study participants in this review represents a relatively narrow demographic profile of majority white and higher-resourced older adults. Notably, seven studies obtained their sample from the existing Senior Neighborhood Quality of Life Study (SNQLS), an observational study that explored the relationship between neighborhood environments and health outcomes among ambulatory, community-dwelling older adults (≥66 years). Participants in SNQLS were sampled from neighborhoods stratified based on GIS-measured walkability (i.e., residential density, land use mix, intersection density, and retail floor area ratio) and median household income in two regions (Baltimore, MD-Washington D.C. and Seattle-King County, WA).[16] Although each study using the SNQLS sample had unique objectives, research aims, and contributions to this review, the use of the same sample and study locations may have skewed this review's findings. While SNQLS intended to recruit a socio-economically diverse audience, it was comprised of a sample that was both less diverse and more educated than the U.S. older adult population. This overall lack of sample diversity indicates a need for adjustments in the recruitment techniques of future research, and efforts should be made to prioritize recruitment or oversample underrepresented groups. Additionally, racial, ethnic, and socioeconomic disparities seen in PA engagement necessitates further exploration of populations at higher risk for sedentary behavior, such as non-Hispanic black and Hispanic older adults, and older adults with less than a college education.[13]

A few studies in this review did deviate from the typical sample profile, such as Li and colleague's[41] exploration of correlates of the neighborhood environment with walking among older Asian Americans. Their findings suggest that older Asian Americans not only walk more than their white counterparts, but that neighborhood effects varied significantly across different Asian subgroups (e.g., Chinese, Korean, Filipino).[41] Given these findings, greater consideration needs to be taken regarding the influence of older adults' cultural, racial, or ethnic background on PA behavior, especially among non-white and more socioeconomically diverse populations.

In regards to gender, three of the seventeen studies included in the final study set focused on women only,[37-39] one explicitly explored gender effects,[43] and none examined men only. While many studies had approximately equal distributions by gender, proportions tended to skew more heavily towards women. The emphasis on older women was not surprising, as past research has tended to focus more on women due to their longer life expectancy, greater likelihood of living alone and independently, and increased sensitivity and vulnerability to neighborhood environment features.[43] Future research is needed, however, to better tease out gender-specific differences and patterns in walking behavior. For example, Gallagher et al[43] identified gender differences between older men and women in regards to self-efficacy and perceived barriers for neighborhood walking, however, a clearer understanding is needed in order to effectively tailor physical activity interventions by gender.

2. Geographic diversity

The majority of research included in this review was located in the Northeast, Mid-Atlantic, West Coast, or Northwest regions of the U.S, with two studies conducted in the Midwest as well (Chicago, Illinois and Ann Arbor, Michigan). As such, generalizability of this review's findings may be limited to older adults residing exclusively in these regions. While studies with multiple study sites found similar results across different states (e.g., California, Massachusetts, and Pennsylvania), these effects may not hold true over different geographies, and generalizability cannot be assumed.[38] This finding reveals a large and problematic gap in the literature regarding how the built environment impacts the walking behavior of older adults in other regions of the U.S. This gap is especially important as many cities in the Southeast, Midwest, and Southwest are characterized by urban sprawl, a pattern of development in which large percentages of the population live in lower density residential areas across a metropolitan area.[54] Sprawl is associated with increased reliance on automobiles, lack of sidewalks, decreased ability to walk to destinations, and a higher risk for physical inactivity and obesity, all of which are serious concerns among older adults.[54]

The association between sprawl and reliance on automobiles is particularly problematic for older adults, as age-related reductions in physical, cognitive, and visual functioning commonly diminishes the ability to operate a vehicle overtime.[55] The adverse effects of driving cessation may be intensified in automobile-dependent sprawling cities, especially those without a convenient, accessible transportation alternative. These adverse outcomes, including decreases in social integration and activities outside the home, increases in depression and anxiety symptoms, and an increased risk of nursing home placement, may adversely impact the ability of older adults to maintain functional independence and age-in-place.[56,55] In particular, loss of driving status is of great concern for older women: compared to men, older women are more likely to report driving cessation at a younger age,[55] have lower self-efficacy for walking,[43] and lower overall engagement in physical activity.[39] Findings suggest, however, that both men and women in lower density urban areas engage in less physical activity,[16,37-39] and more research is needed in sprawling, automobile-dependent cities to determine the ways in which communities can better support and encourage walking. Future research is especially critical for non-driving populations, as their lack of driving status indicates a heightened risk for the physical, cognitive, or visual limitations that also create barriers to PA engagement.[55]

Regional differences in walking behavior and disparities in population rates of older adult disability further underscore the need for geographical diversification of research. In regards to walking, only 57% and 60% of adults in the South and Midwest reported recent walking, compared to 66% in the Northeast and West.[13] These disparities are likely reflected across older adult populations across these regions, as adults who do not exercise when younger are even less likely to engage in PA with older age due to the associated losses in physical ability, higher prevalence of disability, and reduced exercise-related self-efficacy, a key determinant of PA behavior.[57] Adding to these region-specific challenges to older adult walking is the high proportion of older adult disability in the Southeast (40%), with states in this region containing the highest proportion of older adults living with at least one disability, including Mississippi (48%), Alabama (45%), Texas (42%), and Georgia (41%).[58] By comparison, older adults living with disabilities in the states included in this review are significantly lower, such as 39% in Washington D.C., 35% in Maryland.[58] Although many of these higher disability Southern states have large proportions of the population living in rural areas (and thus not within the scope of this review), small, mid-sized, and large cities dot these regions and are in need of further study to better understand how place shapes PA engagement in areas with high proportions of vulnerable and more physically limited older adults. Although disability issues were not widely discussed within the studies included in this review, they warrant discussion considering the large percentage of older adults who have, or will develop, a mobility limitation or disability.[8]

3. Age representation

The studies included in this review lack full age representation of the entire older adult population, and in particular, older adults in the middle-old (75-84 years) oldest-old category (≥85 years). As the baby boomer population shifts into older age categories, both populations are projected to grow significantly over the next few decades, with the middle-old age group rising from 4.2% to 7% and the oldest old rising from 1.9% to 4.5% by 2050.[59] Currently, only 14% of the older adult population is over 85 years, however, this proportion is expected to increase to over 21% by 2050.[2] While studies in this review included participants in the middle-old and oldest-old age groups, most mean ages were in the upper 60s and low 70s, and the highest mean age reported was 75.8 years, further underscoring insufficient representation of the older age categories in this review. Additionally, by defining older adults as individuals ≥65, this review was forced to reject numerous studies that defined older adulthood as those who are >55 or 60 years. As older adults experience longer functional independence and life expectancy, defining this population by a cut-point of 55 and 60 years is likely to increasingly misrepresent the needs of the population, indicating the need for an update to the definition of older adulthood, especiallly to facilitate cross-study comparisons.

4. Wayfinding

Wayfinding was among the topics that emerged from this review, yet was insufficiently addressed across the studies. Only one exploratory study from Marquez and colleagues[48] discussed wayfinding as a component of older adult engagement in PA. The ability to safely navigate one's neighborhood and the surrounding area is key in overcoming barriers to and enhancing self-efficacy for engaging in PA, especially in an environment an older adult may be less familiar with on a day-to-day basis (e.g., neighborhood near one's doctor or dentist, area surrounding a friend or family member's home). Wayfinding is especially important for the many older adults who are unfamiliar with or lack the ability to use mobile GPS technology.[48] This topic was not discussed in prior reviews on this topic, further emphasizing the need for additional attention and exploration.

5. Climate change

Older adults are particular vulnerability to extreme temperatures and weather patterns.[60] For example, extreme heat exposure increases risk of illness, hospitalization, and death among older adults, especially those with chronic health conditions such as diabetes, congestive heart failures, or lung conditions.[60] Given the changing climate, future research needs to focus on better understanding how older adults respond and adapt to weather, as well as identifying the ways in which the built environment can support PA despite these changes. While the research included in this review does mention older adult concerns about unpleasant or extreme weather, it was not done so in great depth and focused more on concerns regarding cold weather (e.g., snow and ice removal, slush, darkness) or rain.[15] Older adults did cite particular concerns about their ability to engage in PA in the face of severe or unpleasant weather, such as high heat and humidity, snow and ice, and extreme cold, yet no solutions were offered in how they manage such challenges beyond staying inside.[14,43] Additionally, the multistate research included in this review offered no comparisons in how older adults in different climates respond to or manage weather (e.g., California compared to New York). Future research is needed to explore these gaps in greater detail, as this issue is projected to only increase in the coming decades.[60]

6. Naturally occurring retirement communities

Naturally occurring retirement communities (NORCs) are defined by the residential density of large numbers of community-dwelling seniors and tend to be characterized by a range of healthy living built environment qualities, such as close access to destinations, services, and facilities, safe and well-maintained walking paths, low crime and high perceived safety, social support of seeing other peers be active, and having local government that prioritizes the needs of older adults.[6] Future research needs to better explore qualities of these communities, as they commonly demonstrate the features older adults need to successfully age-in-place. Additionally, because these communities are not intentionally planned, studying their qualities allows for a better understanding of the environmental variables that older adults seek out when choosing a place to live. Better understanding of NORCs may provide valuable information regarding key

PA facilitating features, and thus help planners, developers, and public health workers determine which improvements to the built environment will best encourage PA.[6]

Study Limitations

This systematic review is limited by a few methodological shortcomings. In regards to search processes and query development, it is possible that search terms and criteria included in this review may have excluded relevant research. For example, the query development process revealed that the MeSH term "aged," refers to adults over the age of 65. However, the MeSH definition of "aged" is not consistently applied across databases, and in an effort to achieve more narrow, targeted results, the term "older adult" was added to the search query. While "older adult" is the commonly used term in current research on this population, it is possible that additional studies would be identified by including other synonyms, such as "seniors" or "elderly." Research may also have been missed due to a lack of searching all possible health-related databases and by the lack of robust searches of the grey literature. Additionally, this review included studies published in English only. However, due to this review's focus on research in the U.S. only, it is unlikely that studies were missed due to this limitation.

All literature searches and evaluation of selected studies were conducted by the author of this review. Due to the large number of abstracts reviewed in Phase One (n=3254), it is possible that eligible studies were inadvertent excluded. This risk was mitigated by limiting the number of studies reviewed in one sitting throughout Phase One. Additionally, in the case of uncertainty regarding the fit of a study with inclusion and exclusion criteria, an eligibility decision was made without consensus from other researchers. As a way of managing this limitation, all articles that elicited uncertainty were flagged and reviewed a second time at a later date. An additional limitation of a single-researcher approach is that the risk of bias is higher and more likely to be introduced. As a way of managing this risk, exclusion and inclusion criteria were specifically defined and were applied fastidiously.

Lastly, due to an exclusive focus on urban, community-dwelling, older adults (≥65 years) in the U.S., this review is limited in generalizability to older adult populations outside of these criteria. Furthermore, this review excluded research that focused exclusively on older adult populations with a pre-existing health condition, such as diabetes, obesity, or physical limitations. Due to the prevalence and rise of chronic illness among older adults, and in particular, the increase in physical limitations with age, this exclusion criterion may have resulted in omission of key and informative literature. Despite this potential limitation, most studies included in this review did not explicitly exclude older adults with physical limitations, including those who use assistive devices, from the study population. Due to the prevalence of assistive device use among older adults included in this review, findings from this study may be applicable to community-dwelling older adults living with some degree of mobility disability or limitation.

CONCLUSION

This review presents evidence documenting the role the built environment plays in encouraging or preventing PA among older adults, as well as gaps in the current literature and areas of future research. The research synthesized in this review adds to the body of knowledge on how the built environment shapes older adult PA, and should be used to complement previous evidence, programs, and case studies of successful communities to help develop interventions for this population. From this review, it is evident that the creation and preservation of walkable communities is instrumental in supporting active living among older adults, which thereby helps reduce, prevent, and manage the many chronic illnesses associated with sedentary living. Even in neighborhoods with high walkable indices, the majority of older adults fail to meet PA recommendations, further emphasizing the need to diversify the scope of built environment features that are designed to encourage and motivate PA among this population.[32]

When optimized for the particular needs of older adults, the compendium of features that make up the built environment can serve as key support structures to allow older adults to remain active, independent, and successfully age-in-place. Over the coming decades, the older adult population will continue to grow and experience increasingly longer life expectancy. This major shift in demographics, combined with the social, health, and fiscal costs associated with sedentary living and loss of functional independence, underscores the need for design solutions tailored to an older population. By intervening at key leverage points and prioritizing the development of thoughtfully designed urban environments, communities can become essential drivers of active living and improved longevity among this vulnerable and growing segment of the U.S. population.

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APPENDIX I. Adapted Newcastle Ottawa Quality Assessment Scale for Observational Research

	ASSESSMENT CRITERIA	POINTS
1	**SELECTION (Maximum 5 points)**	
1.1	**Representativeness of the sample**	
	Truly representative of the average in the target population (e.g., all subjects or random sampling).	1
	Somewhat representative of the average in the target population (e.g., non-random sampling).	1
	Selected group of users.	0
	No description of the sampling strategy.	0
1.2	**Sample Size**	
	Justified and/or satisfactory	1
	Not justified and/or unsatisfactory	0
1.3	**Non-respondents**	
	Comparability between respondent and non-respondent characteristics is established, and the response rate is satisfactory.	1
	The response rate is unsatisfactory, or the comparability between respondent and non-respondent is unsatisfactory.	0
	No description of the response rate or the characteristics of the responders and the non-responders.	0
1.4	**Ascertainment of the exposure (risk factor)**	
	Validated measurement tool (e.g., Neighborhood Environmental Walkability Scale).	2
	Non-validated measurement tool, but the tool or method of data collection is available or described.	1
	No description of the measurement tool or ascertainment of exposure.	0
2	**COMPARABILITY (Maximum 2 points)**	
2.1	**Controls for confounding factors to ensure that subjects are comparable.**	
	The study controls for important demographic confounders.	1
	The study includes partial adjustment for important confounders.	1
	The study lacks adjustment for potential confounders.	0
3	**OUTCOME (Maximum 3 points)**	
3.1	**Assessment of the outcome**	
	Independent, objective assessment (e.g., Actigraph accelerometer).	2
	Record linkage.	2
	Self-report (e.g., CHAMPS Activities Questionnaire for Older Adults).	1
	No description.	0
3.2	**Statistical test**	
	The statistical test used to analyze the data is clearly described and appropriate, and the measurement of the association is presented, including confidence intervals and the probability level (p value).	1
	The statistical test is not appropriate, not described or incomplete.	0
	Total possible points	**10**

APPENDIX II. Results of Adapted Newcastle Ottawa Quality Assessment Scale

Study		Selection				Comparability	Outcome		Total
First author, year	**Study Design**	**Representativ e-ness of the Sample**	**Sample Size**	**Non-respondents**	**Ascertainme nt of exposure**	**Controls for confoundin g factors**	**Assessment of outcome**	**Statistical test**	**Total Points (out of 10)**
Adams, 2012	Cross-sectional	1	1	0	2	1	2	1	8
Bracy, 2014	Cross-sectional	1	1	0	2	1	2	1	8
Cain, 2014	Cross-sectional	1	1	0	2	1	2	1	8
Carlson, 2012	Cross-sectional	1	1	0	2	1	2	1	8
Ding, 2014	Longitudinal	1	1	0	2	1	2	1	8
Gallagher, 2014	Cross-sectional	1	1	0	2	1	1	1	7
King, 2011	Longitudinal	1	1	0	2	1	2	1	8
Li, 2015	Cross-sectional	0	1	0	1	1	1	1	5
Maisel, 2016	Cross-sectional	1	0	0	2	1	2	1	7
Sallis, 2015	Cross-sectional	1	1	0	2	1	2	1	8
Siu, 2012	Cross-sectional	0	1	0	2	1	2	1	7
Tamura, 2014	Cross-sectional	0	1	0	2	1	2	1	7
Troped, 2014	Cross-sectional	0	1	0	2	1	2	1	7

APPENDIX III. Mays and Pope Scale for Quality Assessment Qualitative Research and Results

Key to Results	
0	Low clarity and quality as assessed by the reviewer.
1	Reasonable clarity and quality as assessed by the reviewer.
2	Reflects a finding of high clarity and quality as assessed by the reviewer.
NC	Not clear or not available from the paper

		Buman, 2013	Chaudhury, 2012	Chippendale, 2015	Marquez, 2015
1	**Worth or Relevance**				
	Was this piece of work worth doing at all? Has it contributed usefully to knowledge?	2	2	2	2
2	**Clarity of Research Question**				
	Was the research question clear?	2	2	2	2
3	**Appropriateness of the Design to the Question**				
	Was an appropriate method used to answer the research question?	2	2	2	2
4	**Context**				
	Is the context or setting adequately described so that the reader could relate the findings to other settings?	2	2	1	2
5	**Sampling**				
	Did the sample include the full range of possible cases or settings (so that conceptual generalizations could be made)?	2	2	1	1
	Were efforts made to obtain data that might contradict or modify the analysis by extending or modifying the sample?	2	2	0	1
6	**Data Collection and Analysis**				
	Were the data collection and analysis procedures systematic? Was an 'audit trail' provided, such that someone else could repeat each stage, including the analysis?	2	2	2	2
	How well did the analysis succeed in incorporating all the observations?	2	2	2	2
	Did the analysis develop concepts and categories capable of explaining key processes (e.g., coding, thematic analysis)?	2	2	2	2
	Was it possible to follow iteration between data and the explanations for the data?	2	0	NC	2
	Did the researcher search for or provide information about cases that do not fit observed patterns)?	2	2	1	2
7	**Reflexivity of the Account**				
	Did the researcher assess the likely impact of the methods used on the data obtained?	2	1	1	1
	Were sufficient data included in the reports to provide sufficient evidence for readers to assess whether analytical criteria were met?	2	1	1	2

APPENDIX IV. Characteristics and Results of Quantitative Studies

Key
sr: self-report
obj: objectively measured
ea: environmental audit
PA: physical activity
MVPA: moderate-to-vigorous physical activity
GIS: Global Information Systems
NEWS: Neighborhood Environment Walkability Scale
CHAMPS: Community Healthy Activities Model Program for Seniors Survey
MAPS: Microscale Audit of Pedestrian Streetscapes
MET: Metabolic equivalence task

First author, year	Focus of study	Study design, sample size, ages	Built environment features and measures	Activity-related outcomes and measures	Findings
Adams, 2012	To explore associations between multivariate neighborhood profiles, physical activity (PA), and BMI.	Cross-sectional n= 728 Age: 66-97	*sr: perceived neighborhood* (NEWS)	*obj: MVPA* (Actigraph accelerometer worn for 7 days) *sr: PA* (CHAMPS)	Physical activity differed significantly by differences in neighborhood profiles (based on assessment of urban form and recreation environment variables). MVPA differed significantly by as much as 10 minutes/day, 1.1 hours/week for walking for errands, and almost 50 minutes/week for leisure PA. Low social/recreational environment variables clustered along with low walkable environment scores.
Bracy, 2014	To tease out the relationship between safety concerns and PA, looking specifically at crime, pedestrian, and traffic safety as moderators of built environment associations with PA.	Cross-sectional n=718 Age: ≥66	*sr: perceived traffic, pedestrian, and crime safety* (modified NEWS) *obj: neighborhood environment* (GIS walkability index)	*obj: MVPA* (Actigraph accelerometer worn for 5 days) *sr: PA* (CHAMPS)	Total MVPA was associated with walkability and number of parks. Leisure walking and walking for transport associated with pedestrian safety. Relationship between crime, pedestrian, and traffic safety and PA remains elusive.

First author, year	Focus of study	Study design, sample size, ages	Built environment features and measures	Activity-related outcomes and measures	Findings
Cain, 2014	To identify associations of microscale streetscape attributes with multiple PA measures across four age groups, including older adults.	Cross-sectional n=367 Age: ≥66	*ea: neighborhood environment* (MAPS) *obj: neighborhood environment* (GIS walkability index)	*obj: MVPA* (Actigraph accelerometer worn for 5 days) *sr: transport, leisure, and neighborhood PA* (CHAMPS)	Both macro and microscale attributes of the environment influenced older adult PA. Factors associated with significantly more MVPA: residential mix, crossing and segment characteristics, and objective walkability index. Factors related to increased transport activity: presence of destinations, non-residential land use, and positive land uses (e.g., restaurants, shops, service); streetscape characteristics and street segment score (e.g., design features, slope, sidewalk quality); positive building height and set-backs (i.e., human-scale building design); quality of street crossing (e.g., positive crossing and segment characteristics); positive aesthetics/social features.
Carlson, 2012	To evaluate ecological model predictions of cross-level interactions among psychosocial and environmental correlates of PA.	Cross-sectional n=718 Age: ≥65	*obj: neighborhood environment* (GIS walkability index; number of parks and private recreation facilities) *sr: perceived neighborhood environment* (modified NEWS)	*obj: PA* (Actigraph accelerometer worn for 5 days) *sr: PA* (CHAMPS)	Walkability, social support, and self-efficacy were consistently related to PA; combination of walking partner and supportive environment may be particularly effective in facilitating older adult PA. Significant interactions related to walking for transport involved walkability, while significant interactions related to walking for leisure involved walking infrastructure.

First author, year	Focus of study	Study design, sample size, ages	Built environment features and measures	Activity-related outcomes and measures	Findings
Ding, 2014	To determine whether associations between attributes of neighborhood environments and PA were moderated by driving status among older adults.	Longitudinal (two time points) n=880 Age: 66-97; M=75	*obj: neighborhood environment* (GIS walkability index; number of parks and private recreation facilities) *sr: perceived neighborhood environment* (modified NEWS)	*obj: PA* (Actigraph accelerometer worn for 7 days) *sr: walking* (CHAMPS)	Driving status may moderate the association between the neighborhood environment and leisure walking. Almost all environmental attributes showed positive, significant interactions with PA among driving older adults, but not among non-driving older adults. Most attributes of neighborhood environments were related to transport walking regardless of driving status. Non-driving older adults were more likely to live in neighborhoods with activity-friendly environmental features.
Gallagher, 2014	To compare mobility, self-efficacy, outcome expectations, neighborhood (density, destinations, and design), and neighborhood walking among older men and women	Cross-sectional n=326 (106 men; 216 women) Age: 60-99; M=76.78 (men), 75.81 (women)	*sr: perceived neighborhood environment* (modified NEWS)	*sr: neighborhood walking* (Neighborhood Physical Activity Questionnaire)	Built environment variables explained 32% of the variance in neighborhood walking in men ($p<.001$) and 27% of the variance in women ($p<.01$). For men, density and design characteristics, specifically sidewalks and perceived crime safety, were associated with walking, in addition to scores on measures of walking self-efficacy. For women, built environment destinations were association with neighborhood walking, as well as walking self-efficacy scores. Regarding walking self-efficacy subscales, women were significantly less confident than men in their ability to walk for increasing durations of time, walk in the face of neighborhood or personal barriers. safely navigate common obstacles, and maintain balance. Walking was associated with self-efficacy for walking despite individual barriers in women and neighborhood barriers in men.

First author, year	Focus of study	Study design, sample size, ages	Built environment features and measures	Activity-related outcomes and measures	Findings
King, 2011	To uncover relations among objectively measured neighborhood design, mobility impairment, PA, and body weight by comparing two neighborhoods differing in walkability and income levels.	Longitudinal (two time points) n=719 Age:≥66	*obj: neighborhood environment* (GIS walkability index)	*obj: MVPA* (Actigraph accelerometer worn for 7 days) *sr: transport and leisure walking* (CHAMPS)	Across regions, time, and neighborhood income, older adults living in more walkable neighborhoods had 400% more transport activity ($p<.0001$) relative to those living in less walkable neighborhoods. Residents in high walkability neighborhoods were 33% more active than those in low walkable neighborhoods. The most mobility-impaired adults living in more walkable neighborhoods reported transport activity levels that were similar to less mobility-impaired adults living in less walkable neighborhoods.
Li, 2015	To explore the relationship between neighborhood factors and walking among older Asian Americans, examining specific ethnic subgroups (e.g., Chinese, Korean, Filipino).	Cross-sectional n=1,045 Age: ≥65 (55-64 included for comparison purposes)	*sr: neighborhood variables* (social cohesion; availability of recreational facilities, perceived neighborhood safety)	*sr: transport and leisure walking* (past week)	Asian older adults walked significantly more than White counterparts. There is heterogeneity among Asian subgroups in terms of relationship of neighborhood factors with walking behavior. Social cohesion was associated with increased minutes of walking regardless of subgroup, though most notable among Chinese older adults. Access to park/playground associated with increased amounts of walking among older Chinese/Korean adults. Neighborhood safety related to increased walking among Filipino adults but no other subgroups.
Maisel, 2016	To examine the effect of neighborhood perceptions and self-reported walking behavior for older adult residents of urban, suburban, and rural neighborhoods.	Cross-sectional n=32 urban older adults (study total n=112) Age:≥65	*sr: perceived neighborhood environment* (modified NEWS)	*sr: job, transportation, recreational, and total neighborhood walking* (past 7 days, International Physical Activity Questionnaire)	Total weekly walking associated with overall neighborhood satisfaction and more positive perceptions of street connectivity ($r=.25$; $p<.01$) and crime safety. Job walking and total weekly walking associated with perceptions of traffic safety. Recreational walking associated with aesthetics and crime safety. Transportation walking was moderately correlated to recreation walking. Job walking, transportation walking, and total weekly walking were associated with perceptions of street connectivity.

First author, year	Focus of study	Study design, sample size, ages	Built environment features and measures	Activity-related outcomes and measures	Findings
Sallis, 2015	To evaluate the efficacy of a condensed 15-item environmental audit tool compared to a full version. Tool was evaluated through assessment of microscale elements of neighborhood design and their relationship with PA.	Cross-sectional n=367 Age: ≥66	*ea: neighborhood environment* (MAPS)	*obj: MVPA* (Actigraph accelerometer worn for 7 days) *sr: active transport and leisure PA* (CHAMPS)	Significant associations found for self-reported walking for transport and microscale features ($p<.05$): street lights, benches, curb cuts, presence of a sidewalk, buffers between streets, sidewalks, crossing and intersection characteristics (crosswalk, curb cuts, crossing signal). Findings show a linear and positive relationship between positive microscale BE features and walking for transport. No single attribute was dominant. Aesthetics and social characteristics were largely unrelated to active transport. Lowest v. highest quintiles on neighborhood microscale environment scores: 242% different in PA.
Siu, 2012	To explore neighborhood attributes that may affect health outcomes, specifically evaluating the relationship between urban forms and walking behavior among older women.	Cross-sectional n=2005 women Age: ≥65	*obj: neighborhood environment* (GIS measures of accessibility to transit services, land use mix, street connectivity, population density)	*sr: utilitarian and leisure walking* (total number of blocks walked daily)	Urban areas with the best access to amenities (transit, parks, and commercial areas), high street connectivity, and high population density were most likely to promote walking in older women. Characteristics of the central city were associated with increased utilitarian and leisure walking as compared to the city periphery, the suburbs, or urban fringe with poor commercial area or park access. Across all six neighborhood clusters, those who walked for leisure purposes tended to walk more than those who walked only for utilitarian purposes.

First author, year	Focus of study	Study design, sample size, ages	Built environment features and measures	Activity-related outcomes and measures	Findings
Tamura, 2014	To explore spatial clusters of PA, examine whether the geographic distribution of covariates affects clusters, and compare built environment characteristics inside and outside clusters.	Cross-sectional n=22,599 women Age: 57-85; M=69.9	*obj: neighborhood environment* (GIS measured population density, intersection density, density of facilities)	*sr: walking for exercise or transport* (MET value assigned for walking based on pace; dichotomous walking outcome categorized participants as meeting or not meeting DHHS PA recommendations)	Population density, intersection density, and diversity/density of facilities significantly greater in higher PA clusters compared to low PA clusters. Variables associated with greater odds of meeting DHHS PA recommendations: higher population density; intersection density, >2-11 intersections/km compared to <2 (18% greater odds); additional service facility/km of road (53% greater odds) Significant interactions between population density, facility density variables, and odds of meeting PA recommendations via walking mostly found among women living in the 90.1-95th and 95.1-100th percentiles of population density.
Troped, 2014	To examine the relationship between objective built environment variables and the likelihood of meeting the U.S. Department of Health and Human Services PA recommendations via walking and weight status, using individual residential buffers to define environmental exposures.	Cross-sectional n=22,599 women Age: 57-85; M=70	*obj: neighborhood environment* (GIS measured population density, intersection density, density of facilities)	*sr: walking for exercise or transport* (MET value assigned for walking based on pace; dichotomous walking outcome categorized participants as meeting or not meeting DHHS PA recommendations)	Population density (odds ratio(OR)=1.04 [1.02,1.07]), intersection density (ORs=1.18-1.28), and facility density (ORs=1.01-1.53) were positively associated with walking. Strongest associations between facility density variables and walking found among women from higher population density areas. Relationships between accessible facilities and walking may be most important in higher density areas. No clear pattern of differences in associations across CA, MA, and PA.

APPENDIX V. Characteristics and Results of Qualitative Studies

Key
sr: self-report
ea: environmental audit
PA: physical activity

First author, year	Focus of study	Study design, sample size, ages	Built environment features and measures	Activity-related outcome(s)	Findings
Buman, 2013	To develop and evaluate the utility of a computerized, tablet-based participatory tool designed to identify neighborhood elements that affect active living.	Community-based participatory research (photovoice and audio narratives) n=27 Age:≥65	*sr: neighborhood environment* (GPS to recorded common walking routes; geocoded audio narratives; photographs of facilitators/barriers to active living)	*sr: PA* (GPS recorded common walking routes; geocoded audio narratives)	*1. Common facilitators* Aesthetics (e.g., presence of trees, flowers); parks/playgrounds (e.g., walking paths; public garden); amenities/destinations (e.g., shops, restaurants, public services); personal safety (e.g., "crime free," "upscale living"); sidewalk features (e.g., convenient, well-kempt routes) *2. Common barriers* Negative sidewalk features (e.g., cracks, unevenness); personal safety issues (e.g., afraid of being hit by a vehicle); disability issues (e.g., street not suitable for wheelchair or walker, lack of ramps); crosswalk limitations (e.g., cars do not stop, signals inoperable); and road safety (e.g., speeding cars, blind driveways)
Chaudhury, 2012	To explore the influence of neighborhood residential density and physical/social environments on physical activity of older adults.	Photovoice n=32 Age: ≥65 (65-92; 62% from ≥75)	*sr: neighborhood environment* (Participants instructed to photograph facilitators or barriers to PA)	*sr: leisure and transport PA*	*1. Safety and security* Barriers: maintenance and upkeep of the physical environment (e.g., uneven sidewalks, obstacles/barriers that were tripping hazards/made it unsafe to walk, absence of sidewalks, ending or narrow sidewalks; facilitators: paved, flat, smooth, and wide walking surfaces with good lighting/accessible seating, ramps); traffic hazards (e.g., busy streets, high traffic volume and speed, unsafe intersections and crosswalks, dangerous/impatient drivers with little respect for rules of the road, poor visibility); neighborhood atmosphere (e.g., feeling unsafe, crime, graffiti, vandalism)

First author, year	Focus of study	Study design, sample size, ages	Built environment features and measures	Activity-related outcome(s)	Findings
					2. Accessibility Facilitators: access to convenient public transportation; access to neighborhood facilities or services (i.e., accessible amenities with utilitarian purpose and recreational/social component, such as bank, grocery store, post office, mall, library, gym, recreation center) Barrier: poor access to local parks *3. Comfort of movement* Facilitators: available seating, railings, handrails, ramps, safe stairs, water fountains *4. Peer support* Facilitators: community gardens, spaces for socialization in public areas (e.g., benches, picnic tables), formal social support (e.g., planned activities such as walking groups, community based programs), informal social support (socializing and peer support after or during PA was valuable, e.g., walking with others for exercise, walking to a meeting spot for coffee, meeting or socializing while on a walk)
Chippendale, 2015	To explore neighborhood factors that influence barriers to PA and safety (including fear of falling), resources that support PA and safety, and motivators for PA.	Semi-structured interview n=14 Age: ≥65 (M=75.86)	*sr: neighborhood environment* (semi-structured interview)	*sr: physical activity, time spent outdoors per day*	*1. Barriers to PA* Built barriers: sidewalks (e.g., cobble stones, brick surfaces, uneven grates, broken surfaces, curbs); insufficient street crossing amenities; insufficient park benches; poor visibility or insufficient street lighting; barriers to transit (e.g., steps, wet subway floors, tiled walkways) Natural/environmental barriers: wind, snow, ice; lack of or delayed snow removal, pools of slush or rainwater Program/service specific barriers: lack of programmatic accommodation for older adults at gyms/exercise facilities Social barriers: presence of too many pedestrians, dog walkers, cyclists/skateboarders; gait speed of other pedestrians; personal safety; vulnerability due to looking older

First author, year	Focus of study	Study design, sample size, ages	Built environment features and measures	Activity-related outcome(s)	Findings
					2. Resources for PA and safety Built resources for PA: walking trails, benches for rest, stores for browsing and shopping, senior centers, gyms and recreation facilitates, low/no cost facilities, street fairs, farmers markets, public transit as alternative form of mobility in case of fatigue Built structures safety: structures to hold for support (e.g., railings, fences), benches, timed pedestrian crossings, kneeling buses, elevators in the subway, Social environment: perception of safety (e.g., pedestrians to help cross the street, crossing guards) *3. Motivators for PA* Environmental motivators: appealing architecture, well maintained green spaces, water views, settings that promote connectivity to nature Built motivators: continuous and spacious walking paths and benches Social motivators: places that promote socialization serve as walkable destinations (e.g., basketball courts, playgrounds/parks that promote conversation and people watching; dog parks; senior centers)
Marquez, 2015	To identify features that facilitate or inhibit wayfinding in outdoor settings and better understand how they impact mobility, PA, and community engagement.	Mixed methods (environmental audit, in-person interviews, community walks; map drawing exercise) n=35 ≥65 (M=70.6)	*ea: neighborhood environment* (CDC Healthy Aging Research Network Environmental Audit Tool) *sr: neighborhood environment* (interviews, community walks, map drawing exercise	*sr: transport and leisure walking* *sr: self-efficacy for walking and wayfinding* (Healthy Aging Research Network Protocol)	*Wayfinding facilitators and barriers* Facilitators: landmarks, numbers on buildings, signage (e.g., street signs, block number, advance street signs); land use items (e.g., railroad tracks), transit stops; availability of people to ask for help Barriers: places with no good landmarks or missing signs; distractions (e.g., noise of train); confusing street alignments; lack of other pedestrians deemed trustworthy to ask for help Preferred cues: landmarks, smells, memorable features, logical street labeling system