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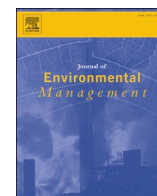
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Review

Green space exposure, mediators, and health in older adults: A systematic review

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ABSTRACT

Rapid population ageing and increasing chronic disease burdens highlight the need to better integrate older adults' green space exposure into environmental and health impact assessment. However, current evidence is fragmented by inconsistent age definitions, reliance on static availability-based greenness metrics, and limited attention to mechanisms, vulnerability, and bias. Following PRISMA 2020 guidelines, we systematically searched Web of Science and Scopus and included 117 studies on green-space exposure and health among older adults. Exposure metrics were grouped within an accessibility–availability–visibility (A–A–V) framework and examined together with environmental modifying factors, behavioral pathways, and health outcomes; keyword co-occurrence and clustering were used to map research foci. NDVI-based availability indicators dominate, while accessibility (e.g. distance, network/time-based access, public transport, street connectivity) and visibility (e.g. street-level greenness, Green View Index) measures are inconsistently defined and applied. Near-home green space and tree canopy are linked to light-to-moderate physical activity and reduced heat, air pollution, and noise exposure, with reported benefits across multiple health domains. We identify major gaps, including scarce dynamic exposure assessment, limited distributional and age-specific equity analyses, and inconsistent risk-of-bias evaluation. We propose an A–A–V indicator framework that links measurable exposure metrics, pathways, and age-relevant health endpoints, offering a practical basis for integrating older adults' green space-related health into impact assessment and age-friendly urban planning.

1. Introduction

In recent years, research on the well-being of older adults has attracted increasing attention (Lau et al., 2021). Notably, the global trend of population aging is intensifying. The World Population Prospects 2019 Revision indicates that by 2050, 1 in 6 people worldwide (16%) will be aged 65 or older (United Nations, 2019). Relevant studies have shown that urban green spaces (UGSs), as a core component of urban green public infrastructure, possess functions such as environmental beautification and improving outdoor environmental quality. Consequently, older adults' exposure to urban green spaces contributes to enhancing their physical and mental health (Macintyre et al., 2019; van Heezik et al., 2020; Wu et al., 2024). Investigating green space

exposure among older adults may contribute to improvements in environmental exposure and human well-being amid the current severe public health context (Li et al., 2024; Vasconcelos et al., 2024). However, while numerous studies on green space exposure for older adults exist, there is a lack of systematic synthesis and a summary of the mechanisms underlying its impact on older adults' health outcomes. Therefore, this study aims to conduct a systematic review of relevant research in recent years to clarify the current research status and challenges, and to identify which factors related to green space exposure influence the health and well-being of older adults, as well as the forms of such influence.

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1.1. Older-adult health and green space exposure

Age-related declines in physical function and psychosocial changes among older adults collectively increase their risk of physical and mental health issues. Physiologically, advancing age is associated with gradual declines in bodily function, increasing the risk of multiple health problems (McDougall et al., 2021; Roe et al., 2017; Taczanowska et al., 2024). This is accompanied by reduced mobility and a higher prevalence of conditions such as cardiovascular diseases and obesity (Aliyas, 2021; Kaczyńska, 2024). Psychosocially, decreased social participation and weakened support networks are often associated with increased risks of adverse outcomes, including anxiety, cognitive decline, and depression.

Green space, a vital component of the urban environment (Paudel and States, 2023), encompasses diverse forms such as urban parks, community green spaces, linear greenways, pocket parks, nature reserves, and ecological vegetation areas, delivering substantial ecological benefits. Meanwhile, by providing accessible activity venues and pleasant landscape experiences, green space exhibits a positive correlation with individuals' physical and mental health outcomes, such as weight management, reduced loneliness, enhanced social interaction, and improved subjective well-being (Astell-Burt et al., 2022; Li et al., 2023), exerting significant effects on human health (Enssle and Kabisch, 2020; Korcz et al., 2024). Therefore, in the context of aging, expanding opportunities for older adults to access and use urban green space holds great significance.

As a core indicator for measuring the intensity of human-ecosystem interaction, green space exposure features distinct spatiotemporal dynamics and multi-dimensional evaluation characteristics, and has become a research focus in fields like environmental ecology and urban planning (Freymueller et al., 2024; Liu et al., 2023). Scholars have pointed out that individuals' green space exposure is spatiotemporally dynamic: exposure levels update along daily activity trajectories and spatial movements, breaking the limitations of traditional static exposure assessment (Chaix et al., 2013; Xie et al., 2023; Yu and Kwan, 2024). In recent studies, green space exposure is widely regarded as a key quantitative basis for linking the acquisition of environmental well-being among populations. Its evaluation framework is mostly constructed around a three-dimensional analytical system of Accessibility, Availability, and Visibility (A-A-V), which collectively form the core dimensions of green space exposure assessment (Labib et al., 2021; Przewoźna et al., 2024) (Fig. 1). In this framework, Accessibility captures how people reach green spaces through transportation modes, travel time, and road-network connectivity (P. C. Chen et al., 2024; Luo

and Wang, 2003); Availability concerns the natural and artificial infrastructure associated with green spaces (Wolch et al., 2014), encompassing the quantity and quality of green infrastructure as well as the necessity and safety of grey infrastructure; Visibility reflects the amount and connectivity of greenery perceived at eye level (Peng et al., 2026a), commonly operationalized with Green View Index and visual-field/street-view analyses (Li et al., 2015).

Green-space exposure research based on this three-dimensional framework facilitates a comprehensive analysis of green space exposure among older adults, thereby offering quantitative evidence for resource allocation oriented toward spatial equity and environmental justice, and laying a solid environmental analysis foundation for understanding the physical and mental health outcomes of older adults resulting from green space exposure. At the same time, discrepancies in exposure definition, measurement methods (static/dynamic), and health outcome scales across disciplines (geography, psychology, public health, landscape planning, etc.) lead to heterogeneity in conclusions. For instance, one study assessed the relationship between “green space contact” (within a 300 m buffer of residential locations) and cognitive ability in older adults but observed no significant association (Ricciardi et al., 2022); in contrast, another study found older adults exhibited better cognitive performance in areas with high community canopy coverage, with physical activity playing a mediating role (Dalecká et al., 2025; de Keijzer et al., 2019), and this effect was more pronounced in females. Therefore, it is necessary to systematically sort out the research focuses and result differences from various perspectives through literature analysis on the same topic, and integrate the potential mechanisms of action.

Beyond these health-oriented pathways, urban green spaces should also be understood as multifunctional green infrastructure within urban environmental management. For ageing cities, this broader framing is important because accessible, useable, and visible green spaces can simultaneously support daily mobility, social participation, and psychological restoration, while also mitigating heat, air pollution, and noise exposure. Older-adult green-space exposure is therefore not only a public-health issue, but also a question of how urban environmental resources are distributed, managed, and translated into social, ecological, and equity-related co-benefits. This perspective links the A-A-V framework to wider sustainability goals, including healthy ageing, reduced environmental inequality, sustainable cities, and climate resilience.

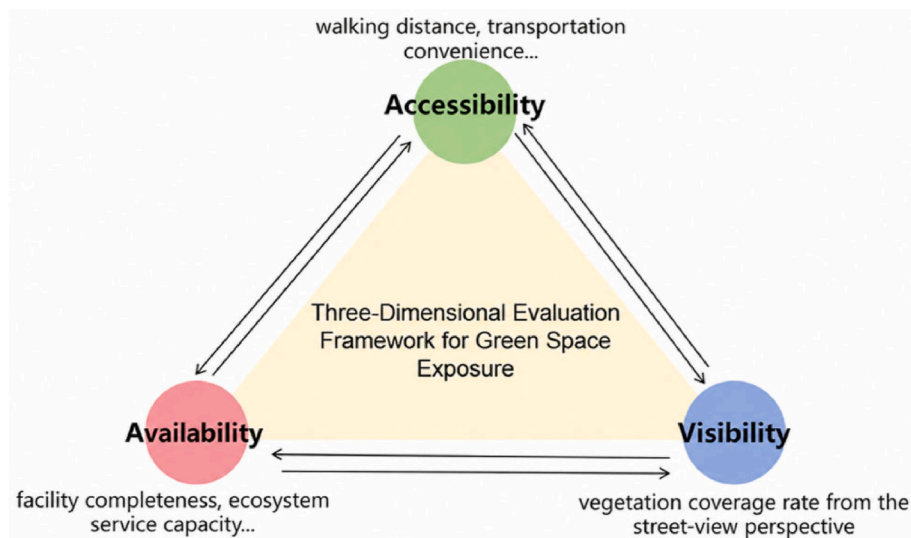


Fig. 1. A three-dimensional analytical system of accessibility, availability, and visibility.

1.2. Literature review in related fields

Centered on older adults, this review systematically synthesizes health effects and mediating/moderating mechanisms under the “A-A-V” three-dimensional framework, complementing existing reviews in terms of time window, research subjects, and methodology. It serves as a comprehensive summary of studies on green space exposure and health in older adults. Such research spans multiple disciplines, including landscape planning, environmental psychology, public health, regional climate, and transportation planning (Banwell et al., 2024; De Bell, 2017; H. Wang et al., 2024), and employs a variety of quantitative and qualitative methods, such as questionnaires, green space assessment using buffer zones, health monitoring, and the establishment of data correlation models.

In recent years, several review studies have summarized related topics, but differences remain between these works and the current review, as detailed below:

- (a) Incomplete overlap in research scope: In relevant literature reviews, green space research is often incorporated into built environment or community environment indicators for assessment (Iamtrakul and Chayphong, 2024; Sharma and Jain, 2023), making it difficult to accurately isolate the independent impact of green spaces on populations. When focusing on specific types of green spaces (e.g., pocket parks, community parks, or large-scale parks), discrepancies in their scale and functions lead to a lack of generalizability in research conclusions. Additionally, among reviews exploring how populations can better benefit from green spaces, studies targeting older adults are scarce. Other syntheses focus on particular health domains, such as respiratory or mental health, rather than integrating multiple outcomes and exposure pathways (L. Wang et al., 2024; Wang et al., 2019).
- (b) Divergences in research focus: Some reviews emphasize summarizing research tools, such as instruments for green space exposure assessment and population activity measurement (e.g., buffer zone measurement, sensor-based monitoring) (Marquet et al., 2022; Yi et al., 2019). Others categorize and introduce literature based on research scales (e.g., urban scale vs. community scale). In contrast, the current review focuses on analyzing the three-dimensional indicators of green space exposure, comprehensively evaluating the application of green space exposure elements through three dimensions, and synthesizes health outcomes by integrating the analysis of mediating factors (Gianfredi et al., 2021; Zhang et al., 2017).
- (c) Differences in temporal scope and evidence coverage: Existing reviews vary substantially in their temporal framing. Some syntheses focus specifically on green-space use or health during the COVID-19 pandemic (Kleinschroth et al., 2024), whereas others address broader populations, longer time periods, or individual health domains. Although these reviews provide useful contextual evidence, they do not offer a recent synthesis centered on older adults that simultaneously integrates exposure measurement, behavioral and environmental pathways, and health outcomes. The present review therefore examines studies published between 2020 and 2025 as the most recent wave of evidence.

1.3. Research gap and research questions

In research on green space and later-life health, several gaps persist. First, existing research remains insufficiently age-sensitive: older adults' specific vulnerabilities and environmental requirements are often underrepresented in general green-space assessments, while dedicated assessment tools remain limited to particular settings and applications (Xiang and Mei, 2024). Second, scale effects remain underexplored; owing to limited mobility, older adults may respond to spatial scale differently from the general population (Portegijs et al., 2020). Third,

methods are rarely adapted to older adults' exposure needs and measurement realities. Finally, population heterogeneity in mechanisms is understudied, for example, age-related sensory and functional declines may heighten demand for specific exposure dimensions relative to other groups.

In summary, these core gaps hinder the formation of a systematic understanding in this field. To address the above gaps, this review aims to fill current research voids by integrating studies from the past five years, refining scale classification, adapting methodologies to older adults, and analyzing differences in mechanisms. To this end, we propose the following research questions (RQs):

RQ1: What are the dominant and emerging research themes in older-adult green-space exposure studies, and how are these themes interrelated?

RQ2: How do study design, spatial scale, case context, and exposure-measurement choices shape empirical findings?

RQ3: Which A–A–V exposure pathways link green space to behavioral/environmental mechanisms and older-adult health outcomes?

RQ4: What methodological limitations, evidence gaps, and policy implications should guide future research and environmental management?

The structure of this paper is as follows: (a) Materials and Methods: Details the literature sources, screening process, and volume of literature, explains the steps for selecting and analyzing literature in this review, and elaborates on the literature analysis methods. (b) Results of Literature Analysis: Analyzes the overall publication status and research characteristics to address RQ1; further codes the literature and conducts in-depth analysis of methodological patterns, exposure dimensions, mediating/moderating factors, and health outcomes to address RQ2 and RQ3. (c) Discussion: Synthesizes and summarizes the preceding content to address RQ4. The contributions of this review to the field of green space and later-life health can be concisely summarized as follows: Theoretically, it organizes fragmented evidence within an age-sensitive A–A–V analytical framework and clarifies how spatial scale, mobility constraints, and population heterogeneity shape the associations between green-space exposure and health in later life; methodologically, it compares study designs, spatial scales, exposure measures, and analytical approaches, while identifying priorities for more age-adapted and reproducible research; practically, it provides evidence-based guidance for age-friendly green-space planning and environmental management and clarifies research priorities needed to strengthen the translation of academic evidence into policy and practice.

2. Materials and Methods

Literature retrieval was conducted on Web of Science (WoS) and Scopus. Web of Science Core Collection and Scopus were selected because they provide broad multidisciplinary coverage across environmental science, urban planning, geography, public health, and gerontology, while also supporting standardized bibliographic export for reproducible keyword-network analysis (Page et al., 2021). The PRISMA2020² reporting guidelines were followed to present the retrieval strategy, inclusion/exclusion criteria, and screening process (Rethlefsen et al., 2021). Subsequently, VOSviewer was used for keyword co-occurrence, clustering, and time-based color overlay analysis (Arruda et al., 2022). For the measurement of exposure, this study statistically analyzed three dimensions separately: (a) Accessibility: Measured by distance, time, and network cost; (b) Availability: Measured by NDVI, canopy coverage, facility diversity, accessibility for people with disabilities, and safety; (c) Visibility: Measured by GVI and visual

² PRISMA 2020: The updated reporting guideline for systematic reviews and meta-analyses.

field. On this basis, the screened literature was coded using NVivo, and relevant results were summarized and presented (Fig. 2). Screening was conducted by one reviewer using predefined eligibility criteria. Before independent verification, two reviewers jointly reviewed a calibration set to standardize the interpretation of the inclusion and exclusion criteria. A second reviewer subsequently reassessed a random subset of title-and-abstract records and a stratified subset of full-text records, ensuring that both included and excluded records were represented. Inter-reviewer reliability was evaluated using percentage agreement and Cohen's κ . Disagreements were resolved through discussion and consensus. A structured codebook was developed for study design, spatial scale, A–A–V exposure indicators, behavioral and environmental pathways, and health outcomes. Before independent verification, two coders jointly reviewed a calibration set to clarify the operational definitions, decision rules, and representative examples. A second coder then independently coded a stratified subset of the included studies. Inter-coder reliability was evaluated using percentage agreement and Cohen's κ across the principal coding domains. All discrepancies were discussed and resolved by consensus before the coded dataset was finalized.

2.1. Data collection

Web of Science (WoS) and Scopus are comprehensive academic literature retrieval platforms. The search timeframe was restricted to January 1, 2020, to July 17, 2025. For this study, only peer-reviewed journal articles indexed in the Science Citation Index Expanded (SCI-EXPANDED), Social Sciences Citation Index (SSCI), Arts & Humanities Citation Index (A&HCI), and Emerging Sources Citation Index (ESCI) were included. These sources were selected because they undergo formal peer review and adhere to established academic standards.

To retrieve relevant literature from the platforms, this study defined

specific thematic keywords tailored to the research focus: “the impact of urban green space system accessibility on the well-being of older adults”. The keywords were categorized into three groups, green space, exposure, and older adults, with synonyms incorporated into each group to ensure comprehensive literature coverage. The three core keyword groups used are as follows:

- (a) **Green space:** TS1 = (“urban green space” OR “green space” OR “urban park*” OR “green area*” OR “green exposure” OR “green infrastructure*” OR “green zone*” OR “greenness”)
- (b) **Exposure:** TS2 = (“exposure” OR “availab*” OR “visibility” OR “access*” OR “proximity” OR “distance”)
- (c) **The elderly:** TS3 = (“older people” OR “aging” OR “elderly” OR “Older adult*” OR “Senior*” OR “The aged” OR “Older generation*” OR “Older individual*”)

To mirror the Web of Science strategy, we searched Scopus using the basic field Article title, Abstract, Keywords. Three concept blocks were combined with AND: (i) green space terms (“urban green space” OR “green space” OR “urban park*” OR “green area*” OR “green exposure” OR “green infrastructure*” OR “green zone*” OR “greenness”); (ii) exposure terms (exposure OR availab* OR visibility OR access* OR proximity OR distance); and (iii) older-adult terms (“older people” OR aging OR elderly OR “older adult*” OR senior* OR “the aged” OR “older generation*” OR “older individual*”). Alternative population terms were retained in the database search strings to preserve search sensitivity and reproducibility, whereas the narrative text consistently uses “older adults.” We then filtered results to Source type: Journals and Document type: Article and Review (Language: English). The complete database-specific search strings, field tags, truncation rules, filters, and search dates are provided in Supplementary S1.

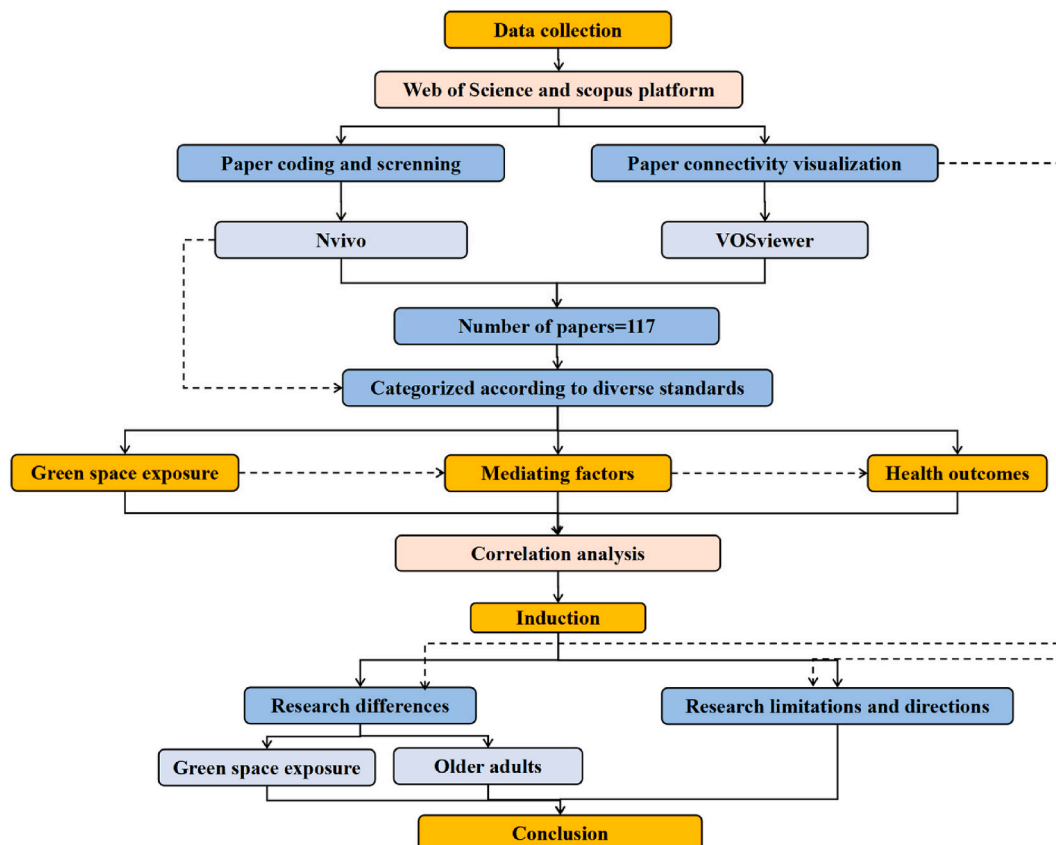


Fig. 2. The workflow diagram for literature review.

2.2. Literature screening and coding

In accordance with the PRISMA guidelines (Page et al., 2020; Takkouche and Norman, 2011), the literature screening was conducted through record identification, duplicate removal, title/abstract screening, abstract-level eligibility assessment, full-text assessment, and final inclusion. The initial search retrieved 942 records from Web of Science and Scopus, including 520 records from Web of Science and 422 records from Scopus. After removing 340 duplicate or ineligible records, 602 records remained for title and abstract screening.

Eligibility criteria were established to ensure consistency and reproducibility. Studies were included if they were peer-reviewed English journal articles or reviews published between 1 January 2020 and 17 July 2025; focused on older adults or included older-adult subgroup analysis; examined urban green space, greenness, parks, green infrastructure, or related exposure; included at least one exposure dimension corresponding to accessibility, availability, or visibility; and reported health, behavioral, environmental, well-being, or social-perception outcomes. Studies were excluded if they lacked an older-adult sample or subgroup, did not address urban green-space exposure, focused only on blue space or non-urban natural environments without separate

analysis of urban green space, lacked empirical exposure or outcome information, were non-peer-reviewed formats, or had unavailable full text.

During title and abstract screening, 327 records were excluded as irrelevant, non-eligible in format, or non-English. Of the remaining 275 records, 140 were excluded after abstract-level eligibility assessment, leaving 135 articles for full-text assessment. At the full-text stage, 18 articles were excluded because they did not meet the population, exposure, outcome, or full-text availability criteria. Finally, 117 studies were included in the review (Fig. 3; Appendix A). The included studies were subsequently coded according to study design, spatial scale, A–A–V exposure indicators, mediating and moderating factors, health outcomes, and methodological characteristics for further synthesis.

Subsequently, literature coding was performed during the analysis process. This step facilitates the classification of literature for statistical and qualitative analysis (Mortelmans, 2024, 2025). By clarifying the research direction, scope, methodology, and results of each study, key information was extracted from the articles. Through classification and integration based on different criteria, underlying research patterns were further explored.

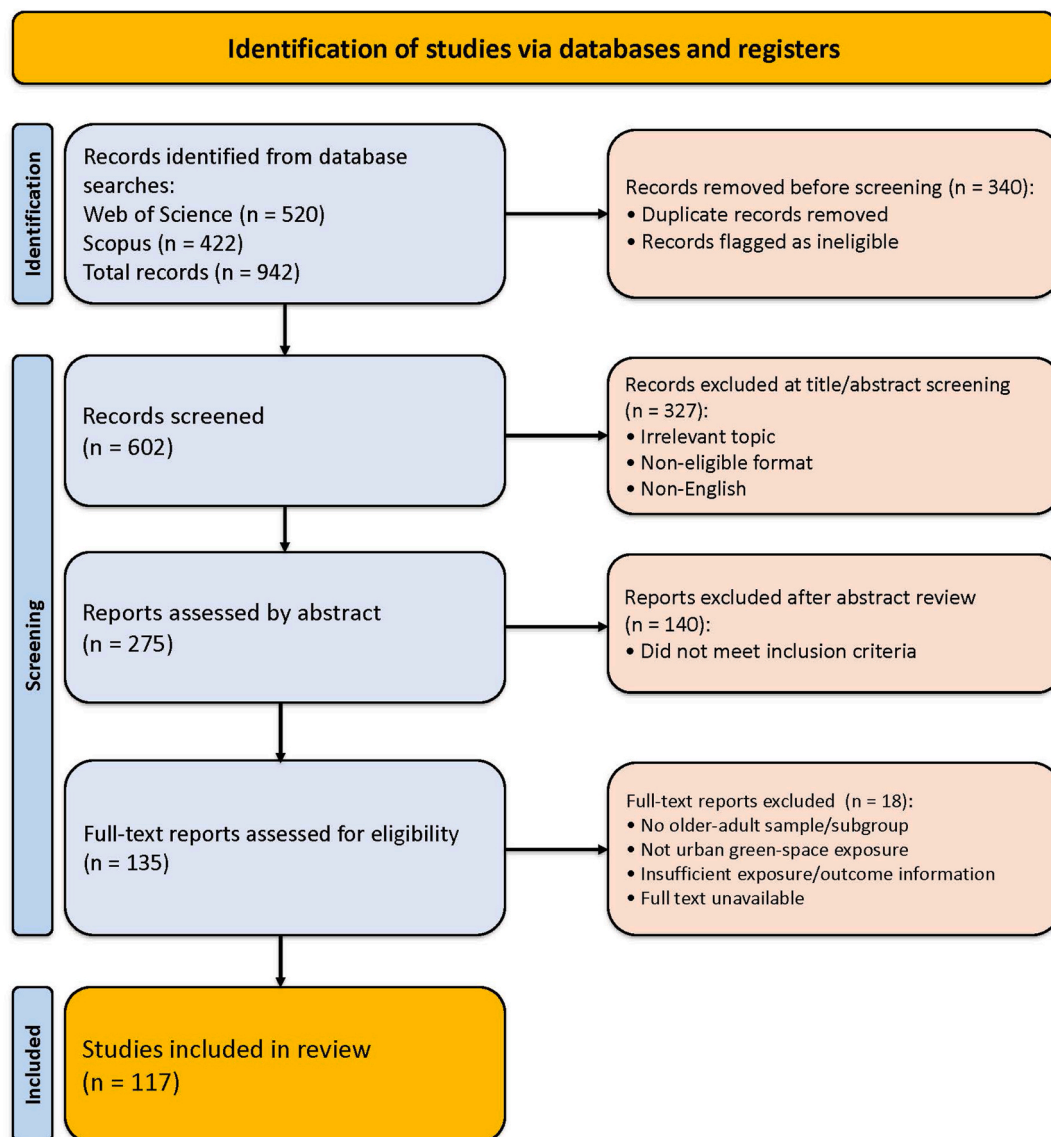


Fig. 3. PRISMA flow for this research.

2.3. Literature analysis

VOSviewer was used to map the intellectual structure and temporal development of the reviewed literature through keyword co-occurrence, clustering, and overlay visualization. To move beyond descriptive cluster interpretation, the VOSviewer map and network files were exported and converted into a weighted, undirected keyword network, in which nodes represented keywords and edges represented co-occurrence links. In addition to occurrence frequency and total link strength, we calculated betweenness centrality, closeness centrality, network density, and modularity (Xu and Zhang, 2021, 2023b, 2024). Betweenness centrality was calculated using inverse link strength as distance, so that stronger co-occurrence links represented shorter conceptual distances. These network indicators were used to identify core and bridging keywords, assess the degree of thematic integration or fragmentation, and supplement the VOSviewer clustering and temporal overlay analysis. Based on the coding results, the included studies were further classified and synthesized according to green-space exposure dimensions, mediating/moderating factors, and health outcomes, with graphical visualization used to illustrate relationships across these categories.

2.4. Study-quality and risk-of-bias appraisal

To assess the robustness of the evidence base, we conducted a structured six-domain study-quality and risk-of-bias appraisal for all included studies. The corpus encompassed heterogeneous research designs, including cross-sectional and longitudinal observational studies, cohort studies, qualitative and mixed-methods research, spatial-equity analyses, and experimental or quasi-experimental studies. Because no single design-specific checklist was directly applicable to the entire evidence base, we retained a harmonized domain-based framework informed by common appraisal criteria contained in the Joanna Briggs Institute (JBI) critical appraisal tools. The JBI tools were used as methodological references rather than applied verbatim as separate design-specific scoring instruments.

The framework assessed six domains: study-design clarity, exposure measurement, outcome measurement, confounder adjustment, temporal ordering, and missing-data/reporting quality. Each domain was rated as low risk, some concerns, or high risk according to predefined decision rules. The overall judgment reflected the combined pattern and substantive importance of the six domain ratings rather than a mechanical count of individual ratings. Full operational definitions and decision rules are provided in Supplementary S2, and study-level ratings are reported in Supplementary S2.

3. Results

The following results provide a comprehensive analysis and summary of literature on green space exposure in older adults published over the past five years. This section focuses on core topics including publication overview, research focuses, characteristics of study cases, and research findings in this field.

3.1. Literature characteristics

Over the past five years, research on green space exposure in older adults has shown an overall upward trend (Fig. 4a). This increase may reflect growing attention to healthy ageing, environmental exposure, and age-friendly urban planning, especially in the context of heightened concern about outdoor environments and public health. It may also be associated with the wider availability of remote-sensing data, street-view imagery, geospatial datasets, and health-related cohort or registry data, which have expanded the methodological possibilities for green-space exposure research.

Fig. 4b summarizes the journals with the highest publication volumes on this topic. *International Journal of Environmental Research and Public Health* ranked first in terms of publication quantity, with 18 relevant articles published; followed by *Frontiers in Public Health* with 13 articles; *Sustainability*, *Environmental Research*, and *Urban Forestry & Urban Greening* ranked third to fifth with 9, 7, and 6 articles respectively. Research on green space exposure in older adults is mainly published in journals related to environmental public health, while some studies also appear in journals focusing on sustainability, landscape planning, and social sciences. From the perspective of journal publications, this field primarily involves disciplines such as landscape planning, public health, geography, environmental science, and geriatrics, with a high prevalence of interdisciplinary research.

In terms of the number of papers published by country (Fig. 4c), China ranks first, followed by the United States, Australia, and the United Kingdom. From the color distribution of the publication timeline, it can be observed that countries such as the United States and Germany initiated relevant research relatively early, and most participating countries are developed nations. In recent years, China's participation in such research has increased significantly, and several Asian countries (e. g., South Korea, Saudi Arabia) have also newly joined this field of study.

The study-quality and risk-of-bias appraisal indicates uneven support for causal exposure-health inference across the 117 included studies (Table 1). Study-level ratings for the six appraisal domains and the overall judgment are provided in Supplementary S2. Across the 117 included studies, 32 were judged as low risk, 76 as having some concerns, and 9 as high risk with respect to their capacity to support

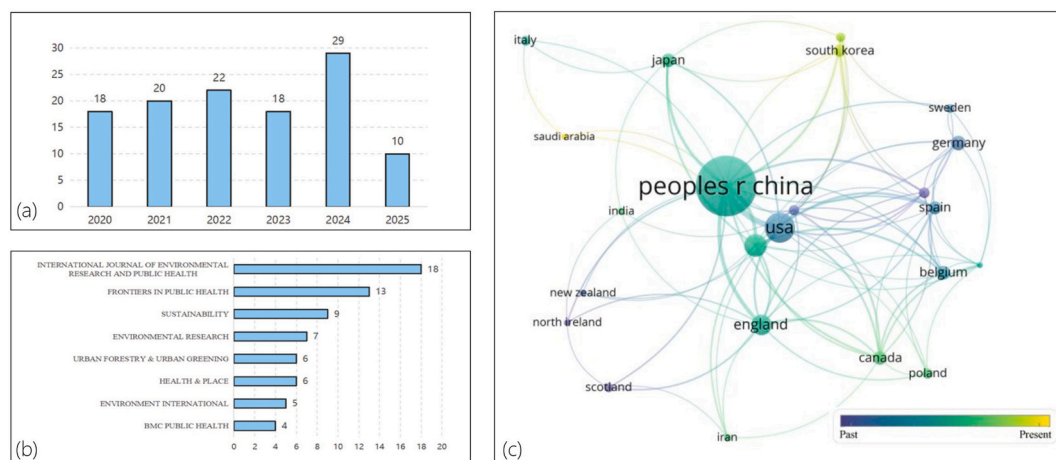


Fig. 4. (a) Number of publications on relevant topics; (b) Major journals; (c) Number and trend of publications by country.

Table 1
Summary of study-quality and risk-of-bias appraisal.

Domain	Low risk	Some concerns	High risk
Study design clarity	90	27	0
Exposure measurement	74	43	0
Outcome measurement	41	67	9
Confounder adjustment	31	66	20
Temporal ordering	31	60	26
Missing data/reporting	31	86	0
Overall judgement for causal inference	32	76	9

exposure–health inference. Stronger evidence generally came from longitudinal, cohort, fixed-effects, register-based, case-crossover, or prospective designs with objective exposure and outcome measures. By contrast, weaker evidence often relied on cross-sectional designs, static residential greenness proxies, subjective outcomes, limited confounder adjustment, or unclear temporal ordering. These findings support cautious interpretation of the reviewed associations and justify the narrative evidence-strength categories used in the subsequent pathway synthesis.

3.2. VOSviewer-based network analysis: research focuses and emerging hotspots

This section primarily uses VOSviewer software to analyze the current research focuses and emerging hotspots. Keyword co-occurrence

mapping was conducted in VOSviewer using all keywords, full counting, and association-strength normalization. Keywords occurring at least nine times were retained. The final network contained 62 keywords, 1125 weighted links, and four clusters.

3.2.1. Research focuses

As shown in the figure, a keyword analysis network generated by VOSviewer is presented (Fig. 5a). In this network, the size of each circle corresponds to the frequency of the respective keyword in the literature retrieval, and related keywords are connected by lines. The keywords are divided into 4 distinct clusters. The most frequently occurring terms in each cluster are “built environment”, “health”, “physical activity”, and “accessibility”. From these terms, it can be inferred that research on older adults mainly focuses on the impact of exposure to external environmental factors and accessibility on their physical activity and health.

- (a) **Blue cluster:** Core keywords include “older adults”, “built environment”, and “walking”, focusing on neighborhood walking environments and mobility. Their frequencies are 60, 62, and 32 respectively. For example, a study in Luxembourg examined the impact of amenities, street connectivity, low-speed zones, and greenery on the daily travel of older adults (Klein et al., 2023).
- (b) **Green cluster:** Core keywords include “health”, “exposure”, and “mortality”, focusing on macro-scale exposure and health risks. Their frequencies are 96, 55, and 52 respectively. For example, a

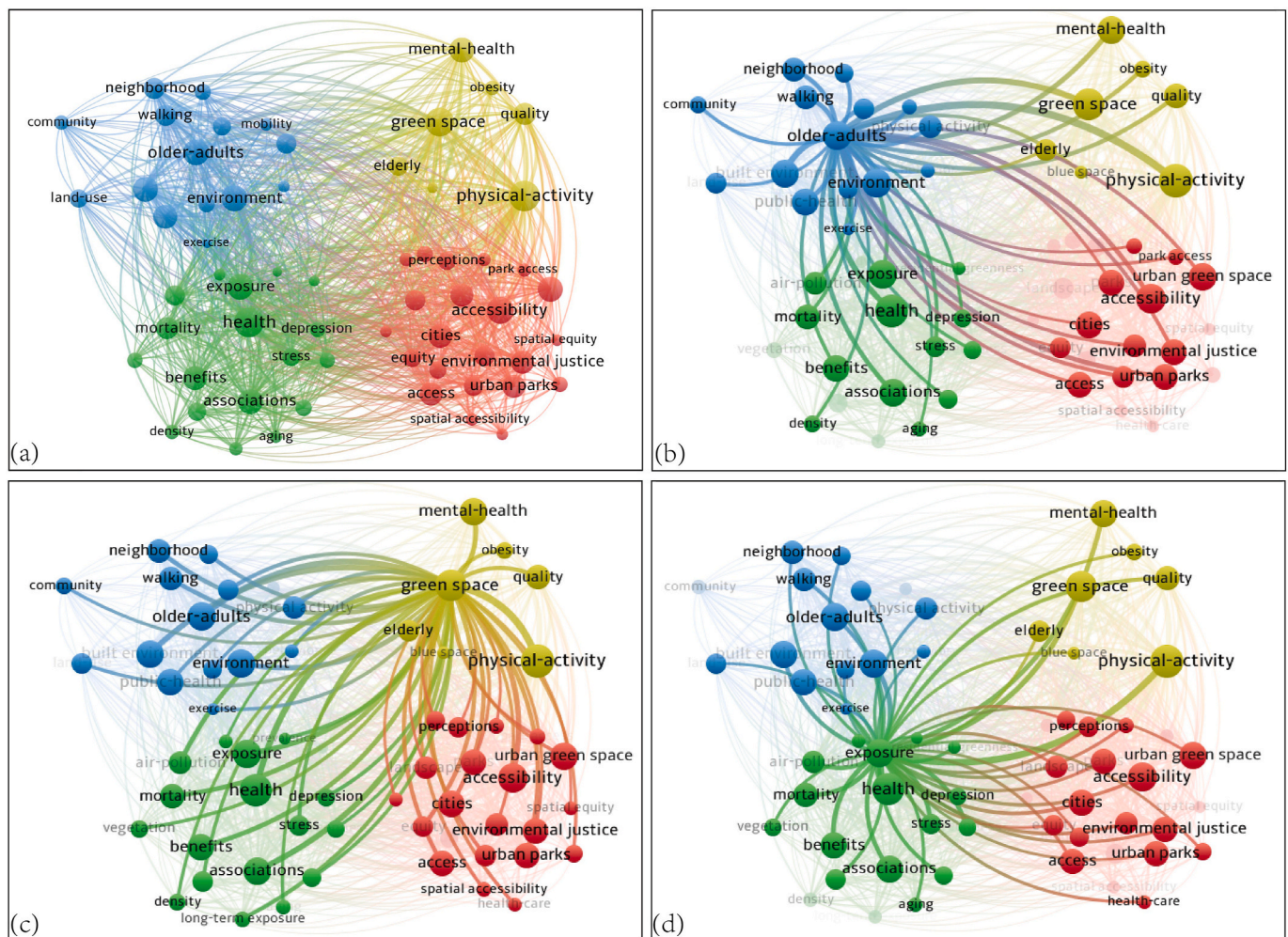


Fig. 5. Network analysis & research focuses. (a) Clustering analysis results of keywords in this field of research. (b) Keywords with high relevance to older adults (c) Keywords with high relevance to green space (d) Keywords with high relevance to exposure.

nationwide study in China analyzed the relationship between NDVI within a 500-m radius of residential addresses and the cognitive function of older adults (Zhu et al., 2020).

- (c) **Yellow cluster:** Core keywords include “physical activity”, “green space”, and “obesity”, with physical activity identified as a key mediator. Their frequencies are 100, 59, and 15 respectively. Evidence indicates that the distribution and distance of nearby green spaces influence older adults' walking activity and obesity status in dense urban settings (Cao et al., 2023).
- (d) **Red cluster:** Core keywords include “accessibility”, “environmental justice”, and “equity”, focusing on accessibility and spatial equity. Their frequencies are 56, 38, and 23 respectively. For example, a study analyzed the accessibility of regional green spaces in the Melbourne metropolitan area and summarized the accessibility differences between regions (Sharifi et al., 2021).

Fig. 5(b)–(d) show the same keyword network filtered by relevance to three anchors. In Fig. 5b older adults–relevant, the structure tightens around neighborhood mobility: “built environment,” “walking,” and “mobility” cluster closely with “health,” while ties to “accessibility/justice” thin out, indicating a micro-scale focus on walkable environments for older adults. In Fig. 5c green space–relevant, “physical activity” emerges as the dominant bridge linking “green space” to outcomes such as “mental health” and “obesity,” with dense links to “parks/quality,” suggesting a prevalent pathway of *green space - activity - health*. In Fig. 5d exposure–relevant, the core is the “exposure–health” nexus, strongly connected to risk terms (“mortality,” “depression,” “air pollution,” and heat-related terms) and outward to “accessibility,” “environmental justice,” and “equity,” highlighting differential exposures across neighborhoods. Taken together, the three views indicate that older-adult studies emphasize local mobility settings, green space studies foreground behavioral mediation, and exposure studies foreground health risks and fairness; the themes interlock through bridge terms such as “accessibility,” “parks/quality,” and “physical activity,” consistent with an A-A-V exposure framework leading to health via behavioral and environmental mediators.

To further identify the core and bridging keywords in the co-occurrence network, additional centrality indicators were calculated (Table 2).

Following network-analytic logic in which centrality and modularity indicators are used to identify bridging nodes and heterogeneous substructures in complex relational systems, the enhanced keyword network contained 62 nodes and 1125 weighted co-occurrence links. The network formed a single connected component, with a density of 0.5949 and a VOSviewer-cluster modularity of 0.1391, indicating that the field is thematically differentiated but strongly interconnected rather than fragmented. The centrality results show that “physical-activity” had the highest total link strength and betweenness centrality, followed by “health” and “accessibility”. This pattern indicates that behavioral activity serves as the main bridging concept connecting

green-space exposure, older-adult mobility, and health outcomes. “Health” acts as the primary outcome hub, while “accessibility” connects exposure assessment with planning, equity, and environmental-justice concerns.

3.2.2. Emerging hotspots and temporal dimension analysis

Fig. 6 illustrates the temporal progression of research on different keywords. Research areas shaded yellow represent newer topics, while those shaded blue-purple represent established areas. As shown in the figure, green space is the primary research object, linked to the physical activity and health of older adults, indicating that the basic health effects of green space and its association with the built environment are core themes. Population-related terms were not merged automatically. “Aging” was retained as a process-level concept, while “elderly,” “older people,” and “older adults” were kept as separate author/index keywords to preserve disciplinary and temporal differences in terminology; these terms were interpreted collectively when characterizing the older-population theme. Among these, keywords related to older populations (e.g., “older adults,” “older people,” “aging”) are relatively new, suggesting that refinement and focus on specific populations are emerging and rapidly growing trends in recent years.

Based on keywords such as “depression”, “temperature”, and “obesity”, new studies focus on specific health outcomes of green space exposure and associated mediating factors (e.g., temperature-related microclimates and heat island effects). Additionally, newer keywords including “cultural ecosystem services”, “environmental justice”, and “equity” reflect the expansion of research from single health effects to integrated ecological, cultural, and social benefits, as well as spatial equity, for example, focusing on exposure equity for older adults and their social health needs. Keywords such as “exposure”, “perceptions”, and “exercise” indicate that research is deepening from “whether individuals are exposed to green space” to how exposure occurs, exposure patterns, and subjective perceptions.

3.3. Analysis of dimensional elements of green space exposure, mediating factors, and health outcomes in older adults

Within the existing A-A-V framework, this section integrates indicators of green space exposure, sample characteristics, behavioral and environmental mediators, and health outcomes to structure the subsequent synthesis and comparative analysis (Fig. 7). Literature sources were categorized through NVivo coding, and the indicator–mediator/moderator–outcome triadic framework was employed throughout to ensure a coherent and systematic synthesis.

To evaluate screening reliability, a second reviewer independently reassessed 60 of the 602 title-and-abstract records and a stratified sample of 20 of the 135 full-text records. For title-and-abstract screening, the reviewers agreed on 52 of 60 records, corresponding to 86.7% agreement and a Cohen's κ of 0.73. For full-text assessment, they agreed on 18 of 20 records, corresponding to 90.0% agreement and a Cohen's κ of 0.73. Both results indicated substantial inter-reviewer agreement.

For coding reliability, a second coder independently coded a stratified sample of 18 of the 117 included studies. Across the principal coding domains, percentage agreement ranged from 83.3% to 88.9%, and Cohen's κ values ranged from 0.72 to 0.78 (Supplementary S3). All coding discrepancies were resolved through discussion and consensus.

3.3.1. Analysis of green space quality

Green space quality is measured with a multi-metric panel rather than a single proxy. While NDVI remains the most prevalent indicator, extended implementations incorporate EVI/SAVI, canopy cover/shade, vegetation composition, and patch-level structure (connectivity, fragmentation, edge effects), complemented by diversity and openness measures. These quality metrics directly inform Availability and condition perceived Accessibility and Visibility through shade, safety, and

Table 2
Central and bridging keywords in the co-occurrence network.

Keyword	Total link strength	Betweenness centrality	Closeness centrality	Interpretive role
physical-activity	616	0.5739	1.0000	Main behavioral bridge
health	514	0.3500	0.9839	Outcome hub
accessibility	328	0.2142	0.8841	Planning and equity bridge
green space	329	0.0311	0.9385	Exposure hub
built environment	261	0.0675	0.8356	Contextual hub
environmental justice	203	0.0126	0.8026	Equity-oriented bridge

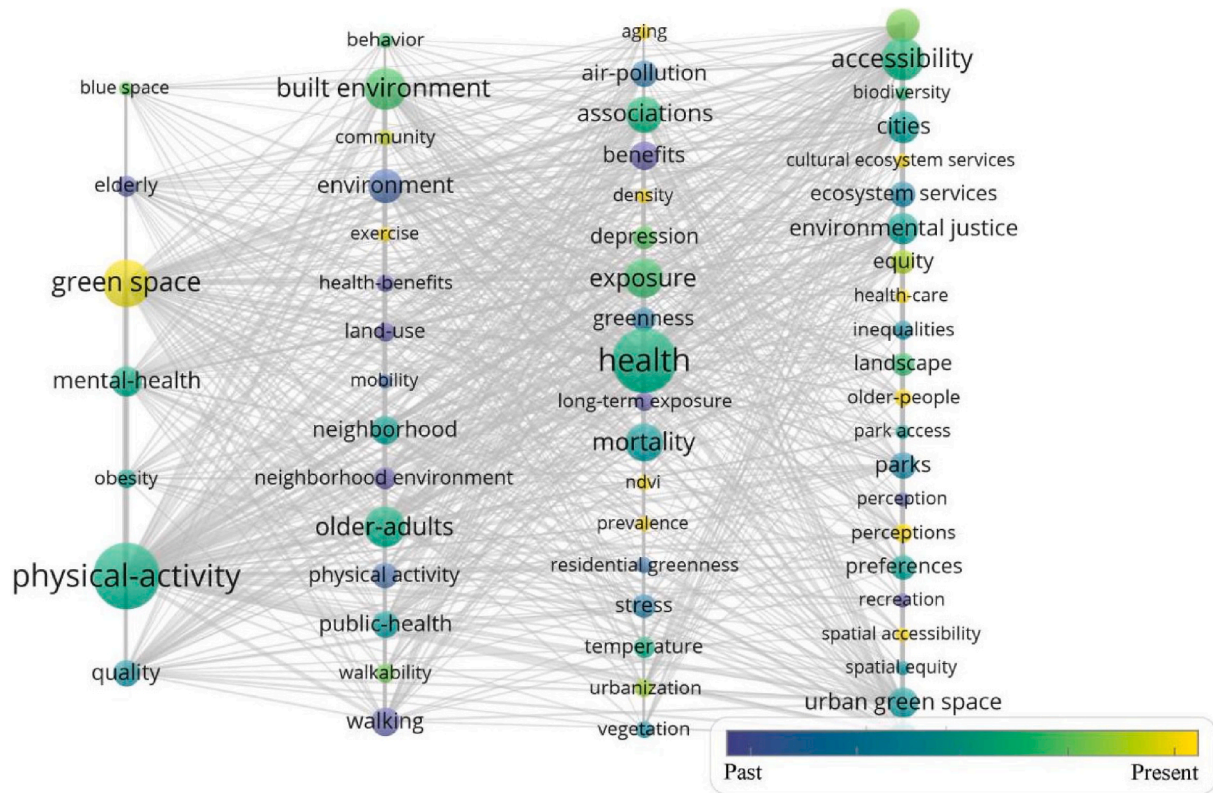


Fig. 6. Clustering and publication timeline analysis results of keywords in the field.

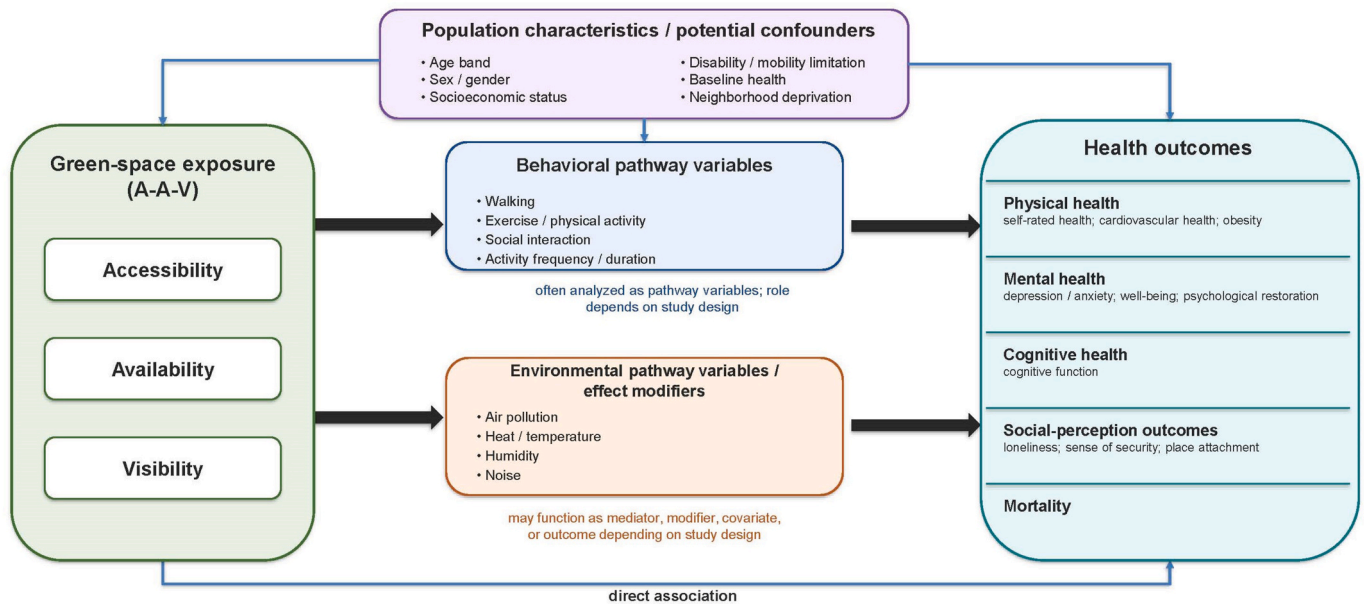


Fig. 7. Conceptual pathway framework linking A-A-V dimensions of green-space exposure with behavioral and environmental pathway variables and health outcomes among older adults.

spatial legibility for older adults. The full indicator list, operational definitions, scales, and data sources are consolidated in Table 3 (Availability–quality block). Using this multi-metric set mitigates single-metric bias and improves comparability across studies focused on ageing populations.

3.3.2. Sample definition and stratification of older adults

Older adults are most commonly defined as ≥ 65 years (with a

minority at ≥ 60), with frequent stratification by sex, socioeconomic status, health behaviors, and mobility constraints. Several studies apply age bands (e.g., 60–70 vs. ≥ 70 years) to examine heterogeneity and strengthen confounder control. These definitional choices affect exposure assignment and effect estimates, particularly for near-home and route-based measures, and should be interpreted alongside the indicator families summarized in Table 3, which maps measurement choices to older-adult use cases.

Table 3
Analytical synthesis of A-A-V indicators in green-space exposure research.

Exposure Type	Green-space Exposure Research Indicators	Study IDs
Accessibility	Distance to the nearest public green space or park entrance	3, 10, 12, 14, 34, 41, 43, 49, 50, 57, 61, 63, 64, 82, 83, 87, 91, 98, 99, 107
	Network/time-based accessibility by mode (walking/PT/driving)	5, 6, 8, 10, 11, 12, 13, 26, 28, 29, 37, 38, 50, 62, 67, 74, 90, 97, 100, 101, 107
	Traffic connectivity	8, 9, 11, 12, 37, 38, 56, 80, 100, 101
	Low-speed roads within the buffer zone	4, 8, 9, 10, 12, 23, 38, 47, 56, 58, 59, 80, 82, 90, 99, 100
Availability	Area of various green spaces available within the buffer zone or percentage	9, 10, 11, 12, 13, 15, 16, 20, 21, 22, 23, 24, 25, 26, 27, 30, 31, 32, 33, 35, 39, 40, 46, 48, 49, 51, 52, 53, 55, 57, 58, 59, 60, 63, 64, 66, 70, 72, 75, 76, 77, 78, 79, 80, 82, 84, 85, 86, 87, 88, 89, 90, 94, 102, 106, 109, 110, 111, 112, 113, 114, 115, 116, 117
	Number of parks within the buffer zone	7, 10, 28, 47, 56, 61, 92, 103, 104,
	Canopy coverage within the buffer zone	11, 19, 22, 26, 54, 82, 102, 108, 109, 112
	Green space patch structure and connectivity	30, 44, 48, 61
	Amenities (seats, fitness equipment, restrooms, recreational facilities, shaded areas, walking trails, etc.)	1, 14, 17, 18, 29, 41, 42, 43, 44, 45, 47, 68, 69, 73, 77, 81, 83, 87, 91, 100, 105
	Environmental safety (slope, barrier-free access, anti-slip features, streetlights)	1, 41, 42, 43, 44, 56, 68, 69, 74, 76, 83, 91, 100
	Peripheral facilities and functional mix	21, 31, 34, 38, 76, 88
	Diversity of green space types	21, 23, 26, 36, 37, 40, 43, 54, 95, 98, 110
	The structural layout and available area within the green space	17, 21, 62, 81, 91, 105, 108
	Cultural and civilizational relevance	14, 69
	Balcony and courtyard greening	2, 65, 93
	Green view index of block	8, 45, 54, 59, 84, 85, 96, 97, 102, 103, 104, 114
	Richness of green space habitat elements	37, 91, 93, 108, 112
	Aesthetics, color, cleanliness	41, 42, 54, 87, 93, 102
	Visual connectivity or enclosure	59, 71, 81, 82, 87
Visibility		

3.3.3. Core exposure dimensions and indicator families (A–A–V)

Accessibility asks whether green spaces can be reached and is captured by distance to the nearest public green space or park entrance, network/time-based reach by mode (walking, public transport, driving), and street/traffic connectivity (including low-speed networks reflecting walk safety and continuity). Availability indicates the quantity and spatial supply of nearby green space, measured via buffer-based quantity, canopy/shade, park supply and grading, in-park amenities and environmental safety, patch configuration, and neighborhood functional mix. Visibility reflects everyday visual contact with greenery, measured by streetscape greenness/GVI from street-view imagery with semantic segmentation, together with visual connectivity/enclosure and domestic greening (balcony/courtyard). This mapping clarifies how different facets of exposure align with behavioral mediators and environmental moderators considered in subsequent sections (Table 3).

Building on Table 3, Across the 117 included studies, 245 study-indicator coding instances were identified. An individual study could contribute to more than one coding instance when it assessed multiple green-space exposure indicators. Although study-level membership

across the A–A–V dimensions was non-mutually exclusive, each coded instance was assigned to one dimension; consequently, the dimension-level percentages reported in Fig. 8 sum to 100% (Fig. 8).

(a) Accessibility analysis

Accessibility accounted for 67 of the 245 coded study-indicator instances (27.3%). Network- or time-based accessibility by travel mode was the most frequently coded accessibility indicator, contributing 21 instances (8.6%) (Godina et al., 2023), followed by distance to the nearest green space or park entrance with 20 instances (8.2%) (C. P. Chen et al., 2024). Low-speed roads within buffer zones contributed 16 instances (6.5%), while traffic connectivity contributed 10 instances (4.1%). Together, these indicators capture travel effort, route continuity, transport options, and pedestrian safety relevant to older adults' ability to reach green spaces (Klein et al., 2023).

(b) Availability analysis

Availability was the most frequently represented dimension, accounting for 147 coded instances (60.0%). Green-space area or percentage within residential buffers was the dominant indicator, with 64 instances (26.1%). Amenities, including seating, fitness equipment, restrooms, shaded areas, and walking trails, contributed 21 instances (8.6%) (Chu et al., 2021), while environmental safety contributed 13 instances (5.3%) (Kou et al., 2021). Other availability indicators included diversity of green-space types (11 instances; 4.5%), canopy coverage (10; 4.1%) (Egorov et al., 2025), number of parks within the buffer zone (9; 3.7%), structural layout or useable area (7; 2.9%), peripheral facilities and functional mix (6; 2.4%), patch structure and connectivity (4; 1.6%), and cultural relevance (2; 0.8%).

The predominance of availability-based indicators, particularly buffer-based green-space area and greenness measures, reflects their scalability, reproducibility, and compatibility with satellite imagery, administrative boundaries, and large health datasets. However, this methodological dominance should not be interpreted as evidence that availability is necessarily the most meaningful dimension for older adults. Residential greenness and total green-space area do not indicate whether green spaces can be safely reached, whether facilities are useable, or whether greenery is visually experienced in daily life.

(c) Visibility analysis

Visibility accounted for 31 coded instances (12.7%). The Green View Index was the most frequently coded visibility indicator, contributing 12 instances (4.9%). Aesthetics, color, and cleanliness contributed 6 instances (2.4%) (Lak et al., 2020; Meng et al., 2020); richness of green-space habitat elements and visual connectivity or enclosure each contributed 5 instances (2.0%); and balcony or courtyard greening contributed 3 instances (1.2%) (Xu et al., 2023). These indicators capture eye-level and near-home visual contact with greenery, which may be particularly relevant for older adults with limited mobility.

Overall, the distribution indicates that the current evidence base remains oriented toward scalable availability measures, while route-level accessibility, age-sensitive usability, perceived safety, and eye-level visibility are comparatively underrepresented.

To move from indicator classification to analytical use, Table 4 links each A–A–V dimension to older-adult-specific measures, dominant pathways, key sources of bias, and planning actions.

Table 4 therefore shifts the A–A–V framework from a coding scheme to an evaluative tool. It shows that each exposure dimension has a different failure point: accessibility measures may overlook unequal mobility, availability measures may overstate useable greenness, and visibility measures may miss lived visual experience. This distinction matters for planning because adding green area alone may not improve older adults' exposure if routes remain unsafe, facilities are unusable, or

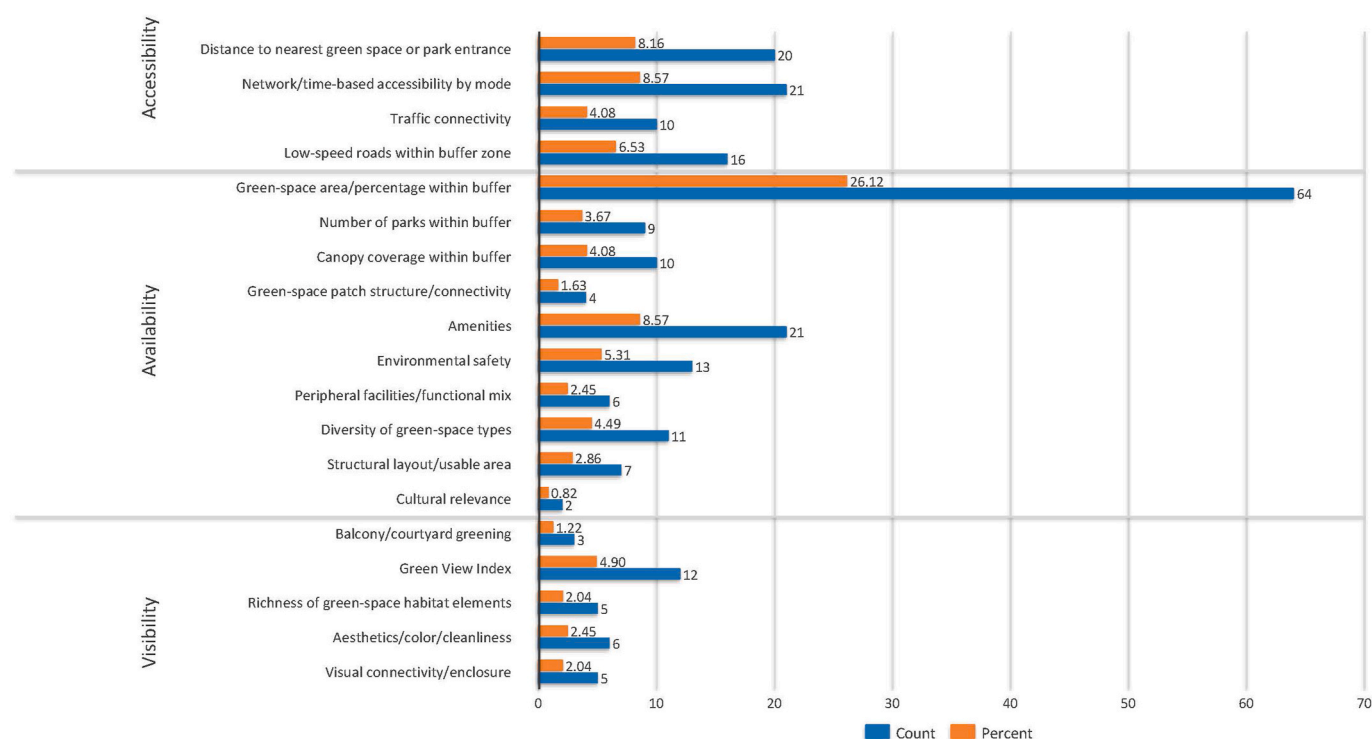


Fig. 8. Distribution of A–A–V green-space exposure indicators across 245 study-indicator coding instances derived from 117 included studies. An individual study could contribute multiple instances when it assessed more than one indicator.

Table 4

From A–A–V measures to mechanisms, bias, and planning actions.

A–A–V dimension	What it captures	Better measures for older adults	Main pathway	Key bias	Planning action
Accessibility	Whether older adults can reach green space	Network walking time, 300–500 m routes, slope, crossings, barrier-free paths	Walking, park use, social participation	Assumes equal mobility; ignores barriers and perceived safety	Build safe short routes, low-speed streets, crossings, benches
Availability	How much useable green space is nearby	NDVI/canopy plus shade, toilets, seating, amenities, safety audits	Heat, air, noise reduction; activity opportunity	NDVI may overstate useable greenness	Improve canopy, shade, seating, toilets, maintenance
Visibility	How greenery is seen in daily life	GVI, street-view greenness, window/courtyard views, eye-level routes	Restoration, perceived safety, place attachment	Street-view data may miss time, perception, and indoor views	Add eye-level greening, window views, restorative streetscapes

greenery is not visible in everyday settings.

3.3.4. Potential pathway variables and effect modifiers

Green-space exposure has been examined in relation to several potential behavioral and environmental pathway variables associated with older-adult health. Environmental variables commonly include air pollution, noise, temperature, and humidity, whereas behavioral variables include walking, exercise, social interaction, and other outdoor activities. The analytical role of these variables differs across studies; they may be treated as mediators, effect modifiers, covariates, intermediate outcomes, or independent outcomes depending on the original study design. Some studies examined only the association between green-space exposure and these pathway variables without subsequently analyzing health outcomes. Table 5 summarizes the categories and frequencies of the reported variables (Table 5):

(a) Environmental Moderating Factors

Across the reviewed studies, environmental moderators centre on air pollution (20.5% of papers), typically paired with buffer-based greenness (NDVI/canopy) derived from land-use or satellite grids; vegetation can dilute/interrupt pollutant exposure, although PM–mental-health

links are mixed across settings (Zhou et al., 2020). Temperature/heat and humidity appear in 7.7%, quantifying micro-to macro-climatic moderation (cooling, urban-heat-island mitigation) (Fossa et al., 2024) and, in several cases, associations with heat-related mortality (Wicki et al., 2024). Noise is examined in 6.0% of papers; tree cover and park edges provide partial shielding, with dynamic monitoring indicating higher noise during walking than at static points (Marquet et al., 2023). Together, these moderators specify the environmental channels through which greenness conditions health risk.

(b) Behavioral Mediating Factors

Behavioral mediators are led by walking (20.5%), measured via 10–15-min walkability indices and GPS/accelerometer traces, with consistent links to higher activity and improved cardiometabolic profiles (Klein et al., 2023). Other light-to-moderate activities (tai chi, cycling, gardening, etc.) account for 18.8%, typically captured by surveys and shaped by amenities, safety, and weather (Leng et al., 2020a). Social interaction appears in 6.0%, mitigating loneliness and supporting well-being (Astell-Burt and Feng, 2019), while activity frequency/duration (5.1%) clarifies how repeated, short near-home visits accumulate benefits.

Table 5

Categories of mediating and moderating factors linking green space exposure to older-adult health.

Type	Subtype	Study IDs	Share (%)
Environmental moderating factors	Air pollution (PM2.5, PM10, NO, O ₃)	1, 9, 11, 16, 19, 27, 33, 35, 43, 46, 52, 58, 66, 72, 75, 76, 78, 80, 88, 96, 100, 106, 113, 114	20.5
	Noise exposure (dB)	1, 16, 27, 58, 80, 88, 102	6.0
	Temperature and humidity (thermal comfort)	24, 33, 46, 54, 88, 89, 96, 106, 113	7.7
Behavioral mediating factors	Walking	4,6, 8, 9, 10, 12, 23, 31, 36, 38, 45, 47, 56, 58, 67, 68, 80, 81, 90, 91, 97, 104, 105, 107	20.5
	Social interaction	7, 15, 17, 35, 50, 96, 114	6.0
	Various outdoor physical activities (tai chi, mahjong, dog walking, gardening, and sports, etc.)	1, 7, 13, 15, 17, 18, 19, 29, 33, 41, 44, 47, 62, 74, 77, 81, 83, 87, 96, 99, 101, 114	18.8
	Frequency and duration of activities	17, 34, 35, 37, 61, 117	5.1

Overall, mediators and moderators co-act: useable, safe, and shaded green spaces both foster activity and buffer environmental stressors, shaping older-adult physical and mental health. The mediator pattern further suggests a distinction between behavioral mechanisms and environmental-risk mechanisms. Walking and broader physical activity constitute the most stable behavioral pathways because they directly connect green-space access and usability with older adults' daily routines, mobility capacity, and cardiometabolic or psychological outcomes. These mechanisms are also relatively interpretable from a planning perspective: safe paths, short distances, benches, shade, toilets, lighting, and barrier-free design can plausibly increase repeated outdoor activity. By contrast, air pollution, heat, humidity, and noise represent macro-environmental modifying mechanisms. They are often measured using spatially modelled surfaces, monitoring stations, or remotely sensed environmental data, and are therefore more compatible with large-scale epidemiological designs. However, these two mechanism types differ in evidential quality and causal interpretability. Behavioral mediators can capture individual exposure more directly when GPS, accelerometry, or activity diaries are used, but they are often limited by small samples and short observation windows. Environmental moderators offer broader spatial coverage and stronger comparability, but may obscure individual time–activity patterns and are vulnerable to temporal mismatch between environmental exposure and health outcomes. This distinction indicates that future studies should integrate both mechanism types rather than treating behavioral and environmental pathways as interchangeable explanations.

3.3.5. Analysis of physical and mental health outcomes

In most studies, the analysis of green space exposure in older adults ultimately links to physical and mental health outcomes. The reported outcomes encompass physical conditions, psychological and cognitive measures, social-perception outcomes, and mortality. The following provides a classified summary of the outcomes reported in the included studies (Table 6):

(a) Physical Outcome Manifestations

Self-reported health is the most frequent physical endpoint (11.1% of studies), typically captured by structured scales or composite scores.

Table 6

Outcome manifestations linked to green space exposure among older adults: categories, representative measures, and shares.

Type	Subtype	Study IDs	Share (%)
Physical outcome manifestations	Cardiovascular diseases (including arterial stiffness, hypertension, heart rate investigation, serum concentration, etc.)	6, 9, 20, 36, 43, 45, 52, 108, 111, 116	8.5
	Diabetes mellitus	9	0.9
	Obesity	12, 33, 92, 103, 112	4.3
	Epigenetic age acceleration	22, 30, 55, 88, 94	4.3
	Respiratory health	48, 109	1.7
	Stroke	53	0.9
	Renal failure	85	0.9
	Sleep	113	0.9
	Self-rated health	21, 32, 49, 50, 59, 63, 65, 69, 91, 96, 100, 102, 114	11.1
	Depression and anxiety	2, 7, 14, 15, 23, 24, 31, 46, 51, 59, 60, 63, 66, 79, 84, 93, 110	14.5
Psychological outcome manifestations	Cognitive ability (Alzheimer's disease, dementia, etc.)	10, 11, 16, 19, 26, 35, 39, 51, 72, 73, 106, 115	10.3
	Self-rated life satisfaction	14, 15, 57, 64, 82, 91, 96, 114, 117	7.7
	Subjective well-being	23, 27, 29, 65, 95	4.3
	Sense of security	3, 18, 56	2.6
	Psychological recovery	54, 71	1.7
	Loneliness	7, 25, 59, 65	3.4
	Environmental belongingness (place attachment)	18, 42, 91, 99, 117	4.3
	Mortality rate	70, 75, 76, 78, 86, 89	5.1
Social-Environmental perception outcomes			

Cardiovascular diseases (arterial stiffness, hypertension, heart rate, serum markers) appear in 8.5% (Brown et al., 2024); data commonly derive from health records, enabling wide coverage and longitudinal analyses, while wearable sensors (e.g., ambulatory BP/HR) offer high temporal resolution but limited diagnostic specificity. Evidence indicates that green space quality relates to older-adult cardiovascular profiles via walking as a mediator. Epigenetic age acceleration is examined in 4.3% (Zhou et al., 2023), generally through DNA-based assays; canopy cover is linked to slower ageing, though effects vary with socioeconomic and educational differences. Obesity outcomes (self-reported height/weight/waist) also account for 4.3%; studies implicate green space diversity and activity-supportive settings, with environmental moderators (air pollution, temperature, humidity) often probed to clarify pathways. Less common endpoints include respiratory health (1.7%), stroke (0.9%), renal failure (0.9%), and sleep (0.9%). Collectively, the physical-health literature prioritizes near-home, activity-enabling and shade/amenity-rich environments, and frequently embeds mediators/moderators to explain effect heterogeneity.

(b) Psychological Outcome Manifestations

Depression and anxiety (14.5%) are the most frequently analyzed psychological endpoints. Studies typically use validated epidemiological scales; reported prevalence in older adults is high (e.g., ~26% at ages 60–64, rising to 35.4% at ≥80). Mechanistically, green space relates to depressive symptoms both indirectly via air-pollution reduction (Park et al., 2024) and directly through activity-supportive settings

(distance/quality/activity measures). Cognitive function (10.3%) covers Alzheimer's disease, dementia, and related impairments. Evidence links higher greenness to lower pollution and improved cognition (Rodríguez-Loureiro et al., 2022). Multivariate questionnaires catalogue >10 exposure factors, though some lack rigorous causal testing (Röhr et al., 2022). Other psychological outcomes show generally positive associations: life satisfaction (7.7%), subjective well-being (4.3%), and psychological restoration (1.7%). Perceived sense of security (2.6%) is context-dependent, often improved by well-designed green spaces yet potentially undermined where dense vegetation and poor connectivity elevate perceived crime risk (Bao et al., 2023). Overall, the pattern supports near-home, amenity-rich, and well-connected green spaces as conducive to healthier psychological profiles in older adults.

(c) Social-Environmental Perception Outcomes

Green space exposure supports social connection and place-related meanings in later life, reflected in loneliness (3.4%) and environmental belongingness/place attachment (4.3%) outcomes. Parks and other socially active green spaces can facilitate interaction among older adults, thereby reducing loneliness and strengthening environmental identity and sense of belonging. These psychological effects are closely linked to social and cultural contexts. For example, a study in China found that park green spaces most effectively reduce loneliness among older adults (Fu et al., 2024), as parks have stronger social interaction attributes compared to other green spaces. In contrast, simply exposing older adults to natural green vegetation (without social elements) does not produce a significant loneliness-reducing effect. Additionally, studies have confirmed that people are more likely to help others in green environments, a phenomenon known as “green altruism.” Thus, older adults are more likely to receive and offer help in park green spaces. When positive interpersonal connections are established in a green space, coupled with regular activities and content, and even when older adults gain cultural experience and identity there, their environmental identity can promote a positive cycle between sustained green space exposure and health.

(d) Mortality Rate

This category relies on official vital-statistics and registry data, linking all-cause mortality to green space indicators while testing environmental pathways (air quality, temperature/heat, humidity, noise). In our review, mortality outcomes appear in 6 studies (5.1%). Because individual behaviors are not observed in such datasets, analyses typically employ ecological or cohort designs with area-level greenness (e.g., NDVI/canopy within buffers) and mediator adjustment to assess whether greener, cooler, and cleaner environments correspond to lower mortality risk among older adults (C. Qiu et al., 2021).

The distribution of outcome categories highlights an uneven evidence landscape. Depression/anxiety, self-rated health, cognitive ability, and cardiovascular conditions are more frequently reported, largely because they can be assessed through validated instruments, cohort datasets, or routine health records. By contrast, sleep, stroke, renal failure, respiratory health, epigenetic ageing, place attachment, and loneliness appear less often because they require more specialized biological, clinical, behavioral, or qualitative data. This quantitative summary therefore clarifies both the dominant health endpoints in the literature and the age-relevant pathways that remain underdeveloped.

3.4. Association patterns along the exposure–mechanism–outcome chain

3.4.1. Co-occurrence of exposure dimensions with pathway variables and effect modifiers

In the literature, many studies on green space exposure also involve mediating factors, for example, researching green space accessibility while simultaneously investigating environmental air pollution. To

explore the research association between green space exposure and mediating factors, a summary of the correlation analysis between the two (based on relevant studies) is presented in the figure below (Fig. 9):

As shown in Fig. 9, studies that incorporate mediators/moderators rely most on availability-based exposure, with accessibility and visibility used far less often. For environmental pathways, regional greenness (e.g., NDVI/canopy) is favored because it is standardized, scalable, and comparable across places. Conceptually, having sufficient green volume around older adults is treated as the precondition for pollution, heat/temperature–humidity, or noise mitigation; hence availability becomes the practical intervention handle. The co-occurrence counts are 25/9/1 for air pollution, 7/4/1 for noise, and 9/4/2 for temperature–humidity (availability/accessibility/visibility).

For behavioral mediators, the pattern is more differentiated. Mechanisms hinge on settings that enable activity: older adults must both reach green spaces and find safe, amenity-rich places for walking, exercise, and socializing; otherwise, high accessibility alone may not translate into actual use. Accordingly, walking co-occurs most strongly with accessibility (20/10/3), reflecting its transport-like nature and the salience of route reachability, travel time, and network continuity. By contrast, other outdoor activities, such as tai chi, gardening, and cycling, and persistence of use, measured through activity frequency or duration, cluster more strongly with availability (6/13/5 and 3/5/1, respectively). Visibility plays a smaller but analytically important role where place legibility, perceived safety, restorative experience, and on-site visual quality support social or psychological outcomes.

The co-occurrence pattern therefore clarifies how different exposure dimensions are linked to different explanatory mechanisms. Availability mainly captures environmental buffering, accessibility captures movement and use, and visibility captures everyday perceptual contact with greenery. This distinction is particularly important for older adults, because health-relevant exposure may arise not only from the amount of nearby greenness, but also from whether green spaces are reachable, useable, safe, and visually experienced in daily life.

3.4.2. Association between green space exposure, mediating factors, and health outcomes

To examine how studies jointly represented green-space exposure, potential pathway variables or effect modifiers, and health outcomes, we selected studies containing all three analytical components. Their coded relationships were then summarized using a Sankey diagram to identify recurring exposure–pathway–outcome patterns (Fig. 10).

Among studies satisfying the three-step pathway, availability remains the predominant exposure focus. Most papers quantify green space proportion/area within buffers (e.g., 50–2000 m), favouring indicators that are simple, reproducible, and widely obtainable, and thus preferable to purely qualitative appraisals. A second cluster employs visibility via neighborhood GVI, enabled by recent advances in street-view imagery and crowd-sourced datasets that sharpen fine-scale spatial analysis. For accessibility, the four elements, distance, mode-specific travel time, network connectivity, and low-speed networks, appear relatively evenly, suggesting they are routinely analyzed in combination when assessing reach.

Regarding mediating/moderating factors, walking is most frequently examined, followed by air pollution. Positive walking behaviour is consistently associated with better exposure and healthier physical and mental profiles, and is usually modelled alongside the local walking system and baseline green volume. Air-pollution analyses likewise pair greenness near residences with pollutant surfaces. By contrast, activity duration/frequency is less studied because it requires continuous, participant-level monitoring (e.g., GPS/accelerometry), which is burdensome and yields heterogeneous individual traces that complicate synthesis despite their higher exposure accuracy.

For health outcomes, self-reported physical health appears most often, reflecting the prevalence of scale-based assessment. Within physical endpoints, cardiovascular disease is the dominant topic and is

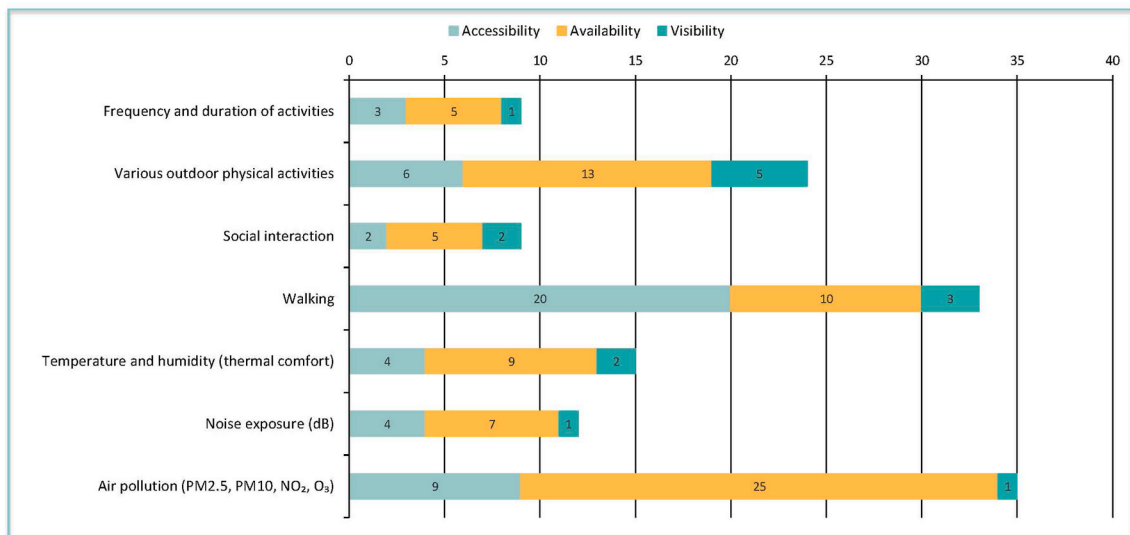


Fig. 9. Counts represent study-level co-occurrences; an individual study may contribute to multiple categories.

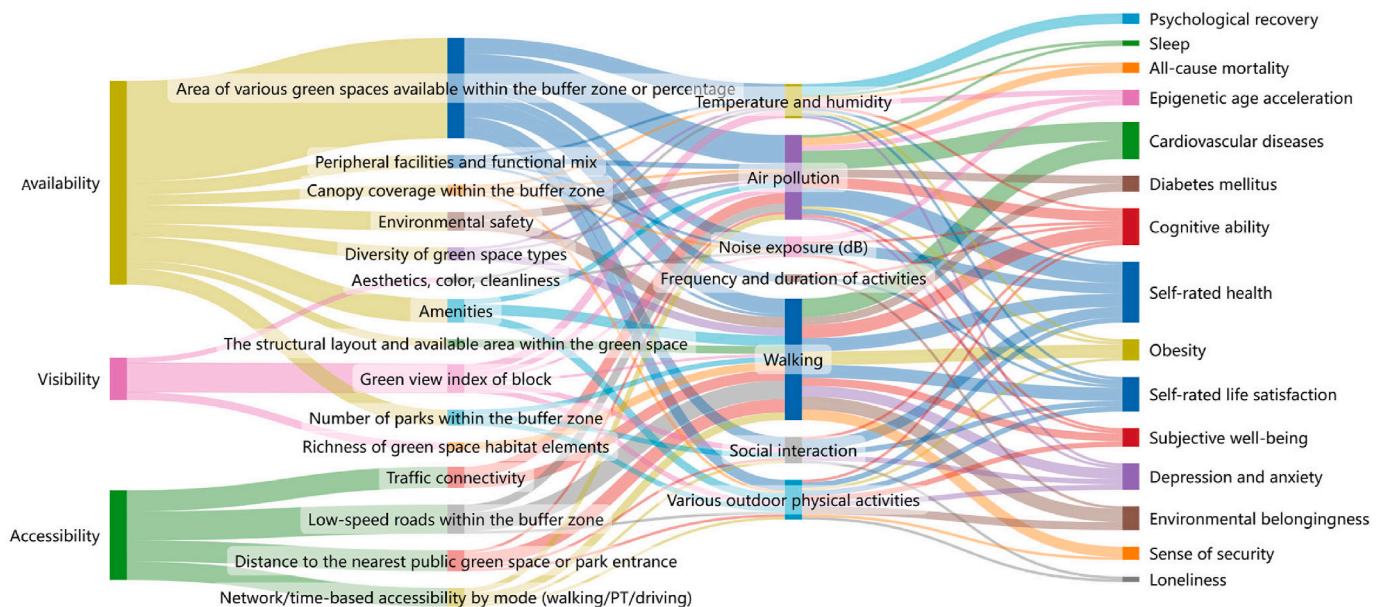


Fig. 10. Coded relationships among green-space exposure, pathway variables or effect modifiers, and health outcomes in older adults.

commonly linked to both walking and air-pollution pathways (e.g., stratifying high/medium/low greenness and walkability to evaluate cardiovascular risk). Obesity outcomes are likewise tied to walking as a mediator. On the mental side, studies frequently address cognition, life satisfaction, depression, and anxiety, consistent with older adults' heightened sensitivity to environmental and social conditions in green spaces (e.g., social interaction, group activities, fresh air, and thermally comfortable green-space settings). Socially perceived health tracks human activity patterns, whereas mortality analyses rely more on environmental mediators, notably air quality and temperature/heat.

The Sankey diagram also provides a basis for differentiating the relative maturity of exposure-mechanism-outcome pathways. The most concentrated pathway in the reviewed literature is Availability → walking/physical activity or air-pollution moderation → health outcomes. This concentration reflects the methodological dominance of availability metrics, the direct observability of walking as a behavioural mediator, and the frequent modelling of air pollution as an environmental moderator. In contrast, Visibility → social interaction,

psychological restoration, perceived safety, or place attachment → mental health represents an emerging but less consolidated pathway. Visibility-based measures such as GVI, window-view greenness, courtyard greening, and visual enclosure are highly relevant for older adults, especially those with limited mobility, but remain less frequently connected to complete mediator-outcome models. These pathway differences motivate the narrative evidence-strength synthesis presented in Table 7.

Overall, Table 7 shows that the evidence base is uneven across the A-A-V framework. The strongest and most consistent evidence concerns activity-related pathways, where availability or accessibility supports walking and light-to-moderate physical activity. Macro-scale environmental pathways, particularly NDVI or canopy cover operating through air-pollution, heat, and noise moderation, are moderately supported but depend heavily on residential and modelled exposure proxies. Visibility-based psychosocial pathways remain underdeveloped despite their conceptual relevance for older adults with limited mobility. This imbalance suggests that the current literature is not simply incomplete

Table 7

Narrative strength of evidence across A–A–V exposure–mechanism–outcome pathways.

Evidence strength	Main pathway	Main outcomes	Interpretation
Relatively consistent	Availability/Accessibility → walking or physical activity	Self-rated health, depression/anxiety, life satisfaction, obesity	Frequently examined; mechanisms are plausible, but evidence remains mainly observational.
Moderate	Availability/canopy/NDVI → air pollution, heat, noise moderation	Cardiovascular health, cognition, mortality	Supported by large-scale studies, but limited individual behavioural data.
Emerging	Visibility/GVI → restoration, perceived safety, social interaction	Depression, loneliness, well-being	Conceptually important for mobility-limited older adults, but empirical evidence remains limited.
Preliminary	Greenness → epigenetic ageing, sleep, renal failure, stroke	Biological ageing, sleep, renal outcomes	Few studies and heterogeneous outcomes; no strong conclusion can yet be drawn.

in quantity, but structurally biased toward scalable availability indicators and away from person-centered accessibility and visual-experiential exposure.

3.5. Analysis of differences in the three dimensions of green space exposure

3.5.1. Spatial scale

The research scales of the literature, along with the principal related research types and directions grounded in these scales, constitute a crucial dimension for assessing the research landscape of this topic (Table 8). Systematically classifying these scales and types enables a comprehensive understanding of the primary research scopes and perspectives within this topic, thereby facilitating in-depth literature analysis.

Across the studies, research spans multiple spatial scales: local community (18%), block/transport-corridor (5%), a few representative parks (9%), district/intra-city (11%), city (21%), multiple cities (12%), national (23%), and multi-scale designs (1%), and scale systematically conditions both exposure metrics and observable health effects. Micro-scale work (community, block, single-park) privileges person-proximal indicators, near-home buffers (≤50–500 m), route-based reach, street-level viewing, and amenity/safety audits, and consequently identifies clearer associations with day-to-day behaviors and psychosocial endpoints (walking, social connection, perceived safety, loneliness/place attachment) (Carver et al., 2024; Levinger et al., 2025). By contrast, city-, multi-city-, and national-scale analyses rely on aggregate proxies (average greenness, park density, canopy percent) and typically detect more indirect, cumulative pathways operating through environmental moderation (air quality, heat), with outcomes registered in cardiometabolic risk, chronic conditions, cognition, and all-cause mortality (Son et al., 2021). District-level studies sit between these poles, combining access and supply measures to reveal intra-urban inequalities. Taken together, the evidence indicates that study scale is not a neutral design choice: it shapes how green space exposure is measured and, in turn, the segment of the exposure–mechanism–outcome chain that is empirically visible in older adults.

The concentration of studies at city, multi-city, and national scales partly explains the dominance of availability-based metrics, especially NDVI, canopy percentage, and park-density measures. These indicators are compatible with administrative, census, satellite, and health-registry

Table 8

Summary of research theme scale types.

Case scale	Examples of related types	Study IDs	Percentage
Local community scale	Community parks; adjacent UGSs; rehabilitation areas in older-adult care institutions; personal gardens	9, 10, 13, 14, 22, 27, 29, 37, 42, 45, 62, 65, 71, 74, 81, 87, 93, 98, 108, 109, 114,	18%
Block of district scale	Street UGSs in a specific urban linear transport network; high-density neighborhoods in important urban areas	6, 7, 8, 23, 40, 85,	5%
A few representative parks of a city	A small number of comprehensive urban parks	34, 36, 44, 50, 54, 83, 91, 96, 101, 105,	9%
A district of a city	Selection of specific city plots; the main urban area; a collection of several representative sub-regions therein	4, 5, 12, 21, 28, 47, 48, 56, 61, 84, 92, 100, 107,	11%
City scale	Major cities globally; large-scale UGSs; city scale community statistics often exceeding a thousand	16, 17, 20, 25, 38, 41, 43, 55, 58, 59, 60, 64, 69, 73, 77, 78, 80, 82, 90, 95, 97, 98, 102, 103, 104,	21%
Multiple cities	City-to-city comparisons between cities of the same type; between adjacent cities; small sub-areas within different cities	1, 2, 11, 18, 19, 26, 31, 57, 70, 75, 76, 79, 89, 94,	12%
National scale	National UGSs macroscopically; using communities and population groups as basic units to analyze the overall situation	15, 24, 30, 32, 33, 35, 39, 46, 49, 51, 52, 53, 63, 66, 67, 68, 72, 86, 88, 106, 110, 111, 112, 113, 115, 116, 117	23%
Multi-scale	The research area from the macro to the micro level	3	1%

datasets, making them suitable for large samples and cross-regional comparison. However, this macro-scale orientation also biases the evidence base toward residential greenness and away from route-level accessibility, facility usability, perceived safety, and eye-level visibility, which are more relevant to older adults' daily exposure.

3.5.2. Spatial coverage range

Accessibility indicators: Primarily analyze road network types, focusing on linear network analysis to evaluate transportation connectivity and distance. The coverage range spans from community to urban scales; for small-scale analyses, it can be combined with linear dynamic exposure research (Motoc et al., 2023). Availability indicators: Cover a wide range of content, including the spatial distribution of green spaces. Such analyses are conducted at scales from community and urban to national, reflecting the basic conditions for residents to access green spaces. Additionally, availability indicators can focus on the internal and external spaces of green spaces and other facility conditions, this type of analysis is limited by green space boundaries, mostly carried out in scenarios such as parks and community green spaces, and requires detailed understanding of the design of the green spaces themselves (Paudel et al., 2023). Visibility indicators: Only reflect visible greenery along streets or within the field of view, limited to road corridors or specific viewpoints, and cannot cover visually obscured areas (Yang et al., 2022). They belong to local linear spatial analysis. Therefore, in terms of spatial coverage, the order is availability > accessibility > visibility, and each dimension focuses on

different analytical content.

3.5.3. Spatial resolution and accuracy

Accessibility indicators: Accuracy depends on the quality of base maps and network analysis, typically reaching the decimeter scale (Zhang et al., 2023). However, high-precision data is generally used for walking analysis of older adults, requiring positioning and measurement with GPS and drones. **Availability indicators:** Resolution decreases when using coarse indicators such as green space proportion by administrative district (Lin and Wu, 2021). Nevertheless, if analyzing data on internal facilities and environments of green spaces, usage conditions can be depicted at the micro-scale, though this is limited by data acquisition scope, and some data requires on-site statistics (Van Puyvelde et al., 2023). **Visibility indicators:** Based on viewshed analysis or street view images, they have high resolution and can accurately reflect greenery along roads or from specific perspectives (Yang et al., 2022; Peng et al., 2026b).

In general, green space exposure analysis can be conducted at different accuracy levels according to specific research needs.

4. Discussion

The findings address the four research questions as follows. The reviewed literature is organized around four interconnected themes, built environment and mobility, health and exposure, physical activity, and accessibility and equity, with physical activity serving as a key conceptual bridge (RQ1). Study design, spatial scale, case context, and exposure-measurement choices substantially shape the findings: macro-scale studies predominantly use availability-based indicators, whereas micro-scale studies are better able to capture accessibility, usability, and eye-level visibility (RQ2). The most consistently examined pathways link availability or accessibility with walking and physical activity, as well as availability with environmental buffering through reduced air pollution, heat, and noise; visibility-based psychosocial pathways remain comparatively underdeveloped (RQ3). These findings highlight the need for dynamic and age-sensitive exposure assessment, stronger longitudinal and causal designs, improved methodological reporting, and equity-oriented environmental-management strategies (RQ4).

4.1. Future research directions

4.1.1. Innovation in technologies and methods

Research on green space exposure among older adults remains relatively traditional in terms of technologies and methods, with a lack of population-specific targeting. Examples of conventional approaches include random questionnaire surveys, extraction of low-precision road networks and green space distribution, and statistical analysis of single-time-point health assessment scale responses. Future methodological innovation should be aligned with the A–A–V framework. For Accessibility, GPS trajectories, accelerometers, mobile-phone tracking, and senior-sensitive routing models can capture actual walking routes, travel time, slope, crossings, and barrier-free conditions. For Availability, satellite NDVI/EVI, UAV photogrammetry, 3D point clouds, canopy models, and on-site audits can quantify green volume, shade, amenities, maintenance, and safety. For Visibility, street-view imagery, Green View Index, VR simulation, wearable cameras, and eye tracking can capture eye-level and perceived greenness (Peng et al., 2026c), including the visual experience of older adults with limited mobility. These methods should be adapted to older adults' cognitive, sensory, and technological capacities through simplified interfaces, voice guidance, visual prompts, and low-burden data-collection protocols.

A feasible pilot design would combine GPS/accelerometer tracking, route-level GVI, wearable heat/noise/air-pollution sensors, and short ecological momentary assessment surveys among older adults with different mobility levels. Such a design would allow Accessibility, Availability, and Visibility to be measured dynamically along actual

daily routes rather than inferred only from residential buffers.

4.1.2. Expansion of research scope

Current research on green space exposure scope remains focused on green volume distribution. Health data are mostly obtained from official sources, which suffer from temporal lags; moreover, older adults are only distinguished through population screening, lacking population-specific targeting in the selection of green space research elements.

For accessibility analysis, auxiliary transportation modes and physiological impedance analysis should be incorporated; Green space types should be classified more precisely by area or function, for example, green-space exposure among older adults who accompany children as caregivers (Leng et al., 2020b); Green space quality assessment should focus more on older adults' specific needs, such as barrier-free facilities, age-appropriate seats, and vegetation planting requirements for safety and aesthetics; Beyond evaluating the effects of green spaces themselves, research should be expanded to include the impacts of cultural elements and social interaction design. The scope should also extend from single visual perception to multi-sensory surveys (including auditory and tactile perceptions), enriching research content and evaluation systems.

4.1.3. Research on mechanisms and models

Current data are mostly static cross-sectional data (e.g., green space accessibility at a specific time, usage frequency over a single week), making it difficult to capture the dynamic and sudden nature of older adults' green space exposure. Furthermore, different disciplines currently have distinct analytical focuses and methodological approaches, leading to fragmented or even contradictory results. To obtain more systematic and scientific findings:

Cross-temporal and multi-scale measurement models for green space exposure should be constructed to further explore underlying linkage mechanisms; The assessment of green space exposure thresholds for older adults' health benefits should be more precise and comprehensive, for instance, establishing specific hard standards; In addition to official data and self-reports, health outcomes should also be assessed using clinical or physiological measures. Interdisciplinary research should be used to further explain the impact of green space exposure on health from an objective physiological and biological perspective; Beyond conventional cross-sectional data, longitudinal observational studies should be increased to analyze long-term spatiotemporal changes and their mechanisms.

4.2. Objectivity vs. subjectivity

Accessibility and visibility: The data used (e.g., road network conditions, GVI) are generally objective indicators. Even in dynamic exposure analysis, data are derived from objective continuous time statistics and are not directly affected by personal preferences. **Availability:** While it involves the analysis of objective attributes such as the quality and quantity of green facilities, detailed statistics on the layout and functions of various facilities within green spaces often require combining questionnaires or interviews (Stanley et al., 2022; Wagner et al., 2020). These statistics rely on older adults' judgments based on their preferences and perceptions regarding usage, making them more subjective.

4.3. Adaptability to older adults

Accessibility: Reflects the connectivity from road networks to green spaces, suitable for evaluating older adults with the willingness and ability to go out and walk. For those with limited mobility, detailed analysis combined with barrier-free facilities is required (Levinger et al., 2025; Perry et al., 2021). **Availability:** Reflects the accessibility and usage of public green spaces, more aligned with older adults who frequently engage in activities in green spaces. It can be combined with behavioral mediating factors to evaluate their usage experience and activity quality. **Visibility:** Has broad adaptability to older adults. For

those with limited mobility, it can be used to study greenery visible from windows, balconies, and courtyards (Ottoni et al., 2024); for older adults who go out, it can also be used to research the aesthetic atmosphere of vegetation they perceive (L. Qiu et al., 2021).

4.4. Research differences between older adults and the general population

During literature coding, the following differences were identified between older adults (as a specific population group) and the general population:

4.4.1. Higher sensitivity to environmental conditions

Older adults exhibit greater physiological vulnerability to environmental hazards such as high temperatures, air pollution, and noise. Consequently, they benefit more significantly from the environmental buffering effects of green spaces. Studies have shown that in regions with extreme climates or severe pollution, increasing neighborhood green volume leads to a more pronounced reduction in health risks for older adults (Wang et al., 2025). Large, contiguous green spaces with good connectivity can significantly lower mortality rates in aging communities (Son et al., 2021). Thus, research often yields more sensitive findings: to mitigate disturbances from environmental factors (e. g., air quality, temperature-humidity, noise), green space design schemes should set environmental indicator targets (such as heat exposure/noise levels) that meet older adult-specific thresholds, rather than relying on average values for the general population. This ensures that the well-being benefits of green space exposure cover all age groups.

4.4.2. Limited mobility

Restricted by their activity range and physical fitness, older adults are more dependent on green space resources that are nearby, easily accessible, and useable. Small-buffer green spaces have a significant effect on improving their daily activities and mood (Kabisch et al., 2021); meanwhile, green spaces equipped with comprehensive facilities, such as walking paths, seats, and barrier-free designs, are more likely to promote light-to-moderate physical activity among older adults, slowing down physical decline. In research, special assessment settings tailored to older adults' age should be established for factors such as their activity range, speed, frequency, mode, and duration.

4.4.3. Diverse emotional needs

As a vulnerable group, older adults have higher emotional needs, such as the need for safety and companionship. Serving as social spaces, green spaces enhance neighborhood interactions and act as important sites for psychological restoration and social connection, helping to alleviate the impact of shrinking social networks after retirement. Additionally, age-specific declines and cognitive disorders in older adults are closely associated with emotions and social interactions (He et al., 2022). Therefore, research should pay greater attention to older adults' emotional experiences and explore how to maximize the unique value of green spaces in preventing mental illnesses and promoting active aging.

These age-specific differences also have implications for research design. Future studies should treat older adults as a heterogeneous group and pair smaller near-home buffers, particularly 300–500 m, with route-level indicators of safety, amenities, shade, and barrier-free conditions. Outcome selection should extend beyond general physical and mental health to include age-relevant domains such as loneliness, perceived safety, social interaction, psychological restoration, cognitive function, and activity duration/frequency. Stratified analyses by age band, sex, socioeconomic status, disability, baseline health, and mobility limitation are needed to avoid treating older adults as a homogeneous population.

4.5. Causality, confounding, and bias in green-space exposure research

Causal interpretation remains limited because most included studies

are observational, and many are cross-sectional. Although associations between green-space exposure and older-adult health are frequently reported, these associations may be affected by residential self-selection, baseline health status, socioeconomic position, mobility limitations, neighborhood deprivation, and unmeasured lifestyle factors. Exposure misclassification is another major concern: residential NDVI or buffer-based greenness may not represent where older adults actually spend time, which routes they use, whether green spaces are physically accessible, or whether they are perceived as safe and useable. Temporal mismatch between exposure data, health records, satellite imagery, and survey responses may further weaken causal inference. Therefore, causal language was avoided unless the underlying study design supported stronger inference. Future research should prioritize longitudinal, quasi-experimental, natural-experiment, and repeated-measure designs, combined with dynamic exposure assessment through GPS, accelerometry, wearable sensors, and route-based environmental audits.

4.6. Policy and environmental-management implications

For environmental management and health impact assessment, older-adult green-space evaluation should not rely solely on NDVI or total green-space area. Instead, assessment should integrate the three A–A–V dimensions. Accessibility indicators should include 300–500 m near-home buffers, 10–15-min walking catchments, slope, crossings, pavement quality, low-speed roads, lighting, and barrier-free routes. Availability indicators should include canopy cover, shade, seating, toilets, maintenance, safety, amenities, and useable area. Visibility indicators should include street-level GVI, window-view greenness, courtyard greening, and perceived visual quality. Equity should therefore be treated not only as a question of spatial distribution, but also as an environmental justice issue. Older adults with disabilities, low socioeconomic status, chronic illness, minority status, or limited mobility may experience compounded disadvantage when limited green-space access overlaps with heat exposure, air pollution, poor walkability, unsafe routes, and inadequate facilities. In practical terms, A–A–V indicators should be combined with vulnerability overlays, including age density, disability, income deprivation, social isolation, heat risk, air-pollution exposure, and walkability barriers, to identify priority intervention zones. This shifts green-space planning from equal provision toward need-sensitive allocation of environmental resources (Peng et al., 2026d).

This framing positions age-friendly green space as multifunctional urban infrastructure rather than a single-purpose health amenity. A single green-space investment can generate multiple co-benefits, including physical-activity promotion, reduced environmental exposure, psychological restoration, social cohesion, and fairer distribution of environmental goods. More broadly, the increasing use of data-driven tools in environmental and resource governance highlights the need for practical frameworks that translate complex environmental evidence into planning decisions (Jin and Xu, 2025a, 2025b; Xu and Zhang, 2023a). The A–A–V framework provides such a structure by linking green-space exposure assessment with age-friendly, equitable, and resource-efficient urban environmental management.

In sustainability terms, the A–A–V framework also links older-adult green-space exposure to broader urban and environmental goals. Accessibility relates to reduced inequalities and fair access to environmental goods, Availability contributes to sustainable cities, ecosystem-service supply, and climate adaptation, and Visibility supports everyday restorative experience and healthy ageing. These links correspond respectively to SDG 10, SDGs 11 and 13, and SDG 3, thereby positioning older-adult green-space exposure as part of a wider agenda for health promotion, environmental justice, sustainable urban development, and climate resilience.

At minimum, age-friendly green-space health impact assessments should report: the age definition and mobility or disability profile of the target population; the operational definition, data source, spatial scale,

and temporal scale of each A–A–V indicator; the hypothesized and tested role of pathway variables; the outcome definition and confounder-adjustment strategy; and distributional results across relevant vulnerability groups. Intervention evaluations should assess not only changes in total green area but also route safety, travel time, useable amenities, shade, eye-level visibility, actual use, and equity in exposure and health-related outcomes.

4.7. Significance and limitations

This review organizes recent evidence within an A–A–V pathway structure linking green-space exposure measures, behavioral and environmental pathways, and health outcomes. Its main contribution lies in clarifying measurement choices, age-specific considerations, and environmental-management implications, while identifying areas in which the evidence remains methodologically weak or incomplete.

Despite the comprehensive screening and coding conducted in this review, several limitations should be acknowledged. Inconsistent reporting of subgroup characteristics limited systematic comparisons by age band, sex, socioeconomic status, disability, mobility limitation, living arrangement, and geographical context. In particular, many studies did not report subgroup-specific effect estimates, preventing a more detailed synthesis of heterogeneity within older populations. Nevertheless, restricting the search to Web of Science and Scopus, English-language publications, and peer-reviewed journal articles may have omitted clinically oriented studies indexed primarily in MEDLINE/PubMed, Embase, PsycINFO, or CINAHL, as well as relevant non-English, locally published, or grey literature. Although such literature is not covered in the databases used, this review still holds reference value for analyzing studies related to green space exposure among older adults. Its urban focus may underrepresent peri-urban and rural nature exposure among older adults. Heterogeneity in exposure metrics, buffer definitions, spatial scale, outcome measurement, and confounder adjustment also limited comparability and precluded formal meta-analysis.

5. Conclusions

This review systematically screened records according to pre-specified eligibility criteria and coded the included studies using NVivo to characterize recent evidence on green-space exposure and health among older adults, as follows:

- (a) Clarified the temporal evolution, publication trends, core research focus, and research frontiers of this field.
- (b) Organized the diverse research perspectives on green space exposure in the screened literature (including accessibility, availability, and visibility), as well as environmental moderating factors, behavioral mediating factors, and different health outcome orientations, forming a systematic research process framework. Within this framework, the review characterizes each element and clarifies the relationships and patterns linking exposure indicators, pathways, and health endpoints.
- (c) Summarized relevant results and trends, such as differences in indicator use and application scenarios of green space exposure, and research differences between older adults and the general population. Finally, we identified future research priorities and potential directions.

This review centres older adults as a priority population for green space research rather than a residual subgroup. By foregrounding their specific mobility limits, thermal sensitivity, safety concerns and social needs, and structuring evidence within an A–A–V lens, it offers a clearer basis for designing and evaluating truly age-friendly environments. In doing so, it turns disparate findings into a practical reference point for targeted interventions and more nuanced, population-specific research

agendas.

CRediT authorship contribution statement

Yingwen Yu: Conceptualization, Funding acquisition, Methodology, Writing – original draft. **Wenchen Zhang:** Conceptualization, Methodology, Writing – original draft. **Zaichen Wu:** Investigation, Software. **Yuyang Peng:** Investigation, Methodology. **Xudong Zhang:** Project administration.

Declaration of competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix B. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jenvman.2026.130706>.

Appendix A

1. Designing Age-Friendly Communities: Exploring Qualitative Perspectives on Urban Green Spaces and Ageing in Two Indian Megacities. <https://doi.org/10.3390/ijerph18041491>
2. Characteristics of Home and Neighborhood Built Environments During COVID-19 for Older Adults in the United States and Italy. <https://doi.org/10.1080/26892618.2023.2269552>
3. Examining Spatial Inequalities in Public Green Space Accessibility: A Focus on Disadvantaged Groups in England. <https://doi.org/10.3390/su151813507>
4. Measuring age-friendliness based on the walkability indices of older people to urban facilities. <https://doi.org/10.1057/s41289-022-00194-w>
5. Simultaneous Inequity of Elderly Residents in Melbourne Metropolitan. <https://doi.org/10.3390/su15032189>
6. Longitudinal Impacts of High Versus Low Greenness on Cardiovascular Disease Conditions. <https://doi.org/10.1161/JAHA.123.029939>
7. Mental health and well-being in times of COVID-19: A mixed-methods study of the role of neighborhood parks, outdoor spaces, and nature among US older adults. <https://doi.org/10.1016/j.healthplace.2022.102813>
8. How Do Block Built Environments Affect Daily Leisure Walking among the Elderly? A Empirical Study of Gaoyou, China. <https://doi.org/10.3390/su15010257>
9. Exploring associations of greenery, air pollution and walkability with cardiometabolic health in people at midlife and beyond. <https://doi.org/10.1111/ggi.14743>
10. Cross-sectional associations between neighborhood characteristics, cognition and dementia risk factor burden in middle-aged and older Australians. <https://doi.org/10.1016/j.pmedr.2024.102696>
11. Neighborhood environments and cognitive health in the longitudinal Personality and Total Health (PATH) through life study: A 12-year follow-up of older Australians. <https://doi.org/10.1016/j.envint.2024.108984>
12. How do urban block built environments affect older adults' walking activities and health effects: a case study in Nanjing, China. <https://doi.org/10.3389/fpubh.2024.1479305>
13. A Path Analysis of the Effect of Neighborhood Built Environment on Public Health of Older Adults: A Hong Kong Study. <https://doi.org/10.3389/fpubh.2022.861836>

14. Effects of Urban Park Quality, Environmental Perception, and Leisure Activity on Well-Being among the Older Population. <https://doi.org/10.3390/ijerph182111402>
15. Increased urban greenness associated with improved mental health among middle-aged and older adults of the Canadian Longitudinal Study on Aging (CLSA). <https://doi.org/10.1016/j.envres.2021.112587>
16. Impact of urban environmental exposures on cognitive performance and brain structure of healthy individuals at risk for Alzheimer's dementia. <https://doi.org/10.1016/j.envint.2020.105546>
17. The Role of Urban Parks in Promoting Social Interaction of Older Adults in China. <https://doi.org/10.3390/su16052088>
18. Outdoor Recreation for Older Adults in Scotland: Qualitatively Exploring the Multiplicity of Constraints to Participation. <https://doi.org/10.3390/ijerph18147705>
19. Neighborhood environment and cognitive functioning in middle-aged and older population: A mediating role of physical activity. <https://doi.org/10.1016/j.ijheh.2025.114521>
20. Long -Term Greenspace Exposure and Progression of Arterial Stiffness: The Whitehall II Cohort Study. <https://doi.org/10.1289/EHP6159>
21. Relationships between health outcomes in older populations and urban green infrastructure size, quality and proximity. <https://doi.org/10.1186/s12889-020-08762-x>
22. Greater residential greenness is associated with reduced epigenetic aging in adults. <https://doi.org/10.1038/s41598-024-82747-3>
23. Micro urban spaces and mental well-being: Measuring the exposure to urban landscapes along daily mobility paths and their effects on momentary depressive symptomatology among older population. <https://doi.org/10.1016/j.envint.2023.108095>
24. Residential greenspace and major depression among older adults living in urban and suburban areas with different climates across the United States. <https://doi.org/10.1016/j.envres.2023.117844>
25. Built environment and loneliness in later life: productive engagement as the pathway. <https://doi.org/10.1080/13607863.2024.2329642>
26. Neighborhood greenspace and cognition: The cardiovascular health study. <https://doi.org/10.1016/j.healthplace.2022.102960>
27. Effects of the Natural Environment on the Subjective and Psychological Well-Being of Older People in the Community in China. <https://doi.org/10.3390/buildings14092854>
28. Equity to Urban Parks for Elderly Residents: Perspectives of Balance between Supply and Demand. <https://doi.org/10.3390/ijerph17228506>
29. Is the garden village an age-friendly planning model? Experiences of growing older in Rhiwbina Garden Village, Wales. <https://doi.org/10.3828/tp.2023.1>
30. Association between residential greenspace structures and frailty in a cohort of older Chinese adults. <https://doi.org/10.1038/s43856-022-00093-9>
31. Cross-Sectional Associations between Living and Built Environments and Depression Symptoms among Chinese Older Adults. <https://doi.org/10.3390/ijerph19105819>
32. Association between residential greenness and general health among older adults in rural and urban areas in China. <https://doi.org/10.1016/j.ufug.2020.126907>
33. Establishing associations between residential greenness and markers of adiposity among middle-aged and older Chinese adults through multilevel structural equation models. <https://doi.org/10.1016/j.ijheh.2020.113606>
34. ANALYSES OF ELDERLY VISITORS' BEHAVIORS TO COMMUNITY PARKS IN SHANGHAI AND THE IMPACT FACTORS. <https://doi.org/10.15302/J-LAF-1-020038>
35. Midlife Residential Greenness and Late-Life Cognitive Decline among Nurses' Health Study Participants. <https://doi.org/10.1289/EHP13588>
36. Physiological and psychological effects of visits to different urban green and street environments in older people: A field experiment in a dense inner-city area. <https://doi.org/10.1016/j.landurbplan.2020.103998>
37. Associations of Environmental Features With Outdoor Physical Activity on Weekdays and Weekend Days: A Cross-Sectional Study Among Older People. <https://doi.org/10.3389/fpubh.2020.578275>
38. What triggers selective daily mobility among older adults? A study comparing trip and environmental characteristics between observed path and shortest path. <https://doi.org/10.1016/j.healthplace.2021.102730>
39. Associations of Greenness, Parks, and Blue Space With Neurodegenerative Disease Hospitalizations Among Older US Adults. <https://doi.org/10.1001/jamanetworkopen.2022.47664>
40. Age-group-based evaluation of residents' urban green space provision: Szeged, Hungary. A case study. <https://doi.org/10.1520/1/hungeobull.71.3.3>
41. Physical environmental factors influencing older adults' park use: A qualitative study. <https://doi.org/10.1016/j.ufug.2021.127353>
42. A Framework for Elder-Friendly Public Open Spaces from the Iranian Older Adults' perspectives: A Mixed-Method Study. <https://doi.org/10.1016/j.ufug.2020.126857>
43. Planning for Supportive Green Spaces in the Winter City of China: Linking Exercise of Elderly Residents and Exercise Prescription for Cardiovascular Health. <https://doi.org/10.3390/ijerph17165762>
44. Recreational Spaces: How Best to Design and Cater for Older People's Safe Engagement in Physical Activity. <https://doi.org/10.1007/s12062-024-09472-7>
45. The Effects of Green and Urban Walking in Different Time Frames on Physio-Psychological Responses of Middle-Aged and Older People in Chengdu, China. <https://doi.org/10.3390/ijerph18010090>
46. The impact of urban green space on the health of middle-aged and older adults. <https://doi.org/10.3389/fpubh.2023.1244477>
47. Positive Association of Physical Activity with Both Objective and Perceived Measures of the Neighborhood Environment among Older Adults: The Aichi Workers' Cohort Study. <https://doi.org/10.3390/ijerph17217971>
48. Impact of Urban Green Infrastructure on the Respiratory Health of Older Adults in Shenyang, China. <https://doi.org/10.3390/f16010041>
49. Green and Blue Space Availability and Self-Rated Health among Seniors in China: Evidence from a National Survey. <https://doi.org/10.3390/ijerph18020545>
50. A Qualitative Study on Leisure Benefits, Constraints, and Negotiations in Urban Parks Based on Perception of Chinese Older Adults. <https://doi.org/10.3390/su151813304>
51. Exposure to residential green and blue space and the natural environment is associated with a lower incidence of psychiatric disorders in middle-aged and older adults: findings from the UK Biobank. <https://doi.org/10.1186/s12916-023-03239-1>
52. Air pollution, residential greenness, and metabolic dysfunction biomarkers: analyses in the Chinese Longitudinal Healthy Longevity Survey. <https://doi.org/10.1186/s12889-022-13126-8>
53. Green space is associated with new-onset stroke among Chinese middle-aged and older adults: data from China Health and

- Retirement Longitudinal Study (CHARLS). <https://doi.org/10.3389/fpubh.2024.1424510>
54. Effects of Environmental Features in Small Public Urban Green Spaces on Older Adults' Mental Restoration: Evidence from Tokyo. <https://doi.org/10.1016/j.eclinm.2021.100927>
 55. Neighborhood physical environment, intrinsic capacity, and 4-year late-life functional ability trajectories of low-income Chinese older population: A longitudinal study with the parallel process of latent growth curve modelling. <https://doi.org/10.3390/ijerph19095477>
 56. Towards Healthy Aging: Influence of the Built Environment on Elderly Pedestrian Safety at the Micro-Level. <https://doi.org/10.3390/ijerph18189534>
 57. The association of access to green space with low mental distress and general health in older adults: a cross-sectional study. <https://doi.org/10.1186/s12877-024-04738-3>
 58. Comparison of static and dynamic exposures to air pollution, noise, and greenness among seniors living in compact-city environments. <https://doi.org/10.1186/s12942-023-00325-8>
 59. The Impact of Street Space Perception Factors on Elderly Health in High-Density Cities in Macau-Analysis Based on Street View Images and Deep Learning Technology. <https://doi.org/10.3390/su12051799>
 60. Social and physical neighborhood characteristics and 10-year incidence of depression and anxiety in older adults: Results from the Longitudinal Aging Study Amsterdam. <https://doi.org/10.1016/j.socscimed.2023.115963>
 61. Park proximity and older adults' physical activity and sedentary behaviors in dense urban areas. <https://doi.org/10.1016/j.ufug.2024.128275>
 62. "I Go Outdoors for Activities Every Day": Go-Along With Seniors With Slow Walking Speeds to Explore Environmental Factors Influencing Mobility. <https://doi.org/10.3389/ijph.2024.1607033>
 63. Green spaces, subjective health and depressed affect in middle-aged and older adults: a cross-country comparison of four European cohorts. <https://doi.org/10.1136/jech-2020-214257>
 64. Effect of changes in green spaces on mental health in older adults: a fixed effects analysis. <https://doi.org/10.1136/jech-2019-212704>
 65. Negotiating connections, confinements, and neighborhood places: Older adults' everyday well-being during the COVID-19 pandemic and beyond. <https://doi.org/10.1016/j.wss.2024.100223>
 66. Association between air pollution (PM10, PM2.5), greenness and depression in older adults: a longitudinal study in South Korea. <https://doi.org/10.1017/S2045796024000684>
 67. Exposure to useable green space and physical activity during active travel: A longitudinal GPS and accelerometer study before and after retirement. <https://doi.org/10.1016/j.healthplace.2024.103366>
 68. Understanding the relative importance of micro-level design characteristics of walking paths in parks to promote walking among older adults. <https://doi.org/10.1016/j.ufug.2023.128129>
 69. "Enticing" but Not Necessarily a "Space Designed for Me": Experiences of Urban Park Use by Older Adults with Disability. <https://doi.org/10.3390/ijerph18020552>
 70. Effect modification of greenness on temperature-mortality relationship among older adults: A case-crossover study in China. <https://doi.org/10.1016/j.envres.2021.111112>
 71. The Effects of Urban Natural Environments on Preference and Self-Reported Psychological Restoration of the Elderly. <https://doi.org/10.3390/ijerph18020509>
 72. Long-term exposure to residential greenness and neurodegenerative disease mortality among older adults: a 13-year follow-up cohort study. <https://doi.org/10.1186/s12940-022-00863-x>
 73. How can urban environments support dementia risk reduction? A qualitative study. <https://doi.org/10.1002/gps.5626>
 74. Issues and Needs of Elderly in Community Facilities and Services: A Case Study of Urban Housing Projects in Bangkok, Thailand. <https://doi.org/10.3390/su14148388>
 75. Long-term Exposure to PM2.5 and Mortality for the Older Population: Effect Modification by Residential Greenness. <https://doi.org/10.1097/EDE.0000000000001348>
 76. Urban health advantage and penalty in aging populations: a comparative study across major megacities in China. <https://doi.org/10.1016/j.lanwpc.2024.101112>
 77. Approach to user group-specific assessment of urban green spaces for a more equitable supply exemplified by the elderly population. <https://doi.org/10.3897/oneeco.7.e83325>
 78. Air pollution associated respiratory mortality risk alleviated by residential greenness in the Chinese Elderly Health Service Cohort. <https://doi.org/10.1016/j.envres.2020.109139>
 79. Association between neighborhood characteristics and antidepressant use at older ages: a register-based study of urban areas in three European countries. <https://doi.org/10.1136/jech-2020-214276>
 80. Associations of changes in neighborhood walkability with changes in walking activity in older adults: a fixed effects analysis. <https://doi.org/10.1186/s12889-021-11368-6>
 81. Park features that encourage park visitation among older adults: A qualitative study. <https://doi.org/10.1016/j.ufug.2023.128026>
 82. Urban green and blue spaces and general and mental health among older adults in Washington state: Analysis of BRFSS data between 2011 and 2019. <https://doi.org/10.1016/j.healthplace.2023.103148>
 83. Association of psychosocial and perceived environmental factors with park-based physical activity among elderly in two cities in China and Germany. <https://doi.org/10.1186/s12889-019-8140-z>
 84. Association between residential greenness and depression symptoms in Chinese community-dwelling older adults. <https://doi.org/10.1016/j.envres.2023.117869>
 85. Exploring "Equigenesis" in the Associations Between Green Space and Kidney Health Among Middle-Aged and Older Adults Using Street View Data. <https://doi.org/10.1093/geroni/igad130>
 86. The effect of residential greenness on cardiovascular mortality from a large cohort in South China: An in-depth analysis of effect modification by multiple demographic and lifestyle characteristics. <https://doi.org/10.1016/j.envint.2024.108894>
 87. Research on Environmental Behavior of Urban Parks in the North of China during Cold Weather-Nankai Park as a Case Study. <https://doi.org/10.3390/buildings14092742>
 88. Association of urban green and blue space with accelerated ageing: A cohort Study in the UK Biobank. <https://doi.org/10.1016/j.ecoenv.2024.117458>
 89. Socio-environmental modifiers of heat-related mortality in eight Swiss cities: A case time series analysis. <https://doi.org/10.1016/j.envres.2024.118116>
 90. Nonlinear and threshold effects of built environment on older adults' walking duration: do age and retirement status matter? <https://doi.org/10.3389/fpubh.2024.1418733>
 91. Relationships between Green Space Perceptions, Green Space Use, and the Multidimensional Health of Older People: A Case Study of Fuzhou, China. <https://doi.org/10.3390/building14061544>

92. Exploring the Mediating Effect of Physical Activities on Built Environment and Obesity for Elderly People: Evidence From Shanghai, China. <https://doi.org/10.3389/fpubh.2022.853292>
93. Person-Centered Climate, Garden Greenery and Well-Being among Nursing Home Residents: A Cross-Sectional Study. <https://doi.org/10.3390/ijerph20010749>
94. Surrounding Greenness and Biological Aging Based on DNA Methylation: A Twin and Family Study in Australia. <https://doi.org/10.1289/EHP8793>
95. Utilizing regression model to characterize the impact of urban green space features on the subjective well-being of older adults. <https://doi.org/10.1016/j.heliyon.2024.e35567>
96. PM_{2.5} Pollutant Concentrations in Greenspaces of Nanjing Are High but Can Be Lowered with Environmental Planning. <https://doi.org/10.3390/ijerph18189705>
97. Spatially varying associations between the built environment and older adults' propensity to walk. <https://doi.org/10.3389/fpubh.2022.1003791>
98. Assessing Urban Park Equity in China Through Supply and Demand Balance: A Case Study of Wuhan City, China. <https://doi.org/10.3390/su17052255>
99. Effects of neighborhood features on healthy aging in place: the composition and context of urban parks and traditional local coffeshops in Singapore. <https://doi.org/10.1186/s12877-022-03679-z>
100. Investigating the Association between Outdoor Environment and Outdoor Activities for Seniors Living in Old Residential Communities. <https://doi.org/10.3390/ijerph18147500>
101. The impact of urban park accessibility in cold regions on leisure-time physical activity levels of older adults during the winter. https://doi.org/10.14246/irspds.10.3_16
102. Urban greenspace and mental health in Chinese older adults: Associations across different greenspace measures and mediating effects of environmental perceptions. <https://doi.org/10.1016/j.healthplace.2022.102856>
103. Effect of built environment on BMI of older adults in regions of different socio-economic statuses. <https://doi.org/10.3389/fpubh.2023.1207975>
104. Nonlinear Effects of the Built Environment on Light Physical Activity among Older Adults: The Case of Lanzhou, China. <https://doi.org/10.3390/ijerph19148848>
105. Seniors' Physical Activity in Neighborhood Parks and Park Design Characteristics. <https://doi.org/10.3389/fpubh.2020.00322>
106. Green Space, Air Pollution, Weather, and Cognitive Function in Middle and Old Age in China. <https://doi.org/10.3389/fpubh.2022.871104>
107. Accessibility Improvement and Renewal of Urban Park Green Space for the Elderly and the Disabled. <https://doi.org/10.3390/f14091801>
108. Green Space Exposure and Human Health: Gender-Specific Physiological and Psychological Benefits of Green Infrastructure for Elderly Residents in Cold-Climate Cities. <https://doi.org/10.3390/su17062774>
109. Effects of green space exposure on acute respiratory illness in community-dwelling older people: A prospective cohort study. <https://doi.org/10.1016/j.landurbplan.2025.105336>
110. The Effects of Urban Green Space on Depressive Symptoms of Mid-Aged and Elderly Urban Residents in China: Evidence from the China Health and Retirement Longitudinal Study. <https://doi.org/10.3390/ijerph19020717>
111. The effects of greenness exposure on hypertension incidence among Chinese oldest-old: a prospective cohort study. <https://doi.org/10.1186/s12940-022-00876-6>
112. The role of residential greenness levels, green land cover types and diversity in overweight/obesity among older adults: A cohort study. <https://doi.org/10.1016/j.envres.2022.114854>
113. Heatwave exposure in relation to decreased sleep duration in older adults. <https://doi.org/10.1016/j.envint.2023.108348>
114. Association Pathways Between Neighborhood Greenspaces and the Physical and Mental Health of Older Adults-A Cross-Sectional Study in Guangzhou, China. <https://doi.org/10.3389/fpubh.2020.551453>
115. APOE ϵ 4 Modifies Effect of Residential Greenness on Cognitive Function among Older Adults: A Longitudinal Analysis in China. <https://doi.org/10.1038/s41598-019-57082-7>
116. Residential Greenness Alters Serum 25(OH)D Concentrations: A Longitudinal Cohort of Chinese Older Adults. <https://doi.org/10.1016/j.jamda.2020.04.026>
117. Relationship between urban green space and mental health in older adults: mediating role of relative deprivation, physical activity, and social trust. <https://doi.org/10.3389/fpubh.2024.1442560>

Data availability

Data will be made available on request.

References

- Aliyas, Z., 2021. Physical, mental, and physiological health benefits of green and blue outdoor spaces among elderly people. *Int. J. Environ. Health Res.* 31 (6), 703–714. <https://doi.org/10.1080/09603123.2019.1681379>.
- Arruda, H., Silva, E.R., Lessa, M., Proença Jr., D., Bartholo, R., 2022. VOSviewer and bibliometrix. *J. Med. Libr. Assoc.: JMLA* 110 (3), 392. <https://doi.org/10.5195/jmla.2022.1434>.
- Astell-Burt, T., Feng, X., 2019. Association of urban green space with mental health and general health among adults in Australia. *JAMA Netw. Open* 2 (7), e198209. <https://doi.org/10.1001/jamanetworkopen.2019.8209>.
- Astell-Burt, T., Hartig, T., Putra, I.G.N.E., Walsan, R., Dendup, T., Feng, X., 2022. Green space and loneliness: a systematic review with theoretical and methodological guidance for future research. *Sci. Total Environ.* 847, 157521. <https://doi.org/10.1016/j.scitotenv.2022.157521>.
- Banwell, N., Michel, S., Senn, N., 2024. Greenspaces and health: scoping review of studies in Europe [Review] *Public Health Rev.* 45. <https://doi.org/10.3389/phrs.2024.1606863>, 2024.
- Bao, Z., Bai, Y., Geng, T., 2023. Examining spatial inequalities in public green space accessibility: a focus on disadvantaged groups in England. *Sustainability* 15 (18). <https://doi.org/10.3390/su151813507>.
- Brown, S.C., Aitken, W.W., Lombard, J., Parrish, A., Dewald, J.R., Nardi, M.I., Mantero, A.M.A., Metalonis, S.W., Szapocznik, J., 2024. Longitudinal impacts of high versus low greenness on cardiovascular disease conditions. *J. Am. Heart Assoc.* 13 (19), e029939. <https://doi.org/10.1161/JAHA.123.029939>.
- Cao, Y., Wu, H., Wang, H., Qu, Y., Zeng, Y., Mu, X., 2023. How do block built environments affect daily leisure walking among the elderly? A empirical study of Gaoyou, China. *Sustainability* 15 (1), 257. <https://doi.org/10.3390/su15010257>.
- Carver, A., Beare, R., Knibbs, L.D., Mavoa, S., Grocott, K., Wheeler, A.J., Srikanth, V., Andrew, N.E., 2024. Exploring associations of greenery, air pollution and walkability with cardiometabolic health in people at midlife and beyond. *Geriatr. Gerontol. Int.* 24 (S1), 208–214. <https://doi.org/10.1111/ggi.14743>.
- Chaix, B., Méline, J., Duncan, S., Merrien, C., Karusisi, N., Perchoux, C., Lewin, A., Labadi, K., Kestens, Y., 2013. GPS tracking in neighborhood and health studies: a step forward for environmental exposure assessment, a step backward for causal inference? *Health Place* 21, 46–51. <https://doi.org/10.1016/j.healthplace.2013.01.003>.
- Chen, C., Cao, Y., Xu, G., Zhong, Q., Chen, B., 2024a. How do urban block built environments affect older adults' walking activities and health effects: a case study in Nanjing, China [Original Research] *Front. Public Health* 12. <https://doi.org/10.3389/fpubh.2024.1479305>, 2024.
- Chen, P., Wang, W., Qian, C., Cao, M., Yang, T., 2024b. Gravity-based models for evaluating urban park accessibility: why does localized selection of attractiveness factors and travel modes matter? *Environ. Plan. B Urban Anal. City Sci.* 51 (4), 904–922. <https://doi.org/10.1177/23998083231206168>.
- Chu, Y.-T., Li, D., Chang, P.-J., 2021. Effects of urban park quality, environmental perception, and leisure activity on well-being among the older population. *Int. J. Environ. Res. Publ. Health* 18 (21), 11402. <https://doi.org/10.3390/ijerph182111402>.
- Dalecká, A., Kšiňan, A., Szabó, D., Čapková, N., Píkhart, H., Bobák, M., 2025. Neighborhood environment and cognitive functioning in middle-aged and older population: a mediating role of physical activity. *Int. J. Hyg Environ. Health* 264, 114521. <https://doi.org/10.1016/j.ijheh.2025.114521>.
- De Bell, S., 2017. *Freshwater Blue Space and well-being: Investigating co-benefits at Different Spatial Scales*. University of York.
- de Keijzer, C., Tonne, C., Sabia, S., Basagaña, X., Valentín, A., Singh-Manoux, A., Antó, J. M., Alonso, J., Nieuwenhuijsen, M.J., Sunyer, J., Dadvand, P., 2019. Green and blue

- spaces and physical functioning in older adults: longitudinal analyses of the whitehall II study. *Environ. Int.* 122, 346–356. <https://doi.org/10.1016/j.envint.2018.11.046>.
- Egorov, A.I., Griffin, S.M., Klein, J., Guo, W., Styles, J.N., Kobylanski, J., Murphy, M.S., Sams, E., Hudgens, E.E., Wade, T.J., 2025. Greater residential greenness is associated with reduced epigenetic aging in adults. *Sci. Rep.* 15 (1), 3558. <https://doi.org/10.1038/s41598-024-82747-3>.
- Ennsle, F., Kabisch, N., 2020. Urban green spaces for the social interaction, health and well-being of older people—an integrated view of urban ecosystem services and socio-environmental justice. *Environ. Sci. Pol.* 109, 36–44. <https://doi.org/10.1016/j.envsci.2020.04.008>.
- Fossa, A.J., D'Souza, J., Bergmans, R., Zivin, K., Adar, S.D., 2024. Residential greenspace and major depression among older adults living in urban and suburban areas with different climates across the United States. *Environ. Res.* 243, 117844. <https://doi.org/10.1016/j.envres.2023.117844>.
- Freytmueller, J., Schmid, H.-L., Senkler, B., Lopez Lumbi, S., Zerbe, S., Hornberg, C., McCall, T., 2024. Current methodologies of greenspace exposure and mental health research—a scoping review [Systematic Review] *Front. Public Health* 12. <https://doi.org/10.3389/fpubh.2024.1360134>, 2024.
- Fu, Y., Wang, Y., Guo, Y., 2024. Built environment and loneliness in later life: productive engagement as the pathway. *Aging Ment. Health* 28 (6), 900–909. <https://doi.org/10.1080/13607863.2024.2329642>.
- Gianfredi, V., Buffoli, M., Rebecchi, A., Croci, R., Oradini-Alacreu, A., Stirparo, G., Marino, A., Odone, A., Capolongo, S., Signorelli, C., 2021. Association between urban greenspace and health: a systematic review of literature. *Int. J. Environ. Res. Publ. Health* 18 (10), 5137. <https://doi.org/10.3390/ijerph18105137>.
- Godina, S.L., Rosso, A.L., Hirsch, J.A., Besser, L.M., Lovasi, G.S., Donovan, G.H., Garg, P. K., Platt, J.M., Fitzpatrick, A.L., Lopez, O.L., Carlson, M.C., Michael, Y.L., 2023. Neighborhood greenspace and cognition: the cardiovascular health study. *Health Place* 79, 102960. <https://doi.org/10.1016/j.healthplace.2022.102960>.
- He, Q., Chang, H.-T., Wu, C.-d., Ji, J.S., 2022. Association between residential greenspace structures and frailty in a cohort of older Chinese adults. *Commun. Med.* 2 (1), 43. <https://doi.org/10.1038/s43856-022-00093-9>.
- Iamtrakul, P., Chayphong, S., 2024. Analyzing the link between built environment and physical activity: a spatial study in suburban area [Original Research]. *FRONTIERS IN BUILT ENVIRONMENT* 10. <https://doi.org/10.3389/fbuil.2024.1420020>, 2024.
- Jin, B., Xu, X., 2025a. Bayesian-optimized gaussian process calibration for forecasting carbon allowance prices in Tianjin. *International Journal of Artificial Intelligence and Robotics Research* 2, 2550006. <https://doi.org/10.1142/s2972335325500061>.
- Jin, B., Xu, X., 2025b. Forecasts of coking coal futures price indices through Gaussian process regressions. *Mineral Economics* 38 (1), 203–217. <https://doi.org/10.1007/s13563-024-00472-9>.
- Kabisch, N., Püffel, C., Masztalerz, O., Hemmerling, J., Kraemer, R., 2021. Physiological and psychological effects of visits to different urban green and street environments in older people: a field experiment in a dense inner-city area. *Landsc. Urban Plann.* 207, 103998. <https://doi.org/10.1016/j.landurbplan.2020.103998>.
- Kaczynska, M., 2024. Urban green spaces' influence on civilization Diseases—meta-analysis and critical review. *Sustainability* 16 (10), 3925. <https://doi.org/10.3390/su16103925>.
- Klein, S., Brondeel, R., Chaix, B., Klein, O., Thierry, B., Kestens, Y., Gerber, P., Perchoux, C., 2023. What triggers selective daily mobility among older adults? A study comparing trip and environmental characteristics between observed path and shortest path. *Health Place* 79, 102730. <https://doi.org/10.1016/j.healthplace.2021.102730>.
- Kleinschroth, F., Savilaakso, S., Kowarik, I., Martinez, P.J., Chang, Y., Jakstis, K., Schneider, J., Fischer, L.K., 2024. Global disparities in urban green space use during the COVID-19 pandemic from a systematic review. *Nature Cities* 1 (2), 136–149. <https://doi.org/10.1038/s44284-023-00020-6>.
- Korcz, N., Kamińska, A., Ciesielski, M., 2024. Is the level of quality of life related to the frequency of visits to natural areas? *Forests* 15 (12), 2257. <https://doi.org/10.3390/f15122257>.
- Kou, R., Hunter, R.F., Cleland, C., Ellis, G., 2021. Physical environmental factors influencing older adults' park use: a qualitative study. *Urban For. Urban Green.* 65, 127353. <https://doi.org/10.1016/j.ufug.2021.127353>.
- Labib, S.M., Huck, J.J., Lindley, S., 2021. Modelling and mapping eye-level greenness visibility exposure using multi-source data at high spatial resolutions. *Sci. Total Environ.* 755, 143050. <https://doi.org/10.1016/j.scitotenv.2020.143050>.
- Lak, A., Aghamolaei, R., Baradaran, H.R., Myint, P.K., 2020. A framework for elder-friendly public open spaces from the Iranian older adults' perspectives: a mixed-method study. *Urban For. Urban Green.* 56, 126857. <https://doi.org/10.1016/j.ufug.2020.126857>.
- Lau, K.K.-L., Yung, C.C.-Y., Tan, Z., 2021. Usage and perception of urban green space of older adults in the high-density city of Hong Kong. *Urban For. Urban Green.* 64, 127251. <https://doi.org/10.1016/j.ufug.2021.127251>.
- Leng, H., Li, S., Zhao, H., Song, Y., Yuan, Q., 2020a. Planning for supportive green spaces in the Winter city of China: linking exercise of elderly residents and exercise prescription for cardiovascular health. *Int. J. Environ. Res. Publ. Health* 17 (16), 5762. <https://doi.org/10.3390/ijerph17165762>.
- Leng, H., Li, S., Zhao, H., Song, Y., Yuan, Q., 2020b. Planning for supportive green spaces in the Winter city of China: linking exercise of elderly residents and exercise prescription for cardiovascular health. *Int. J. Environ. Res. Publ. Health* 17 (16). <https://doi.org/10.3390/ijerph17165762>.
- Levinger, P., McConaghy, R., Dreher, B., James, L., Fearn, M., McKenna, T., Hallissey, M., Hill, K.D., 2025. Recreational spaces: how best to design and cater for older people's safe engagement in physical activity. *Journal of Population Ageing* 18 (3), 525–552. <https://doi.org/10.1007/s12062-024-09472-7>.
- Li, Q., Liu, Y., Yang, L., Ge, J., Chang, X., Zhang, X., 2023. The impact of urban green space on the health of middle-aged and older adults [Original Research]. *Front. Public Health* 11. <https://doi.org/10.3389/fpubh.2023.1244477>, 2023.
- Li, X., Zhang, C., Li, W., Ricard, R., Meng, Q., Zhang, W., 2015. Assessing street-level urban greenery using google street view and a modified green view index. *Urban For. Urban Green.* 14 (3), 675–685. <https://doi.org/10.1016/j.ufug.2015.06.006>.
- Li, Y., Liu, H., Vidal, D.G., Akpinar, A., Li, D., 2024. Editorial: urban green spaces and human health [Editorial] *Front. Public Health* 12. <https://doi.org/10.3389/fpubh.2024.1404452>, 2024.
- Lin, C., Wu, L., 2021. Green and blue space availability and self-rated health among seniors in China: evidence from a national survey. *Int. J. Environ. Res. Publ. Health* 18 (2), 545. <https://doi.org/10.3390/ijerph18020545>.
- Liu, Y., Kwan, M.-P., Wong, M.S., Yu, C., 2023. Current methods for evaluating people's exposure to green space: a scoping review. *Soc. Sci. Med.* 338, 116303. <https://doi.org/10.1016/j.socscimed.2023.116303>.
- Luo, W., Wang, F., 2003. Measures of spatial accessibility to health care in a GIS environment: synthesis and a case study in the Chicago region. *Environ. Plann. Plann. Des.* 30 (6), 865–884. <https://doi.org/10.1068/b29120>.
- Macintyre, V.G., Coterill, S., Anderson, J., Phillipson, C., Benton, J.S., French, D.P., 2019. "I Would Never Come Here Because I've Got My Own Garden": older Adults' perceptions of small urban green spaces. *Int. J. Environ. Res. Publ. Health* 16 (11), 1994. <https://doi.org/10.3390/ijerph16111994>.
- Marquet, O., Hirsch, J.A., Kerr, J., Jankowska, M.M., Mitchell, J., Hart, J.E., Laden, F., Hipp, J.A., James, P., 2022. GPS-based activity space exposure to greenness and walkability is associated with increased accelerometer-based physical activity. *Environ. Int.* 165, 107317. <https://doi.org/10.1016/j.envint.2022.107317>.
- Marquet, O., Tello-Barsocchini, J., Couto-Trigo, D., Gómez-Varo, I., Maciejewska, M., 2023. Comparison of static and dynamic exposures to air pollution, noise, and greenness among seniors living in compact-city environments. *Int. J. Health Geogr.* 22 (1), 3. <https://doi.org/10.1186/s12942-023-00325-8>.
- McDougall, C.W., Hanley, N., Quilliam, R.S., Bartie, P.J., Robertson, T., Griffiths, M., Oliver, D.M., 2021. Neighbourhood blue space and mental health: a nationwide ecological study of antidepressant medication prescribed to older adults. *Landsc. Urban Plann.* 214, 104132. <https://doi.org/10.1016/j.landurbplan.2021.104132>.
- Meng, L., Wen, K.-H., Zeng, Z., Brewin, R., Fan, X., Wu, Q., 2020. The impact of street space perception factors on elderly health in high-density cities in Macau—analysis based on street view images and deep learning technology. *Sustainability* 12 (5), 1799. <https://doi.org/10.3390/su12051799>.
- Mortelmans, D., 2024. Doing a Literature Review with Nvivo, pp. 259–278. https://doi.org/10.1007/978-3-031-66014-6_21.
- Mortelmans, D., 2025. Doing a literature review with NVivo. In: Mortelmans, D. (Ed.), *Doing Qualitative Data Analysis with Nvivo*. Springer, Nature Switzerland, pp. 259–278. https://doi.org/10.1007/978-3-031-66014-6_21.
- Motoc, I., Hoogendijk, E.O., Timmermans, E.J., Deeg, D., Penninx, B.W.J.H., Huisman, M., 2023. Social and physical neighbourhood characteristics and 10-year incidence of depression and anxiety in older adults: results from the longitudinal aging study amsterdam. *Soc. Sci. Med.* 327, 115963. <https://doi.org/10.1016/j.socscimed.2023.115963>.
- Ottoni, C.A., Winters, M., Sims-Gould, J., 2024. Negotiating connections, confinements, and neighbourhood places: older adults' everyday well-being during the COVID-19 pandemic and beyond. *Wellbeing, Space and Society* 7, 100223. <https://doi.org/10.1016/j.wss.2024.100223>.
- Page, M.J., McKenzie, J.E., Bossuyt, P.M., Boutron, I., Hoffmann, T.C., Mulrow, C.D., Shamseer, L., Tetzlaff, J.M., Akl, E.A., Brennan, S.E., 2020. The PRISMA, et al. statement: an updated guideline for reporting systematic reviews. *bmj* 2021 (372), 71. <https://doi.org/10.1136/bmj.n71>.
- Page, M.J., McKenzie, J.E., Bossuyt, P.M., Boutron, I., Hoffmann, T.C., Mulrow, C.D., Shamseer, L., Tetzlaff, J.M., Akl, E.A., Brennan, S.E., Chou, R., Glanville, J., Grimshaw, J.M., Hróbjartsson, A., Lalu, M.M., Li, T., Loder, E.W., Mayo-Wilson, E., McDonald, S., Moher, D., 2021. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *bmj* 372, n71. <https://doi.org/10.1136/bmj.n71>.
- Park, H., Kang, C., Kim, H., 2024. Association between air pollution (PM10, PM2.5), greenness and depression in older adults: a longitudinal study in South Korea. *Epidemiol. Psychiatr. Sci.* 33, e71. <https://doi.org/10.1017/S2045796024000684> e71.
- Paudel, C., Timperio, A., Loh, V., Deforche, B., Salmon, J., Veitch, J., 2023. Understanding the relative importance of micro-level design characteristics of walking paths in parks to promote walking among older adults. *Urban For. Urban Green.* 89, 128129. <https://doi.org/10.1016/j.ufug.2023.128129>.
- Paudel, S., States, S.L., 2023. Urban green spaces and sustainability: exploring the ecosystem services and disservices of grassy lawns versus floral meadows. *Urban For. Urban Green.* 84, 127932. <https://doi.org/10.1016/j.ufug.2023.127932>.
- Peng, Yuyang, Li, Wen, Nijhuis, Steffen, Yu, Yingwen, Wu, Zaichen, 2026a. Seeing heritage through green and blue: Assessing the visual influence of blue-green infrastructure (BGI) in historic urban areas (HUAs). *Environmental Impact Assessment Review* 118, 108301. <https://doi.org/10.1016/j.eiar.2025.108301>. <https://linkinghub.elsevier.com/retrieve/pii/S0195952525004986>.
- Peng, Yuyang, Nijhuis, Steffen, Wang, Zhuoyue, Yu, Yingwen, Verbree, Edward, van Oosterom, Peter, 2026d. When to stop? A visual impact assessment framework for incremental urban and community expansion in rural heritage landscapes. *Sustainable Cities and Society* 143, 107364. <https://doi.org/10.1016/j.scs.2026.107364>. <https://linkinghub.elsevier.com/retrieve/pii/S2210670726002519>.
- Peng, Yuyang, Nijhuis, Steffen, Wu, Zaichen, Yu, Yingwen, 2026b. From comparison to combination: Street view imagery (SVI) and 3D model-based analyses for urban visual environment assessment. *Landscape Architecture and Sustainability* 3 (1),

100034. <https://doi.org/10.1016/j.las.2026.100034>. <https://linkinghub.elsevier.com/retrieve/pii/S3050732426000041>.
- Peng, Yuyang, Nijhuis, Steffen, Yu, Yingwen, Aguiaro, Giorgio, Zhang, Guanting, 2026c. Recurrent visual behavior and viewpoint-specific spatial features in a heritage environment: immersive eye-tracking evidence from Jichang Garden. *Journal of Environmental Psychology* 114, 103144. <https://doi.org/10.1016/j.jenvp.2026.103144>. <https://linkinghub.elsevier.com/retrieve/pii/S0272494426002458>.
- Perry, M., Cotes, L., Horton, B., Kunac, R., Snell, I., Taylor, B., Wright, A., Devan, H., 2021. "Enticing" but Not Necessarily a "Space designed for me": experiences of urban park use by older adults with disability. *Int. J. Environ. Res. Publ. Health* 18 (2). <https://doi.org/10.3390/ijerph18020552>.
- Portegijs, E., Keskinen, K.E., Eronen, J., Saajanaho, M., Rantakokko, M., Rantanen, T., 2020. Older Adults' Physical Activity and the Relevance of Distances to Neighborhood Destinations and Barriers to Outdoor Mobility [Original Research]. *Front. Public Health* 8. <https://doi.org/10.3389/fpubh.2020.00335>, 2020.
- Przewoźna, P., Inglot, A., Mielewczyk, M., Maczka, K., Matczak, P., 2024. Accessibility to urban green spaces: a critical review of WHO recommendations in the light of tree-covered areas assessment. *Ecol. Indic.* 166, 112548. <https://doi.org/10.1016/j.ecolind.2024.112548>.
- Qiu, C., Ji, J.S., Bell, M.L., 2021a. Effect modification of greenness on temperature-mortality relationship among older adults: a case-crossover study in China. *Environ. Res.* 197, 111112. <https://doi.org/10.1016/j.envres.2021.111112>.
- Qiu, L., Chen, Q., Gao, T., 2021b. The effects of urban natural environments on preference and self-reported psychological restoration of the elderly. *Int. J. Environ. Res. Publ. Health* 18 (2). <https://doi.org/10.3390/ijerph18020509>.
- Rethlefsen, M.L., Kirtley, S., Waffenschmidt, S., Ayala, A.P., Moher, D., Page, M.J., Koffel, J.B., 2021. PRISMA-S: an extension to the PRISMA statement for reporting literature searches in systematic reviews. *Syst. Rev.* 10, 1–19. <https://doi.org/10.1186/s13643-020-01542-z>.
- Ricciardi, E., Spano, G., Lopez, A., Tinella, L., Clemente, C., Elia, G., Dadvand, P., Sanesi, G., Bosco, A., Caffò, A.O., 2022. Long-term exposure to greenspace and cognitive function during the lifespan: a systematic review. *Int. J. Environ. Res. Publ. Health* 19 (18), 11700. <https://doi.org/10.3390/ijerph191811700>.
- Rodriguez-Loureiro, L., Gadeyne, S., Bauwelinck, M., Lefebvre, W., Vanpoucke, C., Casas, L., 2022. Long-term exposure to residential greenness and neurodegenerative disease mortality among older adults: a 13-year follow-up cohort study. *Environ. Health* 21 (1), 49. <https://doi.org/10.1186/s12940-022-00863-x>.
- Roe, J.J., Aspinall, P.A., Ward Thompson, C., 2017. Coping with stress in deprived urban neighborhoods: what is the role of green space according to life stage? [Original Research] *Front. Psychol.* 8. <https://doi.org/10.3389/fpsyg.2017.01760>, 2017.
- Röhr, S., Rodriguez, F.S., Siemensmeyer, R., Müller, F., Romero-Ortuno, R., Riedel-Heller, S.G., 2022. How can urban environments support dementia risk reduction? A qualitative study. *Int. J. Geriatr. Psychiatr.* 37 (1). <https://doi.org/10.1002/gps.5626>.
- Sharifi, F., Nygaard, A., Stone, W.M., Levin, I., 2021. Accessing green space in Melbourne: measuring inequity and household mobility. *Landsc. Urban Plann.* 207, 104004. <https://doi.org/10.1016/j.landurbplan.2020.104004>.
- Sharma, T., Jain, S., 2023. Nexus between built environment, travel behaviour and human health: an integrated framework to reinforce transport system. *J. Clean. Prod.* 416, 137744. <https://doi.org/10.1016/j.jclepro.2023.137744>.
- Son, J.-Y., Sabath, M.B., Lane, K.J., Miranda, M.L., Dominici, F., Di, Q., Schwartz, J., Bell, M.L., 2021. Long-term exposure to PM_{2.5} and mortality for the older population: effect modification by residential greenness. *Epidemiology* 32 (4). <https://doi.org/10.1097/EDE.0000000000001348>.
- Stanley, C.H., Hecht, R., Kahir, S., Brzoska, P., 2022. Approach to user group-specific assessment of urban green spaces for a more equitable supply exemplified by the elderly population. *One Ecosyst.* 7, e83325. <https://doi.org/10.3897/oneeco.7.e83325>. [10.3897/oneeco.7.e83325].
- Taczanowska, K., Tansil, D., Wilfer, J., Jiricka-Pürrer, A., 2024. The impact of age on people's use and perception of urban green spaces and their effect on personal health and wellbeing during the COVID-19 pandemic—A case study of the metropolitan area of Vienna, Austria. *Cities* 147, 104798. <https://doi.org/10.1016/j.cities.2024.104798>.
- Takkouche, B., Norman, G., 2011. PRISMA statement. *Epidemiology* 22 (1), 128. <https://doi.org/10.1097/EDE.0b013e3181fe7999>.
- United Nations, Department of Economic and Social Affairs, Population Division, 2019. *World Population Prospects 2019: Highlights (ST/ESA/SER.A/423)*. United Nations.
- van Heezik, Y., Freeman, C., Buttery, Y., Waters, D.L., 2020. Factors affecting the extent and quality of nature engagement of older adults living in a range of home types. *Environ. Behav.* 52 (8), 799–829. <https://doi.org/10.1177/0013916518821148>.
- Van Puyvelde, A., Deforche, B., Mertens, L., Rivera, E., Van Dyck, D., Veitch, J., Poppe, L., 2023. Park features that encourage park visitation among older adults: a qualitative study. *Urban For. Urban Green.* 86, 128026. <https://doi.org/10.1016/j.ufug.2023.128026>.
- Vasconcelos, L., Langemeyer, J., Cole, H.V.S., Baró, F., 2024. Nature-based climate shelters? Exploring urban green spaces as cooling solutions for older adults in a warming city. *Urban For. Urban Green.* 98, 128408. <https://doi.org/10.1016/j.ufug.2024.128408>.
- Wagner, P., Duan, Y.P., Zhang, R., Wulff, H., Brehm, W., 2020. Association of psychosocial and perceived environmental factors with park-based physical activity among elderly in two cities in China and Germany. *BMC Public Health* 20 (1), 55. <https://doi.org/10.1186/s12889-019-8140-z>.
- Wang, H., Gholami, S., Xu, W., Samavatekbatan, A., Sleipness, O., Tassinary, L.G., 2024a. Where and how to invest in greenspace for optimal health benefits: a systematic review of greenspace morphology and human health relationships. *Lancet Planet. Health* 8 (8), e574–e587. [https://doi.org/10.1016/S2542-5196\(24\)00140-2](https://doi.org/10.1016/S2542-5196(24)00140-2).
- Wang, L., Zhang, Y., Jiang, X., 2024b. Greenspace and respiratory health: a systematic review and analytical framework. *The Routledge Handbook on Greening High-Density Cities* 383–403. <https://doi.org/10.4324/9781003318385-26>.
- Wang, R., Liu, Y., Xue, D., Helbich, M., 2019. Depressive symptoms among Chinese residents: how are the natural, built, and social environments correlated? *BMC Public Health* 19 (1), 887. <https://doi.org/10.1186/s12889-019-7171-9>.
- Wang, Y., Shi, X., Yang, F., Wang, S., Han, T., Ma, K., 2025. Association of urban green and blue space with accelerated ageing: a cohort study in the UK biobank. *Ecotoxicol. Environ. Saf.* 290, 117458. <https://doi.org/10.1016/j.ecoenv.2024.117458>.
- Wicki, B., Flückiger, B., Vienneau, D., de Hoogh, K., Rössli, M., Ragettli, M.S., 2024. Socio-environmental modifiers of heat-related mortality in eight Swiss cities: a case time series analysis. *Environ. Res.* 246, 118116. <https://doi.org/10.1016/j.envres.2024.118116>.
- Wolch, J.R., Byrne, J., Newell, J.P., 2014. Urban green space, public health, and environmental justice: the challenge of making cities 'just green enough'. *Landsc. Urban Plann.* 125, 234–244. <https://doi.org/10.1016/j.landurbplan.2014.01.017>.
- Wu, Y., Zhou, W., Zhang, H., Liu, Q., Yan, Z., Lan, S., 2024. Relationships between green space perceptions, green space use, and the multidimensional health of older people: a case study of Fuzhou, China. *Buildings* 14 (6), 1544. <https://doi.org/10.3390/buildings14061544>.
- Xiang, L., Mei, T., 2024. Developing the age-friendly community parks survey for older adults: assessing aging environment. *Urban For. Urban Green.* 99, 128424. <https://doi.org/10.1016/j.ufug.2024.128424>.
- Xie, X., Zhou, H., Gou, Z., 2023. Dynamic real-time individual green space exposure indices and the relationship with static green space exposure indices: a study in Shenzhen. *Ecol. Indic.* 154, 110557. <https://doi.org/10.1016/j.ecolind.2023.110557>.
- Xu, L., Lou, Y., Li, C., Tao, X., Engström, M., 2023. Person-centered climate, garden greenery and well-being among nursing home residents: a cross-sectional study. *Int. J. Environ. Res. Publ. Health* 20 (1), 749. <https://doi.org/10.3390/ijerph20010749>.
- Xu, X., Zhang, Y., 2021. Network analysis of corn cash price comovements. *Machine Learning with Applications* 6, 100140. <https://doi.org/10.1016/j.mlwa.2021.100140>.
- Xu, X., Zhang, Y., 2023a. Coking coal futures price index forecasting with the neural network. *Mineral Economics* 36 (2), 349–359. <https://doi.org/10.1007/s13563-022-00311-9>.
- Xu, X., Zhang, Y., 2023b. Network analysis of housing price comovements of a hundred Chinese cities. *Natl. Inst. Econ. Rev.* 264, 110–128. <https://doi.org/10.1017/nie.2021.34>.
- Xu, X., Zhang, Y., 2024. Network analysis of price comovements among corn futures and cash prices. *J. Agric. Food Ind. Organ.* 22 (1), 53–81. <https://doi.org/10.1515/jafio-2022-0009>.
- Yang, C., Tang, X., Yang, L., 2022. Spatially varying associations between the built environment and older adults' propensity to walk [Original Research] *Front. Public Health* 10. <https://doi.org/10.3389/fpubh.2022.1003791>, 2022.
- Yi, L., Wilson, J.P., Mason, T.B., Habre, R., Wang, S., Dunton, G.F., 2019. Methodologies for assessing contextual exposure to the built environment in physical activity studies: a systematic review. *Health Place* 60, 102226. <https://doi.org/10.1016/j.healthplace.2019.102226>.
- Yu, C., Kwan, M.-P., 2024. Dynamic greenspace exposure, individual mental health status and momentary stress level: a study using multiple greenspace measurements. *Health Place* 86, 103213. <https://doi.org/10.1016/j.healthplace.2024.103213>.
- Zhang, L., Tan, P.Y., Diehl, J.A., 2017. A conceptual framework for studying urban green spaces effects on health. *J. Urban Ecol.* 3 (1), jux015. <https://doi.org/10.1093/jue/jux015>.
- Zhang, R., Huang, L., Wang, H., 2023. Accessibility improvement and renewal of urban park green space for the elderly and the disabled. *Forests* 14 (9), 1801. <https://doi.org/10.3390/f14091801>.
- Zhou, W., Wang, Q., Kadier, A., Wang, W., Zhou, F., Li, R., Ling, L., 2023. The role of residential greenness levels, green land cover types and diversity in overweight/obesity among older adults: a cohort study. *Environ. Res.* 217, 114854. <https://doi.org/10.1016/j.envres.2022.114854>.
- Zhou, Y., Yuan, Y., Chen, Y., Lai, S., 2020. Association pathways between neighborhood greenspaces and the physical and mental health of older adults—A cross-sectional study in Guangzhou, China [Original Research] *Front. Public Health* 8. <https://doi.org/10.3389/fpubh.2020.551453>, 2020.
- Zhu, A., Yan, L., Shu, C., Zeng, Y., Ji, J.S., 2020. APOE ε4 modifies effect of residential greenness on cognitive function among older adults: a longitudinal analysis in China. *Sci. Rep.* 10 (1), 82. <https://doi.org/10.1038/s41598-019-57082-7>.