Research Paper

Research Framework on the Relationship Between Urban Built Environment and Residents' Health: The Mediating Effects of Physical Activity

Xiaohe HOU, School of Architecture and Design, Harbin Institute of Technology; Key Laboratory of National Territory Spatial Planning and Ecological Restoration in Cold Regions, Ministry of Natural Resources, China

Hong LENG, School of Architecture and Design, Harbin Institute of Technology; Key Laboratory of National Territory Spatial Planning and Ecological Restoration in Cold Regions, Ministry of Natural Resources, China

Yilu HOU, School of Architecture and Urban Planning, Tongji University, China

Abstract

Rapid urbanization has intensified changes in the built environment-such as noise, light, heat exposure, and air quality-thereby heightening risks to both the physical and mental health of urban residents. Concurrently, sprawling and unregulated urban expansion has diminished the convenience of non-motorized travel and outdoor activity, leading to increased reliance on private automobiles, reduced physical activity, and consequently rising prevalence of obesity, cardiovascular diseases, diabetes, and other chronic conditions. As global health paradigms shift from "disease treatment" to "health prevention," human-centered, proactive, and preventive health interventions have become a dominant trend. The built environment, as a key determinant of health independent of genetic and medical factors, possesses advantages of cost-effectiveness, durability, and subtle behavioral influence, and is increasingly recognized as a critical platform for active health promotion. Accordingly, the relationship between the built environment and public health has emerged as a central topic in healthy-city research. Although existing studies have identified significant associations between the two, systematic understanding of the underlying mechanisms remains limited, particularly regarding physical activity as a pivotal mediating variable.

This study systematically synthesizes the multidimensional relationships among the built environment, physical activity, and residents' health, and develops an integrative "multi-scale–multi-path–multi-group" analytical framework centered on physical activity as the key mediator. The framework delineates the hierarchical transmission mechanisms of health effects across spatial scales-from macro-level urban form to meso-level neighborhood structure and micro-level place design; distinguishes the mediating roles of commuting, recreational, and other types of physical activity in the behavioral pathways; and identifies the moderating effects of sociodemographic characteristics on the built environment–health relationship. Furthermore, the study incorporates multi-source data fusion, indicator-system construction, and mediation-effect testing, and discusses the framework's applicability to health-oriented urban planning and precision public health interventions.

Overall, the integrative theoretical framework and analytical paradigm proposed herein deepen the mechanistic understanding of how the built environment shapes health outcomes, and provide theoretical foundations and practical guidance for advancing healthy-city development.

Keywords

Built Environment, Physical Activity, Health Intervention

1. Introduction

With the acceleration of global urbanization, urban spatial forms and residents' lifestyles are undergoing profound transformations, accompanied by a general decline in physical activity levels and growing public health concerns. In recent years, multiple health risks-including non-communicable chronic diseases, heat exposure, and psychological stress-have become increasingly concentrated in urban environments, while spatial disparities in health have also intensified (WHO, 2025). According to the World Health Organization, approximately 27.5% of adults worldwide do not meet the recommended level of physical activity (WHO, 2018), and insufficient activity contributes to more than five million premature deaths annually (Lee et al., 2012). In China, over 30% of adults are physically inactive, and fewer than 25% of adolescents meet the recommended standards (Li et al., 2023); related rates of obesity and mental health problems continue to rise (Wang, 2025). Consequently, the question of how the urban built environment influences residents' health has become a central concern in both academic and policy discourse (Mooney et al., 2022; Ding et al., 2023).

Against this backdrop, urban planning has increasingly incorporated health objectives into spatial governance frameworks, marking a paradigm shift from disease prevention to health promotion (Zhong et al., 2022). Early studies on urban health mainly concentrated on environmental exposures and related health risks (Cao et al., 2019), with particular attention to direct threats such as air pollution (Brook et al., 2010), environmental noise (Basner et al., 2014), and urban heat islands (Li & Bou-Zeid, 2013). As the field developed, research increasingly recognized the role of the built environment in shaping residents' behavior, and physical activity was gradually identified as a key behavioral link between environment and health (Zhang et al., 2023). Accordingly, the focus has shifted from describing static environmental characteristics to examining the dynamic interaction between behavior and spatial conditions.

Existing studies largely cluster around two main lines of inquiry: one focuses on direct environmental threats such as pollution and heat stress (Zhang et al., 2023; Zhang et al., 2020), and the other examines statistical associations between built environment indicators and health outcomes (Maharana & Nsoesie, 2017; Li et al., 2024). Together, these lines of work provide an important empirical base, but they often leave the environment–health relationship as a "black box." In response, researchers have increasingly turned to behavioural mechanisms, with physical activity-shaped by environmental context and closely linked to health-now widely viewed as a core mediator connecting the built environment and human health. Within this paradigm shift, the key concepts can be further defined as follows: the built environment refers to an anthropogenic spatial system composed of land use and urban spatial elements, which influences health through both direct environmental exposure and behavioral shaping; physical activity, as a critical mediating variable, reflects individuals' behavioral responses to different environmental contexts; and health is understood as a multidimensional outcome encompassing physical, psychological, and social well-being.

However, current research still faces three major limitations: first, physical activity is often treated as a homogeneous process, overlooking differences among activity types; second, macro-, meso-, and micro-scale analyses are frequently conducted in isolation, lacking cross-scale integration; third, studies commonly assume population homogeneity and pay limited attention to the moderating role of sociodemographic characteristics. With the advancement of emerging data sources and analytical technologies, these limitations are gradually being addressed: the integration of remote sensing imagery, street view data, mobile sensing, and big data platforms has enabled more fine-grained, multi-scale representation of the built environment (Nguyen et al., 2022); the widespread adoption of wearable

devices and health applications has significantly improved the spatiotemporal resolution and accessibility of physical activity data (Cui, 2024); meanwhile, the interdisciplinary integration of geographic information science, public health, and data science has provided stronger methodological support for mechanism-oriented research (Oliver et al., 2019).

Building on these developments, this study reviews how research on the relationship between the urban built environment and residents' health has evolved, identifies current trends and remaining limitations, and places particular emphasis on the mediating role of physical activity. It develops a "multi-scale-multi-path-multi-group" mediation framework and elaborates its internal logic, core dimensions, and associated methodological pathways. On this basis, the study further discusses potential applications and future extensions of the framework. The aim is to provide both a coherent theoretical foundation and a practical analytical scheme for health-oriented spatial planning, while offering insights into strategies that can guide residents toward healthier behavioral patterns.

2. Construction of the "Multi-Scale-Multi-Path-Multi-Group" Mediation Framework

2.1. Logical Structure and Mechanisms of the Framework: A Mediation Model

Within the paradigm evolution of research on the built environment and health, the field has undergone a series of important shifts: from "natural restoration" to environment-based design interventions, from identifying correlations to uncovering underlying mechanisms, and from whole-population assessments to a more targeted focus on specific population groups. Against this backdrop, understanding how the environment influences human health through physical activity has become an essential and unavoidable research priority. Although existing studies have explored this relationship from perspectives such as spatial scale, behavioral pathways, and population heterogeneity, they have largely relied on isolated, single-dimensional analyses. A unified analytical framework that can bridge macro-level structures and micro-level places, while integrating diverse behavioral patterns and group heterogeneity, remains lacking. This fragmentation across dimensions leaves the interaction mechanisms among key factors insufficiently understood, effectively rendering them a "secondary black box" that has yet to be fully unpacked.

In response, this paper develops an integrated "multi-scale-multi-pathway-multi-group" mediation framework (as shown in Figure 1). Centering physical activity as the core mediating variable, the framework establishes a basic causal chain of "built environment-physical activity-residents' health," in which the built environment is conceptualized as the structural condition, physical activity as the behavioral mediator, and health status as the outcome variable. Specifically, the multi-scale dimension captures the differentiated influences of the built environment on physical activity across spatial levels, including urban form, neighborhood configuration and street-level micro-environments; the multi-pathway dimension reflects the composite mechanisms through which the built environment transmits health effects via different types of physical activity, such as utilitarian (commuting) and recreational activity; and the multi-group dimension elucidates how gender, age and socioeconomic status moderate the relationship between the built environment and health. By means of this integrative framework, the paper seeks to advance the field from fragmented empirical findings toward more systematic theoretical explanation, and to provide more comprehensive theoretical support for healthy urban planning and targeted interventions.

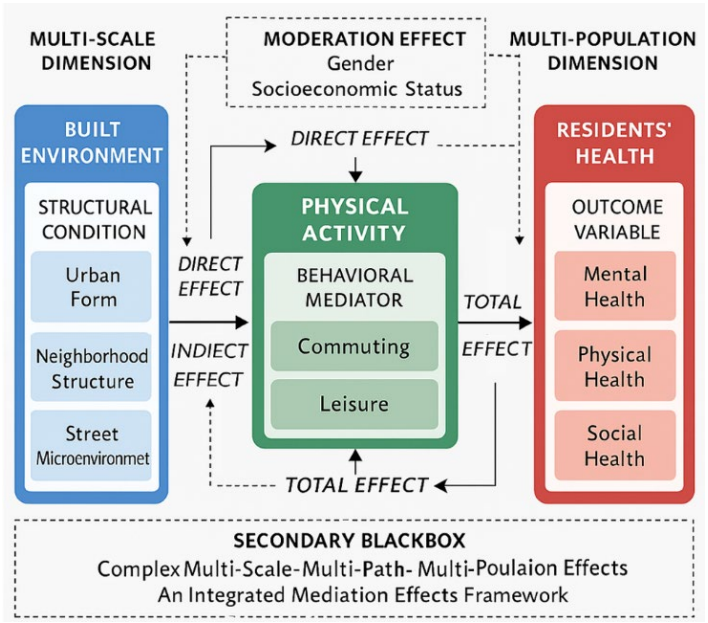


Figure 1. Integrated Multi-Scale × Multi-Path Mediation Framework. Source: Author's illustration.

2.2. Multi-Scale Dimension: Hierarchical Deconstruction of Built Environment Effects

The health impacts of the built environment arise through a nested multi-scale spatial mechanism-where macro-level urban structure, meso-level neighborhood configuration, and micro-level street environments interactively shape residents' physical activity patterns and, ultimately, their health outcomes (as summarized in Table 1).

Spatial scale	Core spatial characteristics (condensed)	Pathways to physical activity & health (condensed)
Macro level	• Urban form (compactness, density) • Land-use mix • Transport system (public transit, network structure)	• Provides structural preconditions for transport-related PA. • Enhances walkability & cycling accessibility; reduces travel distance & energy use. • Mitigates congestion & environmental exposure, benefiting physical & mental health.
Meso level	• Neighborhood layout & block structure • Land-use configuration • Distribution of public & commercial facilities • Community green/open spaces	• Shapes the convenience & frequency of leisure and domestic PA. • High connectivity and accessible green/recreational spaces promote leisure activity. • Diverse neighborhood services enhance daily functional PA and energy expenditure.
Micro level	• Street greenery & landscape features • Lighting, sidewalk continuity, aesthetics • Local environmental quality (air, noise, microclimate)	• Influences occurrence & sustainability of short, spontaneous, or flexible PA. • Improves comfort, safety perception & psychological restoration. • Promotes fragmented movement patterns & emotional well-being.

Table 1. Multi-Scale Mechanisms Linking the Built Environment to Physical Activity and Health. Source: Author's illustration.

2.3. Multi-Path Dimension: Heterogeneous Channels of Physical Activity Mediation

The mechanisms through which the built environment affects residents' health are characterized by multiple pathways, including both direct effects and indirect mediation effects through physical activity (as shown in Figure 2). The direct effects refer to improvements in ecological quality, reductions in environmental exposure, and enhancement of psychological restoration, all of which directly promote physical and mental well-being. The indirect effects occur when the built environment influences the level and type of physical activity, thereby indirectly shaping outcomes related to metabolic health, cardiovascular fitness, and psychological well-being.

As a mediating mechanism, physical activity exhibits diverse transmission channels across different health outcomes. Transport-related physical activity increases aerobic exercise, improves cardiopulmonary function and lipid metabolism, and plays a significant role in preventing chronic diseases. Leisure-time physical activity contributes to psychological recovery and emotional regulation, enhancing subjective well-being and social connectedness. Functional physical activity, often associated with daily travel and light occupational activity, helps improve metabolic function and reduce obesity risk. Although domestic physical activity tends to be lower in intensity, its continuity and universality contribute to maintaining energy balance and weight control (Rhodes et al., 2019).

In addition, psychological perception and social experience represent important supplementary pathways through which the built environment influences health. High landscape quality, visual greenery, and the accessibility of open spaces can reduce stress and promote mental health via mechanisms of psychological relaxation and emotional restoration. Simultaneously, pleasant spatial environments and increased opportunities for social interaction enhance positive emotions, sense of belonging, and community cohesion. These psychological and social processes interweave with behavioral pathways, collectively forming a multidimensional transmission system through which the built environment impacts health.

Incorporating this multi-path mediation dimension into the study of built environment–health relationships helps elucidate the complexity of behavioral mechanisms and provides a deeper understanding of how different forms of physical activity and perceptual experiences jointly mediate health outcomes. This perspective is crucial for advancing from single-mechanism explanations toward a comprehensive interpretation of health effects within urban environments.

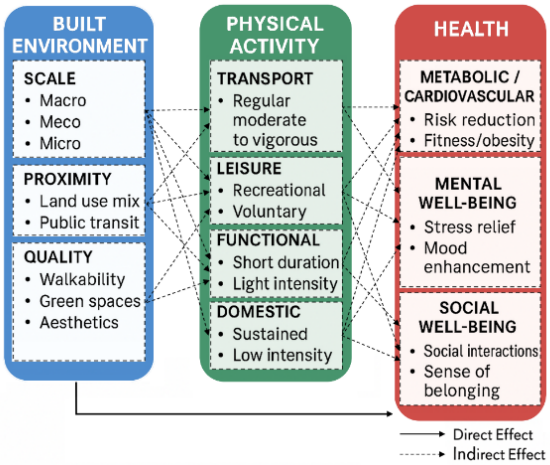


Figure 2. Pathways from the Built Environment to Health. Source: Author's illustration.

2.4. Multi-Group Dimension: Moderating Effects of Socio-Demographic Characteristics

Sociodemographic characteristics such as gender, age and socioeconomic status systematically shape how individuals perceive and use the built environment, the types and levels of physical activity they engage in, and the health benefits they derive, thereby producing pronounced differences in health effects across population groups (as summarized in Table 2).

Sociodemographic Factor	Sub-group	Built Environment Perception / Use	Physical Activity Pattern	Health Benefits / Risks	Key Analytical Poin
Gender	Women	Prefer safe, well-lit, high-quality environments; sensitive to street lighting, visibility, and access to green spaces.	More leisure-oriented and neighborhood-based activities in pleasant and safe settings.	Greater psychological and social well-being gains in high-quality environments.	Safety and environmental aesthetics strongly shape women's activity and health.
	Men	More influenced by facility density, street connectivity, and transport conditions.	Higher proportion of commuting and functional physical activity.	Stronger cardiometabolic benefits from utilitarian and commuting activities.	Men respond more to transport-related buil environment features
Age	Young Adults	Use a wider activity radius; rely heavily on citywide transport and public facilities.	High activity frequency and diverse activity types (commuting, leisure, sport).	Benefit when transport systems and public facilities support extensive mobility.	Activity space is large and shaped by regional-scale infrastructure.
	Older Adults	Prefer neighborhood-scale, barrier-free, quiet, and green environments; sensitive to walkability and micro-scale features.	Predominantly low- to moderate-intensity walking and neighborhood activities.	Significant physical and psychological gains from walkable, green, accessible local environments.	Highly dependent on micro-scale walkabilit and accessibility.
Socioeconomic Status (SES)	Low SES	More likely to live in areas with lower environmental quality, fewer facilities, and limited service accessibility.	Constrained physical activity opportunities; less participation in leisure-time PA.	Higher chronic disease risks due to low-quality environments and limited activity opportunities.	SES restricts "health-supportive spatial opportunities."
	High SES	Greater access to high-quality residential and recreational environments.	Higher participation in leisure and restorative activities (parks, gyms, green spaces).	Greater psychological, social, and restorative health benefits.	SES enables more discretionary and health-enhancing activity patterns.

Table 2. Sociodemographic Differences in Built Environment Perception, Physical Activity Patterns, and Health Effects. Source: Author's illustration.

3. Research Methods and Technical Pathways

3.1. Data Acquisition and Processing Techniques

This study constructs a comprehensive data system encompassing the built environment, physical activity, and residents' health (as summarized in Table 3). The processes of data collection and processing adhere to the principles of multi-source integration, scale matching, and quality control.

Data type	Main sources & spatial scales	Processing & key indicators	Role in BE–PA–Health framework
Built environment data	Coverage across three scales: macro, meso and micro. Macro/meso data mainly from land-use datasets, remote sensing imagery and open-source maps.	At macro/meso scales, compute density, land-use mix, street network configuration, and accessibility of public service facilities, with emphasis on standardising spatial units and accurate geocoding. At micro scale, use street-view imagery and on-site audits combined with deep learning to quantify human-scale indicators such as street greenery, openness and façade continuity.	Provides multi-scale structural and perceptual measures of the built environment, enabling consistent quantification of urban form and human-scale spatial quality.
Physical activity data	Collected through combined subjective (e.g. surveys) and objective methods, and classified by activity type (transport-related, leisure-related, etc.).	All activity is converted to a unified unit using METs. Preprocessing includes outlier removal, missing-value imputation and indicator normalisation, followed by WHO-based activity level classification. Data are then spatiotemporally matched with built environment indicators.	Captures type- and intensity-specific physical activity patterns and links them to built environment characteristics in a comparable multi-scale analytical framework.
Residents' health data	Cover three dimensions: physical, psychological and social health. Sourced from public health databases, health surveys and medical examination records.	Physical health (e.g. BMI, blood pressure, blood glucose) and psychological health (e.g. anxiety, depression, subjective well-being) are preprocessed via missing-value treatment, outlier adjustment and reliability–validity testing. Continuous variables are standardised; categorical variables are dummy-coded; temporal and spatial dimensions are aligned across datasets.	Provides multidimensional health outcome measures that are comparable across individuals and over space–time, forming the dependent variables in the BE–PA–Health analysis.

Table 3. Data Types, Sources and Processing in the BE-PA-Health Framework. Source: Author's illustration.

3.2. Indicator System Development and Quantification

To empirically examine how the built environment, physical activity and residents' health are linked in sequence, this study constructs a multidimensional, multi-scale indicator system that balances theoretical guidance with what can be observed in available data (as summarized in Table 4). In line with the core dimensions of the theoretical framework, the built environment is divided into macro-, meso- and micro-level spatial scales; physical activity is grouped by dominant type, such as transport-related and leisure-related behaviours; and residents' health is described along physical, psychological and social dimensions.

The indicator system is designed to remain faithful to these concepts while still being workable in empirical analysis. Each core variable is translated into concrete indicators that capture its intended meaning and can be measured with sufficient precision and compared across scales. This provides a common measurement basis for the subsequent quantitative models and for testing the proposed chain linking the built environment, physical activity and health outcomes.

BE Indicators		Physical Activity Metrics		Physical Health Indicators	
Macro Scale	Residential Density	**Streetscape Aesthetic Quality**	Proportion of Active Commuting (by Walking/ Cycling)	**Physical Health Indicators**	BMI
	Employment Density		Daily Travel Time Spent on Walking/Cycling		Blood Pressure
	Land-use Mix		Walking/Cycling Distance for Trips		Blood Glucose
Meso Scale	Street Connectivity	**Household and Recreational Activities**	Time Spent on Household Chores / Leisure Walking or Running	**Mental Health**	Depression
	Public Transport Accessibility		Exercise Frequency		Anxiety
	Walkability and Cyclability Network Density		Frequency of Park/Sports Facility Use		Life Satisfaction
	Neighborhood Green Space Ratio		METs of Household and Recreational Activities		Attention / Concentration
Micro Scale	Green View Index	**Occupational Activities**	Daily Sedentary Time	**Social Health**	Interpersonal Trust and Perceived Social Support
	Sidewalk Width		MVPA		Frequency of Social Participation / Social Engagement Frequency
	Street Wall Continuity		Duration of Physical Activity		Activities of Daily Living (ADLs)
	Streetscape Aesthetic Quality		METs of Occupational Activities		Community Cohesion / Neighborhood Cohesion

Table 4. Multi-Level Analytical Framework Linking Built Environment, Physical Activity and Health. Source: Author's illustration.

3.3. Mechanism Exploration and Validation

In empirical studies of the built environment and health, mediation analysis has become a central way to open up the processes that connect the two. Choosing analytical tools that fit the research question, data structure and strength of causal claims is therefore a key step. Within this framework, the methodological basis extends from simple mediation checks to more advanced models that can accommodate complex mechanisms and support more rigorous causal interpretation.

Traditional regression-based approaches-such as the causal-step procedure and the Sobel test-tend to have low statistical power and depend strongly on distributional assumptions. As a result, they have been gradually replaced by Bootstrap methods, which build confidence intervals for mediation effects via repeated resampling, relax normality assumptions and usually yield more stable estimates.

The Structural Equation Model (SEM) provides an integrated setting for complex mediation analysis, allowing simultaneous estimation of multiple mediation paths and explicit treatment of latent variables. Its multilevel extension, the Multilevel Structural Equation Model (MSEM), further addresses nested data structures and enables multi-scale mechanism analysis. Within the built environment-physical activity-health framework, SEM can be used to test commuting, leisure and other types of physical activity as mediators in one model while adjusting for confounders, and MSEM can separate mediation effects at both individual and neighbourhood or community levels.

To move beyond the causal inference constraints of cross-sectional designs, longitudinal models-such as the Latent Growth Model (LGM) and formal causal mediation frameworks-have been increasingly employed. These models capture how changes in environmental conditions shape health trajectories over time through physical activity. At the same time, advanced mediation specifications-such as parallel multiple mediation, chain mediation and moderated mediation-improve the capacity to detect and interpret heterogeneity across different pathways and population subgroups.

More recently, the combination of machine learning and causal inference, together with high-resolution spatiotemporal data from wearable and smart devices, has pushed mediation models in a more dynamic direction. These developments create new possibilities for examining complex, nonlinear routes through which the built environment may affect health outcomes.

Taken together, this expanding methodological toolkit not only offers diverse options for assessing the mediating role of physical activity in the built environment–health relationship, but also supports a shift from merely verifying the presence of mediation toward a more detailed and dynamic exploration of how, when and for whom these mechanisms operate.

4. Application pathways and contextual limitations of the research framework

4.1. Health intervention pathways of the framework

The integration of urban built environment intervention pathways seeks to turn the theoretical framework and empirical results into concrete strategies for spatial planning and health promotion, so that insights on mechanisms can inform practical optimisation. In this perspective, effective spatial interventions should work in three directions at the same time: increasing the frequency and intensity of residents' physical activity, lowering exposure to adverse health risks, and providing supportive external conditions for healthy

behaviour through improvements in environmental quality and functional layout. On this basis, the intervention pathways can be broadly summarized into the following four dimensions:

(1) Health risk exposure control.

By adjusting urban spatial structure and functional organisation, it is possible to reduce how often and how intensely residents are exposed to harmful environmental factors. Typical measures include reshaping the transport network and road cross-section design to curb vehicular traffic intensity and exhaust exposure; installing buffer greenbelts, noise barriers and low-noise pavements to attenuate acoustic pollution; and strengthening ventilation corridors and green infrastructure to improve air circulation and thermal comfort. Taken together, such interventions help to alleviate the physiological and psychological burdens associated with adverse environmental exposure.

(2) Targeted interventions for key populations.

Environmental health improvement strategies need to respond to the differentiated needs and vulnerabilities of groups defined by gender, age, occupation or health status. Examples include creating low-gradient, highly safe pedestrian systems with nearby community activity spaces for older adults; providing barrier-free, functionally diverse outdoor play areas for children; and designing low-intensity yet well-connected rehabilitation trails and green networks for people living with chronic conditions. These targeted arrangements improve both the feasibility and safety of physical activity for different population groups.

(3) Optimization of health resource allocation.

Health-supportive facilities-such as medical institutions, fitness venues, green spaces and parks-should be spatially arranged in ways that improve accessibility and convenience in daily life. Through mixed land-use patterns and public transport-oriented development, the travel time and monetary costs associated with reaching health resources can be reduced. This, in turn, helps to advance spatial equity and inclusiveness in the provision of urban health services.

(4) Promotion and guidance of healthy behaviors.

Well-designed public spaces and urban landscapes can actively encourage residents to move more. Continuous, well-connected and visually appealing walking and cycling networks, combined with adequate greenery and resting points, enhance comfort and make active travel more attractive. At the community scale, shaping a supportive social and recreational atmosphere-through the provision of activity centres, fitness facilities and cultural squares-and combining this with public education and digital health management platforms can guide residents toward more stable, self-reinforcing healthy lifestyles.

4.2. Applicability and Boundaries of the Framework

The research framework proposed in this study shows considerable flexibility and can be adapted to different spatial scales and fields of application. At the micro, community scale, it can be used to examine how local features-such as street layouts within communities, the organisation of public spaces, and the distribution of sports and recreational facilities-shape residents' everyday physical activity and their overall health status. At the meso, neighbourhood scale, the framework helps analyse how street connectivity, non-motorised travel choices and activity patterns. At the macro, citywide scale, it supports more comprehensive assessments of how the urban functional structure, land-use mix, public transport systems

and green infrastructure together affect health outcomes at the population level. In practical terms, the framework is especially suitable for health impact assessments (HIA) in urban renewal projects, the retrofitting of walking and cycling systems, and the optimisation of urban green-space networks. It also offers a methodological and data basis for healthy city programmes, the design of public policies, and interdisciplinary work at the intersection of urban planning, public health and data science.

However, the applicability of this framework is subject to certain limitations. First, its analytical validity relies on the availability of multi-scale, high-resolution spatial data and health survey data; data incompleteness or poor data quality may undermine the robustness of the findings. Second, the framework is primarily designed to capture the mediating role of physical activity in linking the built environment and health, and thus offers limited explanatory power for non-physical pathways such as psychosocial factors and genetic influences. In addition, under conditions of extreme climate events or rapid urban transformation, the relatively stable relationship between the built environment and health may be substantially disrupted.

5. Conclusion

This study systematically examines the complex relationships among the urban built environment, physical activity, and residents' health, and proposes a "multi-scale–multi-pathway–multi-group" framework to elucidate the mechanisms through which the built environment influences health via different types of physical activity. The framework encompasses spatial scales ranging from macro to micro levels, differentiates behavioral pathways such as commuting and leisure activities, and incorporates sociodemographic heterogeneity at the population level. By integrating multi-source data and quantitative indicators, and employing a range of statistical approaches—including regression analysis, structural equation modeling, and causal inference—the framework is underpinned by a robust methodological foundation for empirical application. On this basis, it not only provides multi-level health intervention strategies for healthy urban planning, but also offers a solid theoretical basis for precision health interventions. Future research may further promote deeper interdisciplinary integration, advance dynamic monitoring and precision intervention methods, and test the applicability of the framework across diverse regional and cultural contexts. In doing so, it can support the evolution of built environment and health research toward a more systematic, precise, and inclusive direction, thereby providing stronger evidence for healthy city development.

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6. References

Basner, M., Babisch, W., Davis, A. et al. (2014) 'Auditory and non-auditory effects of noise on health', *The Lancet,* 383(9925), pp. 1325–1332.

Brook, R.D., Rajagopalan, S., Pope, C.A. et al. (2010) 'Particulate matter air pollution and cardiovascular di sease: an update to the scientific statement from the American Heart Association', Circulation, 12 1(21), pp. 2331–2378.

Cao, Y., Zhen, F. and Jiang, Y. (2019) 'A research framework on the relationship between urban built envir onment and residents' health from the perspective of activity', Scientia Geographica Sinica, 39(10), pp. 1612–1620.

Ding, D., Sallis, J.F., Kerr, J., Lee, S. and Rosenberg, D.E. (2023) 'Walkability and urban built environments- a systematic review of health impact assessments (HIA)', *BMC Public Health*, 23, Article 518.

Diez Roux, A.V. (2012) 'Conceptual approaches to the study of health disparities', *Annual Review of Public Health*, 33, pp. 41–58.

Gebel, K., Bauman, A. and Owen, N. (2009) 'Correlates of non-concordance between perceived and object ive measures of walkability', *Annals of Behavioral Medicine*, 37(2), pp. 229–238.

Lee, I-M., Shiroma, E.J., Lobelo, F., Puska, P., Blair, S.N. and Katzmarzyk, P.T. (2012) 'Effect of physical inac tivity on major non-communicable diseases worldwide: an analysis of burden of disease and life e xpectancy', *The Lancet*, 380(9838), pp. 219–229.

Li, D. and Bou-Zeid, E. (2013) 'Synergistic interaction between urban heat island and heat waves: the impa ct in cities is larger than the sum of its parts', *Journal of Applied Meteorology and Climatology*, 52 (9), pp. 2051–2064.

Li, J., Zhuang, J., Chen, P. et al. (2023) 'China trends in physical inactivity from 2013 to 2019: an analysis of 4.23 million participants', *Medicine & Science in Sports & Exercise*, 55 (12), pp. 2189–2197.

Li, M., Li, Y., Liu, Z., Hystad, P., Rangarajan, S., Tse, L.A., Lear, S.A., Ma, Y., Chen, M., Han, G., Li, R., Yusuf, S ., Liu, L., Hu, B. and Li, W. (2024) 'Associations of perceived built environment characteristics usin g NEWS questionnaires with all-cause mortality and major cardiovascular diseases: The prospecti ve urban rural epidemiology (PURE)-China study', *Environment International*, 187, Article 10862

Maharana, A. and Nsoesie, E.O. (2017) 'Using deep learning to examine the association between the built environment and neighbourhood adult obesity prevalence', International Journal of Health Geogr aphics, 16, Article 1. [online]. Available at: https://doi.org/10.1186/s12942-017-0106-8 (Accessed : 10 September 2024).

Mooney, S., Hughes, C. and O'Neill, M.S. (2022) 'The role of built environments on physical activity and he alth promotion: a review and policy insights', *International Journal of Environmental Research an d Public Health*, 19(3), pp. 1234–1256.

Nguyen, Q.C., Belnap, T., Dwivedi, P., Deligani, A.H.N., Kumar, A., Li, D., Whitaker, R., Keralis, J., Mane, H., Yue, X. and Nguyen, T.T. (2022) 'Google Street View images as predictors of patient health outco mes, 2017–2019', *Big Data & Cognitive Computing*, 6(1), 15.

Wang, B. (2025) 'Global and Chinese obesity epidemiology: current status and trends', Chinese Journal of Bases and Clinics in General Surgery, 32(6), pp. 661–668.

World Health Organization (2018) Physical activity fact sheet. [online]. Available at: https://www.who.int/news-room/fact-sheets/detail/physical-activity (Accessed: 10 September 2024).

World Health Organization (2024) 'Guidance on environmental noise'. [online]. Available at: https://www.who.int/tools/compendium-on-health-and-environment/environmental-noise (Accessed: 10 September 2024).

World Health Organization (WHO) (2025) Urban health fact sheet, 19 March. [online]. Available at: https://www.who.int/news-room/fact-sheets/detail/urban-health (Accessed: 10 September 2025).

Zhang, T., Huang, R., Yang, M., Lin, G., Ma, X. and Huang, Q. (2023) 'Perceptions of the health risk from hot days and the cooling effect of urban green spaces: a case study in Xi'an, China', *Frontiers in Public Health*, 11, Article 1211164.

Zhang, Y., Deng, W., Zhao, L. and Li, M. (2020) 'How does the urban built environment influence residents' physical health? Mediation mechanisms and empirical tests', Geographical Research, 39(4), pp. 822–835.

Zhong, J., Liu, W., Niu, B., Lin, X. and Deng, Y. (2022) 'Role of built environments on physical activity and health promotion: a review and policy insights', *Frontiers in Public Health*, 10, Article 950348.