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Spatial Disparity of Sports Infrastructure Development and Urbanization Determinants in China: Evidence from the Sixth National Sports Venues Census

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Abstract

The improvement of well-being of residents is the core of the people-centred urbanization. Inhabitants' emphasis on healthy lifestyle draws attention to the provision of sports infrastructure. However, the spatial pattern of sport infrastructure development and in particular the driving forces from urbanization across China have not been examined yet in the literature. This paper aims to explore how the national sports infrastructure in mainland China is driven and scaled by urbanization, using data from the sixth National Sports Venues Census and a multi-scale geographically weighted regression approach. The results revealed strong regional inequality in the development of sports infrastructure in the stage of accelerating urbanization in China, with better provision of sports infrastructure in eastern than in western regions. The three dimensions of urbanization (urban population, public financial expenditure and built-up area) significantly explained the spatial disparity between 289 cities at prefecture-city level. There should be a feedback loop between the accumulative developments of urbanization and sports infrastructure. The contributing driving forces and subsequent regional heterogeneity suggest that sports space theory, the inequality amplification model, and hysteresis effect are comparatively suitable for explaining the spatial inequality characteristics of sports infrastructure development in China. A Sport Inequality Alert was conceptualized as a policy instrument for monitoring regional inequality and governing the development of sports infrastructure. It is argued that sports infrastructure development should be integrated into the national strategy for sustainable New-type Urbanization.

Keywords Sports infrastructure development · Urbanization · Regional inequality · Spatial heterogeneity · Sport Inequality Alert

Extended author information available on the last page of the article

Introduction

Sports infrastructure, as a type of public service provision, has gained growing prominence in contemporary society (Hadi Nassr & Ghazi Al-Neaimi, 2021; Nagy & Tobak, 2015). It exerts a multifaceted influence on urban development, encompassing economic, social, and environmental dimensions (Bai et al., 2014), thereby shaping the city's holistic advancement. The availability of ample and diverse sports infrastructure is deemed highly imperative. Small and medium-scale sports facilities and spaces are directed towards guaranteeing ample opportunities for residents to engage in physical exercises and social activities (Xiong, 2007). Large-scale sports arenas, exemplified by the Olympic Stadium in Beijing and the Football in Manchester, can strategically employ the hosting of various international or national sport events to encourage investments in foundational infrastructure, elevate the city's image, attract sports enthusiasts, and consequently invigorate urban economic growth (Chen et al., 2021; Gratton et al., 2005; Humphreys & Zhou, 2015). The spatial pattern of sports infrastructure at the national scale is shaped by multiple factors including investment, urbanization, local culture and even climate. Generally, areas with higher levels of urbanization, economic development, and larger populations have a bigger and more dense sports infrastructure, which can provide better spatial and social accessibility to sports facilities, and vice versa (Burillo et al., 2011; Xiong, 2007). Urbanization plays a crucial role in driving and sustaining the supply and demand of sports infrastructure, but the spatial heterogeneity of its impact across a whole country are rarely studied, particularly in developing countries, such as China (Hidalgo Martinez, 2021; Hoekman et al., 2016; Wang & Wang, 2020).

China has experienced a rapid rate of urbanization since economic reform was introduced in 1978. Since 2012, China has entered the new-type urbanization stage, and providing high-quality public services and infrastructure for inhabitants has become one of the central strategy of development (Chen et al., 2017). Increasing public awareness of the health benefits of physical exercise have led to increasing demand for more high-quality sports facilities (Dai et al., 2022; Kohe et al., 2022; Yan et al., 2021; Yang et al., 2018). Simultaneously, construction and renovation of sports infrastructure has been recognized as a sport-driven competitive strategy for promoting a city's image and attracting a variety of investments. For example, Shanghai has been striving to develop "a world-known sport city" to "truly transform the 'hard' sport facilities into 'soft' power of the city" (Notice of general office of Shanghai Municipal People's Government on issuing the outline for developing Shanghai as a world-known sports city, 2021; Xue & Mason, 2019). In China, national physical fitness has elevated to the status of a strategic objective. The government has introduced a range of fitness-for-all initiatives, including the Healthy China 2030 Planning Outline and National Fitness Regulations (*Government of the People's Republic of China*, 2016). To achieve collaboration, participation, and the shared benefits of sports infrastructure development, a development trajectory characterized by "led by the government, participated by private organizations and individuals" has emerged. This

has gradually led to the establishment of a popular national fitness network. Consequently, the prioritization of sports infrastructure development, with a focus on enhancing regional spatial equality and social equity, is being propelled by a dual approach: a top-down government-driven process and a bottom-up impetus rooted in public participation. The top-down process emphasizes government involvement in infrastructure planning and construction, as exemplified by projects like the Beijing Olympic Game Village. Conversely, the bottom-up approach involves public participation in the planning and governance of sports facilities, such as public playgrounds in residential neighborhoods. Integrating both processes into the formulation of local policies for sports infrastructure development contributes to the achievement of spatial equality and social equity objectives. To support the national development strategy and meet the tremendous inhabitants' requirements for improving physical health and social activity, it is imperative to understand the spatial pattern of national sports infrastructure at the city level and examine its relationship with urbanization, including any underlying spatial effects. This paper will generate data-driven evidence for national policy making from a large-scale national survey of sports infrastructure at city level. As the first study on this topic, this paper shows the spatial effects of multiple urbanization dimensions on sports infrastructure development. It also examines the spatial or regional inequalities that contribute to sports geography.

The rest of the paper is structured as follows. Section 2 reviews the relevant literature. Section 3 introduces data sources and quantitative methods. Section 4 presents the analytical results of multi-scale modelling of sports infrastructure development and urbanization in China. Section 5 provides a discussion of key findings with reference to urbanization and healthy China. Section 6 presents the main conclusions and outlines the limitations of the study.

Literature Review

Sports Infrastructure Development at Multiple Scales

After reviewing the interdependence between urbanization and sport development in USA and Britain in the 19-twentieth centuries, it was concluded that examining the role of urbanization on the development of sports remains an important undertaking (Friedman & Bustad, 2017). The development level of sports infrastructure, characterized by its scale, diversity and operation (Wicker et al., 2012) is not spatially balanced in many countries and cities (Wang & Wang, 2020). Its spatial inequality and disparity have been widely investigated in both developed and developing countries, such as the United Kingdom- (Higgs et al., 2015), France (Billaudeau et al., 2011), Iran (Dadashpoor et al., 2016), the Netherlands (Hoekman et al., 2016), and China (Zheng et al., 2018). These studies have shown that the spatial inequality of sports infrastructure can easily lead to unequal opportunities for residents to participate in physical exercise and activities, and may aggravate health inequalities between places and groups. Furthermore, the imbalance of urban competitiveness resulting from disparate capacities to host sports events, will adversely affect regional and

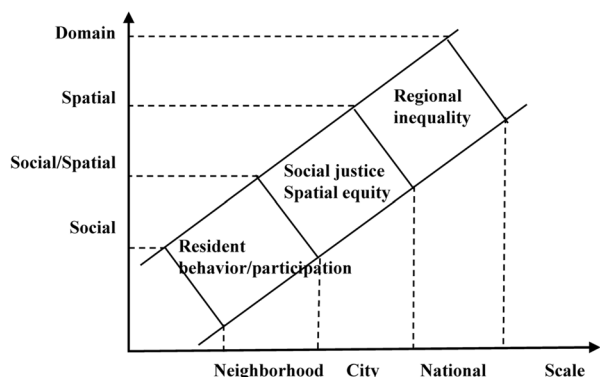
urban socio-economic development (Dadashpoor et al., 2016; Elmosé-Østerlund & Iversen, 2020; Gratton et al., 2005; Huang et al., 2014; Jáuregui et al., 2021).

The spatiotemporal characteristics and social impacts (including health) of sports infrastructure is a burgeoning field in sports and health geography, helped by new approaches, perspectives and evidence from analytical and empirical studies (Wise & Kohe, 2020). Sports infrastructure has been examined at a variety of spatial scales, ranging from national at the macro-scale, city at the meso-scale to neighborhood at the micro-scale (Ahmed et al., 2023), in relation to interdependent social challenges including inequality, equity and justice (Fig. 1). On a national scale, studies have focused on the spatial disparity of sports infrastructure supply, such as uneven spatial distribution, aiming to achieve spatial equalization (Hoekman et al., 2016; Khajoo et al., 2019). Zooming in on a city scale, spatial accessibility to sports infrastructure is frequently studied as a core indicator of social and spatial equity among different groups and neighborhoods (Asefi & Nosrati, 2020; Dadashpoor et al., 2016; Liu et al., 2009; Rabiei-Dastjerdi et al., 2018; Shen et al., 2020). At the neighborhood scale, studies have focused on social participation in physical exercises and activities, exploring various spatial and temporal constraints on residents' behavior (Chen et al., 2016; Halonen et al., 2015; Kawakami et al., 2011; Kokolakis et al., 2014; Pascual et al., 2007; Prins et al., 2012). Many studies have focused on sports infrastructure at city and neighborhood scales, particularly those in developed countries which have examined the topic from a social perspective (Bosch et al., 2020; Koch, 2016). Comparatively few studies have analyzed the factors influencing sports infrastructure from a spatial perspective at a national scale, particularly in developing countries. To some extent, the lack of studies on regional inequality at a national scale can be explained by the paucity of available data, particularly in fast growing countries where frequent surveys are difficult.

Sports Infrastructure Development and Urbanization

Spatial disparity of sports infrastructure development is influenced by multiple social, economic and environmental factors. Sports place theory, originating from the influential central place theory, asserts a positive correlation between the

Fig. 1 The relationship between spatial scale and sport infrastructure development



provision of sports infrastructure and the level of urbanization (Bale, 2002; Hoekman et al., 2016). Highly urbanized areas tend to have higher densities of urban residents and jobs. To meet the varying demands for sports participation, more land and investment are allocated to the construction of sports infrastructure in these areas. Therefore, these areas possess abundant and diverse sports service provisions, leading to higher levels of sports infrastructure development (Lamb et al., 2010). By contrast, sports infrastructure in less urbanized areas is usually characterized by low density and diversity due to insufficient provision, limited accessibility, and uneven spatial distribution (Pelletier et al., 2021; Zheng & An, 2015). As a result, public perception of sports resources is negative, as are attitudes to physical exercise participation. Related studies in Malaysia (Maassoumeh et al., 2010), China (Shen et al., 2020), Norway, and Denmark (Rafoss & Troelsen, 2010) have identified similar imbalances in the geographical distribution of sports infrastructure. However, other studies conducted in the United Kingdom (Lamb et al., 2010), the Netherlands (Hoekman et al., 2016), and Australia (Giles-Corti & Donovan, 2002) have shown that this spatial imbalance in sports infrastructure distribution is less pronounced. In these countries, there is even an inverse relationship between the extent of regional development and the level of sports infrastructure development. In simpler terms, less developed regions might possess a more supply of sports infrastructure. This phenomenon could arise from these countries adopting uniformly elevated standards for sports infrastructure allocation across all regions. Consequently, further research is warranted to explore how urbanization impacts the development of sports infrastructure across different countries and regions.

Urbanization, a complex and dynamic process, is characterized by multiple dimensions including population urbanization, land urbanization, economic urbanization and social urbanization (Chen, 2015; Chen et al., 2009; Zhao et al., 2022). Different dimensions have spatially varying effects on sports infrastructure development. For example, the process of urbanization has played an important role in the formation of modern sports, and in turn sports infrastructure has influenced the urbanization process to some extent through popularization and dissemination of its social benefits and impacts (Hidalgo Martinez, 2021). Urbanization significantly increases the size of the population, the structure of which determines the demand for various sporting activities (Daumann et al., 2015; Gast et al., 2007). Previous studies have also confirmed the inter-dependence between economic development and sports infrastructure development (Burillo et al., 2011; Hoekman et al., 2016; Kim et al., 2017; Panter et al., 2008). There is no doubt that economic advancement furnishes the required investment for sports infrastructure construction. The deprivation amplification model argues that residents in wealthier areas have better access to sports infrastructure than those in deprived areas (Hillsdon et al., 2007; Hoekman et al., 2016; Macintyre, 2007). Sports infrastructure development, particularly commercial sports facilities, can promote urban regeneration, boost tourism, stimulate the sports industry and improve the positive image of a city (Huang et al., 2014; Jones, 2001; Storm et al., 2020; Xue & Mason, 2019). As such, investment in sports facilities and infrastructure has been recognized as a catalyst of urban economic development and city redevelopment in developed countries (Chapin, 2004; Jakar et al., 2021). Many cities in Europe and America, such as Sheffield,

Manchester, Indianapolis, and Cleveland, have successfully used sport-related development strategies in their urban revitalization processes (Geffroy et al., 2021; Gratton et al., 2005). Lastly, the scarcity of land resources poses challenges in planning and constructing sports infrastructure in terms of quantity, types, and locations. In many cities, especially in rapidly urbanizing areas, land resources are prioritized for economically profitable sectors during allocation, while public-service-oriented sports infrastructure are often provided at lower standards. The selection of sites for commercial sports stadiums also considers affordable land prices and predictable profitability (Chapin, 1999; Do et al., 2021). Consequently, land utilization patterns may lead to an uneven spatial distribution of sports infrastructure.

In summary, the interdependence between sports infrastructure and urbanization has been widely studied in developed countries with high rates of urbanization. Relatively little is known about the interdependence, particularly the impacts of urbanization on sports infrastructure, in developing countries in the process of rapid urbanization, such as China. To address this gap, the impacts of urbanization level on the development level of sports infrastructure should be studied further to consider the dimensional and spatial heterogeneity mentioned above.

Data and Methods

Data Collection and Processing

Sports infrastructure refers to physical facilities and organizational construction used for sports activities such as training, competition and fitness and leisure (Hadi Nassr & Ghazi Al-Neaimi, 2021; Hallmann et al., 2012). It is crucial for contemporary cities to possess and enhance their sports infrastructure to meet the demands of sports activities. The data for this study were collected and processed from The Sixth National Sports Venues Census (NSVC) in China, compiled and released by the Sports Economics Department of the State Sports General Administration. The census was conducted on December 31, 2013, based on standard time, with its results published in 2015. This census, comprising data on sports facilities across cities of different hierarchical levels nationwide, includes 82 categories of sports facilities, ranging from outdoor fields (e.g., golf, football, tennis, school playgrounds, health trails) to indoor stadiums (e.g., martial arts, swimming pools, badminton, table tennis). The database reflects the developmental characteristics of sports facilities in various regions in 2013. It is the latest and most comprehensive database available, providing data for two aspects of this study: scale and structure, which measure the development index of sports infrastructure. The scale reflects the overall service capacity, that is, the total quantity of service capacity provided in each category of facility, including the number of facilities, facility area, floor area, land area, and total investment. The structure reflects the composition of sports infrastructure, that is, the ability to meet individual and diverse requirements, including facility diversity, utilization rate, and business model of sports facilities. A total of 289 cities at prefecture-level and above in mainland China, represented as polygon features, were included in this census, and this defines the spatial level and scale of this study. From

the meso-level of city analysis, geographical characteristics such as terrain have no obvious influence on the demand for sports facilities. Therefore, this study excluded the consideration of geographical characteristics' impact. An entropy method was used to quantify the index of sports infrastructure development (Table 1).

The index of utilization rate is measured using Eq. 1 (note 1):

$$U = \frac{0.5b + c}{a + b + c} \times 100\% \quad (1)$$

where U is the utilization rate, a is the number of exclusive sports facilities (e.g., facilities for internal staff members, professional groups or special purposes only), b is the number of sports facilities partially open to the public (e.g. some university and school facilities open to the public only on weekends and holidays), c is the number of sports facilities fully open (more than 8 h.) to the public (e.g., fitness equipment in parks and neighborhoods).

The index of the business model is measured using Eq. 2 (note 2):

$$D = 1 - \sum_{i=1}^i \left(\frac{N_i}{N} \right)^2 \quad (2)$$

where D is the Simpson index, N_i is the number of the i -th sample category; and N is the number of samples.

Independent operation refers to the management of sports venue directly by its owner. Entrusted operation means management by agents rather than the owner. Cooperative operation refers to joint management by the owner and other partners based on contractual agreements (note 3).

Urbanization is a concentrated embodiment of human socio-economic activities. Numerous Chinese scholars commonly measure urbanization through the lenses of demographic, economic and land utilization (Liu et al., 2021; Zhao et al., 2017). In light of this, three indicators—population-urbanization rate (the proportion of permanent urban residents in the total population), public financial expenditure and urban built-up area—were selected to comprehensively reflect the triad of urbanization dimensions: population, economy and land. Urbanization data were collected and processed from the China City Statistical Yearbook (Urban Social and Economic Survey Department of the National Bureau of Statistics of China, 2014). Socio-economic development data from 2013 were extracted from an annual statistical publication. After checking the data quality (i.e., the match between the two censuses), a total of 289 cities were selected for further analysis and statistical modelling. The spatial distributions of the three indicators are shown in Fig. 2.

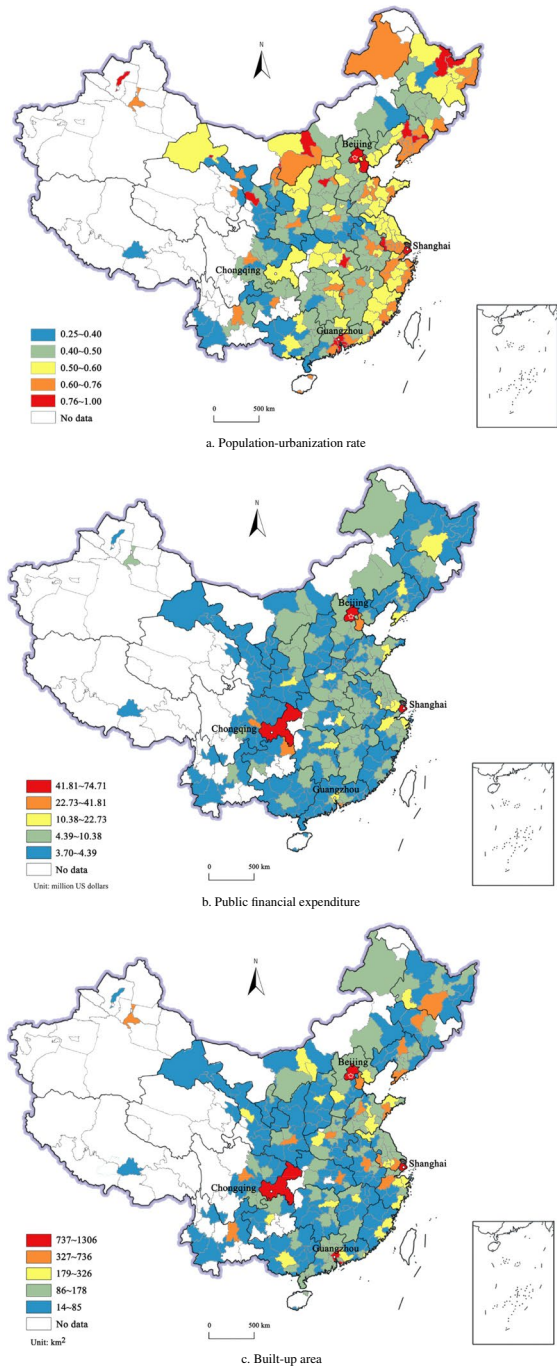
Entropy Based Assessment

In this paper, an entropy method was used to calculate the weights of all the indicators of the development index of sports infrastructure at the national scale (Li & Li, 2014; Zhou et al., 2019). By using the calculated weights between all the chosen indicators, an overall assessment of sports infrastructure development level

Table 1 The indicators and their weights for assessing the development level of sports infrastructure

Dimension	Index	Description	Weights
Scale	Number of facilities	Total number of sports facilities	0.0806
	Facility area	Effective area for training, competition and fitness activities	0.0937
	Floor area	Area of indoor sports venues and ancillary facilities	0.2234
	Land area	The land area covered by sports venues includes the area of ancillary facilities, roads, parking, green belts, etc	0.1965
	Investment amount	Total investment in sports venues	0.0113
Structure	Facility diversity	It reflects the structural differences of sports infrastructure. It is characterized by richness, that is, the number of categories of sports venues	0.0163
	Utilization rate ¹	Residents' temporal access to sports facilities. The openness to the public includes exclusive (a), partial opening (b) and all-day opening (c)	0.2644
	Business model ²	Diversity and flexibility of sports infrastructure business models. The operation model includes independent operation, entrusted operation and cooperative operation ³	0.1139

Fig. 2 Spatial distribution of three urbanization dimensions across major Chinese cities



was conducted for all cities selected using a linear summation method. Before this assessment, all the indicators were standardized or normalized into the range [0–1] using the simple linear method in Eq. 3.

(1) Normalization method

$$X_{ij}' = \frac{X_{ij} - \min[X_j]}{\max[X_j] - \min[X_j]} \quad (3)$$

(2) Entropy method

$$e_j = -k \sum_{i=1}^m (Y_{ij} \times \ln Y_{ij}), k = \frac{1}{\ln m}, Y_{ij} = \frac{X_{ij}'}{\sum_{i=1}^m X_{ij}'} \quad (4)$$

$$w_j = \frac{d_j}{\sum_{j=1}^n d_j}, d_i = 1 - e_j \quad (5)$$

(3) Development level index

$$S_i = \sum_{j=1}^n (w_j \times X_{ij}') \quad (6)$$

where, X_{ij} is the value of the j -th index of the i -th city, X_j is the value of the j -th index, X_{ij}' is the standardized value of the j -th index of the i -th city, e_j is the information entropy of the j -th index, m is the number of cities, n is the index number, Y_{ij} is the proportion of the i -th city in the j -th index, W_j is the weight of the j -index, d_i is the redundancy of the information entropy of the j -th index, which represents the degree of difference between all the schemes under the j -th index, and S_i is the score of integral assessment of sports facility development in the i -th city.

MGWR Model

The spatial effects of urbanization on the development level of sports infrastructure were explored using multiple stepwise regression and Multiscale Geographically Weighted Regression (MGWR) methods. MGWR, an extension of classical GWR, provides valuable information about the scale at which different processes operate by calibrating bandwidth values between all explanatory variables (Fotheringham et al., 2017). A calibrated model with optimal bandwidths can accurately depict spatial non-stationarity at varying spatial scales (Murakami et al., 2019). The generic formula of MGWR is denoted as follows (Eq. 7):

$$y_i = \sum_{j=0}^k \beta_{bwj}(u_i, v_i) x_{ij} + \varepsilon_i \quad (7)$$

where, y_i is the sports infrastructure development level, bw_j is the bandwidth value calibrated for the j -th local relationship, $\beta_{bwj}(u_i, v_i)$ is the j -th coefficient

corresponding to location (u_i, v_i) , X_{ij} is the j -th variable at location (u_i, v_i) that affects the development level of sports infrastructure, ε_i is the normally distributed error term. Several socio-economic and environmental variables reflecting different dimensions of urbanization were also created as explanatory variables. The statistical and computational processes of MWGR are explained in Fotheringham et al. (2017) (Fotheringham et al., 2017) and Oshan et al. (2019) (Oshan et al., 2019).

MGWR has been widely used to analyse regional inequality at national scales (e.g. Ansong et al., 2015). The freeware package MGWR 2.2 (<https://sgsup.asu.edu/sparc/multiscale-gwr>) was used to create the model (Oshan et al., 2019).

Results

The Development Level of Sports Infrastructure

The spatial distribution of sports infrastructure development at the city level, as depicted in Fig. 3, shows uneven development. Its spatial pattern shows a belt-like distribution centered on first-tier cities such as Beijing, Shanghai, and Guangzhou in the eastern coastal region. Sparse development of sports infrastructure dominates in the less-developed western regions, except for Chongqing. Chongqing designated as the youngest centrally-administered municipality in 1997, has consistently received increasing policy and financial support (Bao et al., 2019). Consequently, its sports infrastructure has experienced rapid development, progressively closing the gap with cities in the eastern regions. Nationally, there is

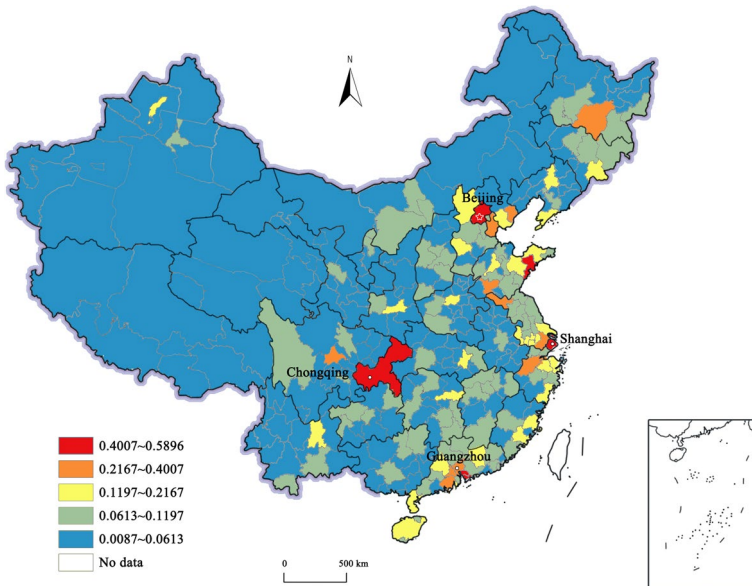


Fig. 3 Spatial distribution of the sports infrastructure development index

a stepwise decline in the level of sports infrastructure development from east to west. Besides the spatial disparity among cities across the country, there exists also a strong disparity within provinces, with better development in provincial capital cities than other cities. Guangdong province, Fujian province and most of the central and western regions exemplify these disparities. In other areas, such as the eastern coastal regions (e.g., Zhejiang, Shandong and Jiangsu) and the western regions (e.g., Qinghai, Tibet and Gansu), sports infrastructure development exhibits a more equitable distribution. However, the connotations of this even distribution differ. The former showcases a high-density even distribution, while the latter displays a low-density even distribution of sports facilities.

The spatial pattern of sports infrastructure was further analyzed using global and local Moran I analysis within Geoda. The Moran's I index was 0.08, with a corresponding p-value nearly approaching 0, indicating that the overall spatial distribution of sports infrastructure was significantly clustered at the national scale. Local indicators of spatial association (LISA) analysis showed the existence of clusters, predominantly hot spots (H–H), in the economically affluent eastern regions. These regions encompassed three urban agglomerations: the Pearl River delta, the Yangtze River delta, and Beijing-Tianjin-Hebei. Conversely, cold spots (L–L) were observed in the economically deprived western regions (Fig. 4). It was clear that over the past few decades (1978–2013), the disparities in economic development and urbanization between the eastern and western regions have played a significant role in shaping the spatial pattern of sports infrastructure. As a result, it is plausible to form a hypothesis that there exists a spatial correlation between sports infrastructure development and urbanization (Zhao et al., 2022).



Fig. 4 Clusters of sports infrastructure development at city level

To test this hypothesis, MGWR models were constructed using different dimensions of urbanization in China from 2013.

MGWR Modelling

Based on a pre-formed hypothesis, four variables were used to develop the MGWR models. The integral assessment score of sports infrastructure development was used as the dependent variable (Fig. 3). Population-urbanization rate, public financial expenditure, and built-up area were used as the three explanatory variables as they reflect the demand for, supply of and constraints on urbanization respectively (Fig. 2). Population-urbanization rate and built-up area were log transformed to achieve a normal distribution. As shown in Fig. 4, the sports infrastructure development score exhibits a degree of spatial dependence across the country. MGWR was used to model the spatial relationships between the sports infrastructure development score and the three dimensions of urbanization. The resulting spatial effects (spatial dependence and heterogeneity) were used to improve model efficiency and reduce calibration bias. When running the MGWR model, coefficients were standardized so the relative contribution of each explanatory variable could be evaluated, and adaptive bandwidth was selected.

The adjusted R^2 of the MGWR model was 0.726, the AIC value was 477.206, and the local R^2 values of 93% cities were greater than 0.65 (Table 2). Nearly 73% of the variance of the sports infrastructure development score can be explained by the MGWR model, indicating a good model performance, even with only three explanatory variables. The results of the MGWR regression analysis showed that the three dimensions of urbanization have a strong explanatory power for the spatial pattern of urban sports infrastructure development.

The regression coefficients of population-urbanization rate, public financial expenditure and built-up area were all positive (from 0.086 to 0.721), indicating that the three dimensions of urbanization positively contributed to sports infrastructure development at the national scale. Population-urbanization rate had the weakest contribution and public financial expenditure the strongest. This means investment in sports infrastructure is the largest driving force. Population-urbanization rate and

Table 2 Summary statistics for MGWR parameter estimates

Variable	Mean	STD	Min	Median	Max	Bandwidth	<i>t</i> statistic
Population-urbanization rate	0.114	0.012	0.086	0.117	0.142	288	289
Public financial expenditure	0.455	0.129	0.152	0.487	0.721	81	288
Built-up area	0.344	0.067	0.234	0.327	0.485	200	242
Diagnostic index	Residual sum of squares	Effective number of parameters	AIC	AICc	R^2	Adj. R^2	Local R^2
Value of diagnostic index	70.505	31.381	477.206	485.663	0.756	0.726	0.62–0.88

urban built-up area indicate long-term accumulative contributions to sports infrastructure development in terms of development demand and constraints. By contrast, public financial expenditure is a dynamic variable, that represents opportunities to develop new sports infrastructure. The power of MGWR, compared with traditional GWR (Cheng & Fotheringham, 2013), is the ability to calibrate the bandwidth of each explanatory variable. In this study, both Population-urbanization rate and built-up area had larger bandwidth values, 288 and 200 respectively, which corresponded to 99.65% and 69.20% of all sampled cities. This indicates that Population-urbanization rate has a near stationary impact on sports infrastructure development nationally (i.e., its standard deviation is also the smallest, only 0.012). This stationary effect might be influenced by the long-term accumulative process of urbanization from 1978 to 2013. It also indicates a consistent pattern in social demand for sport facilities across all cities. By contrast, public financial expenditure had a very small bandwidth of only 81, corresponding to 28.03% of all sampled cities, and exhibits non-stationarity. It also had the largest standard deviation of 0.129. Such geographical variability might be affected by the heterogeneous local decision-making process of sports facility development in each city. Overall, the results have proved the scaling effect of urbanization on sports infrastructure development, as reflected by the varying bandwidth values.

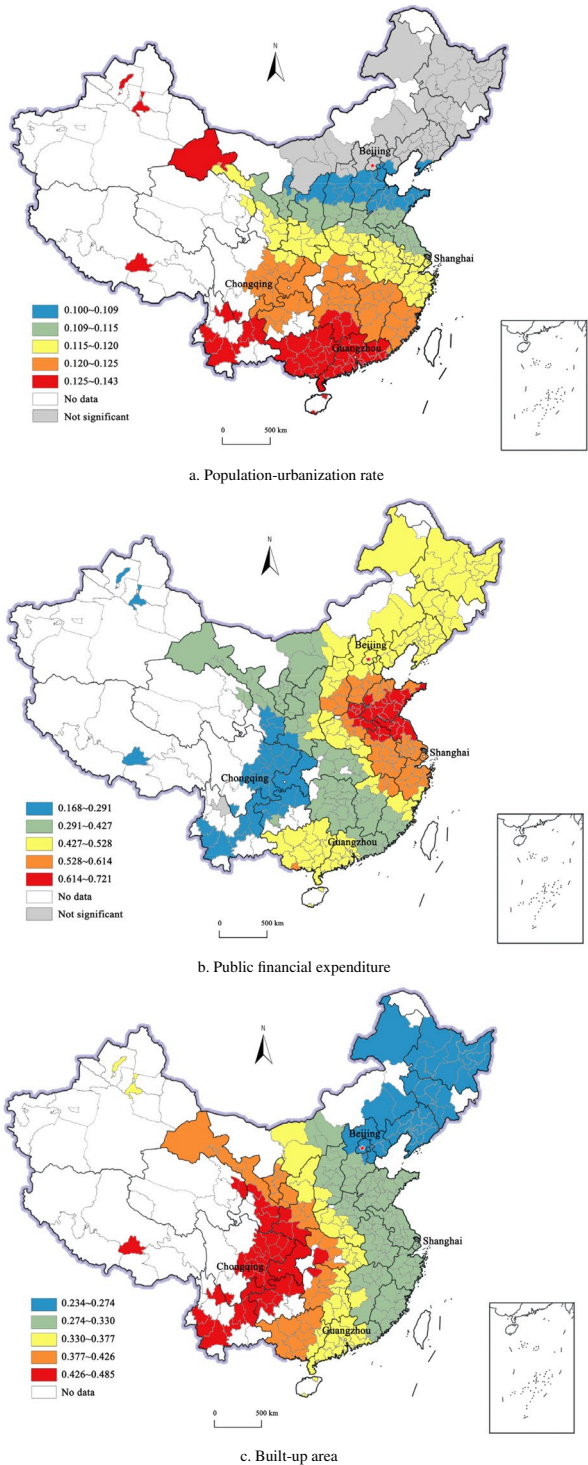
Spatial Heterogeneity of Driving Forces

To interpret the spatial non-stationarity and its spatial scale, the spatial distributions of regression coefficients were mapped for all cities with a t-statistic greater than 1.96, corresponding roughly to 5% significance level (Fig. 5).

The population-urbanization rate in 83.7% of cities showed a significant positive contribution to sports infrastructure development. This suggests the increase in the population-urbanization rate in these cities created demand-driven development of sports infrastructure. The population-urbanization rate did not contribute to sports infrastructure development in north-eastern cities. The degree to which the population-urbanization rate contributes to sports infrastructure development shows a decreasing trend from south to north (Fig. 5 a), with high-value cities in the southern region but with low-value cities in the Bohai Rim region. Urban populations in north-eastern cities have shrunk as an increasing number of residents migrated to southern China after China's reform and opening-up (Yang & Dunford, 2018). The number and scale of declining cities has increased significantly since 2000 (Guan et al., 2021).

Public financial expenditure can measure the government's administrative ability and regulatory capacity, and it can be used to represent economic urbanization (Deng & Zhong, 2023; Liu et al., 2015). The results indicate that public financial expenditure made a significant positive contribution to sports infrastructure development in 99.7% of the cities. As urbanization has led to greater emphasis on public service infrastructures (He & Zhang, 2022), the increase in public financial expenditure had stimulated the supply-driven development of sports facilities and infrastructure. The spatial distribution of its influence showed a decreasing trend from east

Fig. 5 The spatial distribution of localized regression coefficients of urbanization driving forces



to west, with high-value cities mainly along the eastern coastal area, especially the Huang-Huai-Hai plain, and low-value cities in the western regions such as Chongqing (Fig. 5 b).

The extent of built-up area had a significant positive impact on sports infrastructure development in all cities sampled. It created resource-driven development by providing space for sports facilities. The spatial distribution of its influence showed a decreasing trend from southwest to northeast (Fig. 5 c), with high-value cities centered at Chongqing and low-value cities in the northeast. Chongqing, a new centrally-administered municipality, expanded rapidly between 2010–2015, much faster than other first-tier cities in eastern region (Fei & Zhao, 2019). This reflects the changing national strategy for urbanization from eastern to western regions.

In summary, the Pearl River delta is dominated by demand-driven development, the Yangtze River delta and Beijing-Tianjin-Hebei urban agglomeration by supply-driven development and the western region by resource-driven development. Looking at the whole dynamic process of urbanization in China (from south to east and west), the accumulative process of sports infrastructure development may follow three stages from resource to supply and then demand.

Discussion

The modelling results mentioned above are instrumental for exploring and generalizing the key findings from this data driven evidence: how has urbanization driven sports infrastructure development in this Chinese case study? What are the characteristics of inequality in sports infrastructure development?

Firstly, from the demographic perspective of urbanization, sports space theory is more applicable to developing countries than developed countries. China is the largest developing country. This study confirmed a significant, stationary, positive correlation between sports infrastructure development and the Population-urbanization rate in China, similar to that in Malaysia (Maassoumeh et al., 2010), which validates Bale's (2002) sports space theory. However, the driving effect of the population-urbanization rate on the development level of sports infrastructure is relatively stronger in the densely populated and highly urbanized southern region than it is in the sparsely populated and less urbanized (in some cases shrinking) cities of the northern region. The higher the level of urbanization, the stronger the effect of population-urbanization rate on sports infrastructure development, and vice versa. By contrast, in developed countries such as the United Kingdom (Lamb et al., 2010), the Netherlands (Hoekman et al., 2016) and Australia (Giles-Corti & Donovan, 2002), the relationship between the development level of sports infrastructure and the urbanization rate of the population is not as clear because both are relatively high. Here sports infrastructure development is no longer significantly driven by an increase in the urban population due to the spatial migration of population in developed countries (Arif et al., 2022). As a result, the spatial pattern of sports infrastructure does not match the sports space theory (Hoekman et al., 2016). Compared with developed countries (e.g., UK) which are in the re-urbanization or counter-urbanization stages, the level of urbanization in developing countries (e.g. China)

is still growing. For example, China aims to reach a 75% urbanization level by 2050 (Gu et al., 2017). Consequently, the regional inequality in the development level of sports infrastructure, as indicated in this case study, implies a mismatch between the supply and demand of sports infrastructure at the national scale, and this should be considered in future urbanization policies and the development of healthy cities (Yan et al., 2021; Yang et al., 2018).

Secondly, from the economic perspective of urbanization, the strength of the economy not only affects the allocation of sports infrastructure but also reflects residents' ability to participate in sports and cities' willingness to develop sports. A correlation between sports infrastructure development and regional economic growth was confirmed in this case study: economic development levels significantly influence sports infrastructure development (Coates & Humphreys, 2003). In China, the construction of public service facilities such as social security, healthcare, education, and sports infrastructure in urban areas primarily relies on government financial investments. Public financial expenditure reflects the extent and depth of government engagement in economic and social development (He & Zhang, 2022). Greater economic development can lead to increased public financial expenditure, which, in turn, supports sports infrastructure development, improves facility accessibility, and encourages broader public participation in sports activities. Conversely, in economically underdeveloped regions, as demonstrated by the deprivation amplification model, sports infrastructure development tends to lag behind (Macintyre, 2007). Investment-driven sports infrastructure development typically aggravated spatial inequalities due to differences in economic development levels. Additionally, sports infrastructure serves economic functions and can actively stimulate urban revitalization and economic growth through the sports industry and events (Gratton et al., 2005). Compared to North America and Europe, the progress of professional sports in China is comparatively slow and at a lower level, with even lower levels of sports economic development in less-developed regions (Chen & Wang, 2022; Gao et al., 2022). The anticipated returns from sports infrastructure construction are quite constrained, and there is also limited willingness for investment from businesses and individuals (Iversen & Cuskelly, 2015). Therefore, investments in sports infrastructure are more inclined to originate from the public sector rather than private businesses or individuals in the process of rapid urbanization (Xue & Mason, 2019). Consequently, the spatial inequality of sports infrastructure development driven by economic factors is prominent in China.

Thirdly, in terms of the land dimension of urbanization, sports infrastructure development in China has a hysteresis effect on the expansion of urban built-up areas (Henderson, 2019). Larger urban built-up areas in a city provide more space and resources for constructing sports infrastructure, which reduces the environmental constraints for sports infrastructure development (Pujadas, 2012). However, the evidence from this case study did not follow this pattern. The urban built-up area in western cities had a greater positive impact on sports infrastructure than it did in eastern cities (Figs. 2 c and Fig. 5c). During the early stages of urbanization, governments typically prioritized the development of economic growth and essential infrastructure such as transportation, education, and healthcare, upon which people's livelihoods depend. As urbanization progresses, both governments and citizens

increasingly focus on the quality of urban development and living standards. With the growing demand for sports and fitness, there is a corresponding increase in the need for land allocated to sports infrastructure construction (Xue & Mason, 2019). However, land resources in China are unevenly distributed. In eastern regions, due to their large population size and high population density, per capita construction land is extremely scarce, leading to significant constraints on land for sports infrastructure development. In western regions, cities are generally smaller in scale, and during the rapid urbanization process, urban expansion occurred swiftly. Supported by national policies promoting equal access to public sports services, sports infrastructure was considered a fundamental requirement and faced fewer constraints due to land supply. Consequently, the hysteresis effect of sports infrastructure development in eastern regions was more pronounced compared to the expansion of urban built-up area, while in western regions, the hysteresis effect was less noticeable and might even exhibit advancements. As residents' capacity for sports consumption and fitness demands increase, this spatial inequality in sports infrastructure resulting from land supply constraints is challenging to eliminate in the short term.

In summary, sports infrastructure development results from interactive effects among various driving factors of urbanization (population, economy, and land), and reflects the long-term accumulative process of urbanization. All three dimensions of urbanization exhibit significantly positive impacts and spatial heterogeneity on sports infrastructure development in this study. The largest driving force is the economic dimension, in terms of the level of investment (supply), followed by land (resource) and population (demand) dimensions. The varying strength and scale of spatial effects among these three driving forces reflect the different stages of urbanization and the disparate models of sports infrastructure development. Consequently, differences in policies regarding the strategies, governance and planning of urbanization at various levels, from local to national, may contribute to the regional inequality of sports infrastructure development.

Given the role of sports infrastructure development in driving urbanization, such as the sports economy (Chen et al., 2021; Huang et al., 2014), there should be a feedback loop between the accumulative developments of urbanization and sports infrastructure (see Fig. 6). The impacts of urbanization on the inequality of sports infrastructure

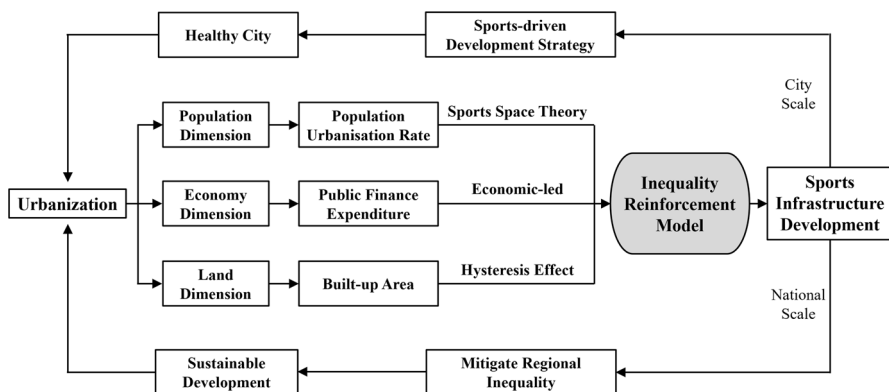


Fig. 6 The interaction between urbanization and sports infrastructure

development were generalized in an Inequality Reinforcement Model based on the feedback loop above. In this proposed conceptual model, the spatial pattern of sports infrastructure development at the national scale emerges from the local policy, management and governance of urbanization and sports infrastructure at the city scale. The positive feedback from urbanization could help reduce regional inequality but negative feedback might reinforce the inequality. Positive feedback benefits the local implementation of the Healthy China 2030 initiative, which emphasizes the importance of physical exercise and activities (Yang et al., 2018). However, negative feedback presents challenges to sustainable urbanization. As mentioned in the Sustainable Development Goals 3 and 11, health and well-being have become crucial social objectives in urbanization (Zhao et al., 2022), especially in the context of China's New Urbanization (Chen et al., 2016). In contrast to the deprivation amplification model proposed at the neighborhood level in the aforementioned countries (Hillsdon et al., 2007; Hoekman et al., 2016; Macintyre, 2007), the Inequality Reinforcement Model at the city level is introduced against the backdrop of accelerated urbanization. In this phase, social and environmental sustainability may not be as important as economic sustainability, but they will increasingly gain importance (Tan et al., 2016).

The spatial process in the feedback loop might be similar to the self-organization principle in the process of urban growth (Cheng & Masser, 2004). The assessment of sports infrastructure development level and the analysis of its regional inequality in this study, provides a "Sports Inequality Alert" from a top-down perspective. Local cities are reminded of the disparity of sports infrastructure development and the heterogeneous impact of urbanization compared with other cities across regions and country. These "Alert" messages could be communicated through a smart city platform, such as a dashboard, and would help city policy makers audit the quantity, diversity and operation of sports infrastructure, and evaluate development opportunities and constraints coming from the three dimensions of urbanization: demographic demand (active population), economic supply (sports facility investment) and land resources (sports built-up area) (Zhao et al., 2022). These sports infrastructure related local policies provide specific development plans that could be incorporated into urbanization strategies (including Healthy City and Sustainable Development) as well as spatial planning practices governing such tasks as the location and protection of sports facilities (Daumann et al., 2015; Geffroy et al., 2021).

More specifically, local policymakers need to incorporate estimates of the demand for sport and leisure facilities and the consumption of sport services that reflect the changing structure and size of the population in the process of urbanization. With investment inputs from marketing forces and management from smart city technologies, multi-level fitness and sports facilities could be built to meet people's personalized, customized and diversified needs, and help achieve healthy communities. The sports-driven development popular in many developed countries and cities (such as Greater Manchester in the UK) should be recognized as an innovative catalyst for New-type Urbanization across China (Chapin, 2004; Davies, 2016; Geffroy et al., 2021). To implement these catalysts, an integrated and diversified financial system, composed of FDI, government investment and social investment, might be required (Jakar et al., 2021; Xue & Mason, 2019). To meet the people-oriented development goals in New-type Urbanization, local spatial planning policies

addressing the location and structure of sports and leisure facilities should give consideration to the context of sustainable use of land resources by linking with the “Sport Inequality Alert”.

Conclusion

Development of sports infrastructure is key to achieve healthy cities and regional urban sustainability. This paper used the 2013 6th national sports venues census data, an entropy-based assessment method and a multi-scale geographically weighted regression model to analyze the heterogeneous effects of three urbanization dimensions on sports infrastructure at the national scale.

The findings showed that the development level of Chinese sports infrastructure in 2013 is characterized by strong spatial inequality between eastern and western regions. The inequality is related to the long-term accumulative process of urbanization (Zhang & Bao, 2015). The hierarchical city system also contributes to intra-province inequality in sports infrastructure development.

Using the population-urbanization rate, public financial expenditure and the extent of built-up area, this paper evaluated the impact of the population, economic and land dimensions of urbanization on sports infrastructure. The modelling results showed the positive contribution of each dimension on the development level of sports infrastructure, albeit with varying intensity and scales. However, the effects of urbanization on sports infrastructure development exhibited spatial non-stationarity.

The empirical findings confirm that sports space theory and economic-led sports infrastructure development are more applicable to explain the driving forces of sports infrastructure development in China than developed countries. Moreover, the hysteresis effect of land urbanization is a unique driving force for the expansion of built-up sport-use areas in China. Unlike developed countries that are at the stage of re-urbanization or counter-urbanization, China, as a fast-developing country, is still at the stage of accelerating urbanization (Gu et al., 2015) and a sports-driven development model has not been incorporated into the strategies for sustainable (new-type) urbanization at a variety of scales. Consequently, reducing regional inequality of sports infrastructure development should be recognized as an attainable challenge for new-type urbanization and a feasible solution to Healthy China 2030 (Yan et al., 2021; Yang et al., 2018).

This paper makes three key contributions. Firstly, this is the first study on sports infrastructure development in China at the city level using sport census data. Our findings highlight the regional inequality of sports infrastructure development and the heterogeneous and scaling effects of multiple urbanization driving forces across the country. It has also consolidated the statement that analyzing spatial heterogeneity can deepen the understanding of regional inequality (Wei, 2015). Secondly, a concept of Inequality Reinforcement Model was proposed to understand the complicated interactions between urbanization and sports infrastructure development, as well as the macro pattern of regional inequality at the national scale. This conceptual model, generalized from this empirical study and previous literature, has addressed an aspect of the research agenda in regional sport geography, although

further validation of the impacts of sports infrastructure on urbanization in China is needed. Thirdly, the paper proposes the “Sport Inequality Alert” as a policy making instrument to monitor regional inequality and to guide urbanization strategies and sports infrastructure development plans. To support the development of Healthy China, sports infrastructure, as well as medical resources, should be allocated equally between provinces and cities.

This study has several limitations. (1) Due to statistical inconsistencies across the country, some cities have been removed from the analysis due to incomplete or poor quality data. (2) Urbanization is a dynamic process. The dynamic modelling of spatio-temporal effects of urbanization driving forces and stages on sports infrastructure using panel data (Lv et al., 2019) would provide more insights into the dynamics of regional inequality. (3) Future studies should consider additional factors and constraints, including geographical terrain. Considering these issues, it is imperative to develop national data on New-type Urbanization and sports infrastructure with higher spatial, temporal and social scales.

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Data Availability Data on sports venues were sourced from the General Administration of Sports of China, available at [<https://www.sport.gov.cn>]. Urbanization-related data were obtained from the National Bureau of Statistics of China. The raw datasets utilized in this study can be provided upon request. For analysis, the software ArcGIS Pro was used, along with the freeware MGWR, accessible at [<https://sgsup.asu.edu/sparc/multiscale-gwr>].

Declarations

Competing Interests The authors declare no conflict of interest.

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