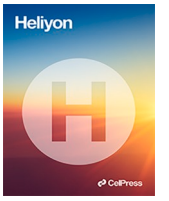
Heliyon 10 (2024) e29293

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon



Research article

Research on the spatial allocation of national fitness resources at the street scale—taking Fuzhou city as an example

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ARTICLE INFO

Keywords:
National fitness resources
Fuzhou city
Modified two-step floating catchment area method
Accessibility

ABSTRACT

To explore the spatial allocation of national fitness resources at different spatial scales in Fuzhou city to provide useful references for optimizing and enhancing the spatial allocation of national fitness resources and urban planning. The equity, spatial distribution characteristics, accessibility and supply-demand balance of national fitness resources in Fuzhou city are analysed in depth by using the two-step mobile search method of multiple travel modes, the Gini coefficient, and exploratory spatial data analysis methods. The results show that the overall spatial allocation of national fitness resources is in a balanced state, but there are serious inequities and spatial mismatches in each district (county); the spatial distribution of national fitness resources is characterized by centralized agglomeration and surface dispersion, being dense in the south and sparse in the north. Areas with insufficient resources per capita have an agglomeration-type scattering distribution; areas with sufficient resources per capita have a dispersed patch distribution. Access to national fitness resources and the relationship between their supply and demand are characterized by positive spatial concentration; however, the layout of the national fitness resources planned for the old urban areas urgently needs to be optimized, with the Chating and Antai streets serving as centres, to increase the effective supply. Finally,we suggestions that Top-level design should be strengthened, the communalization of sports public services should be promoted, the service capacity and utilization efficiency of national fitness resources should be enhanced, and the construction of national fitness resources in new urban areas and new industrial agglomerations should be accelerated.

1. Introduction

In March 2022, the “Opinions on Constructing a Higher Level of Public Service System for National Fitness” were promulgated, in which policy-makers insisted on developing people-centred designs to optimize the national layout of resources for fitness, expanding the supply of services, and constructing a higher level of public fitness services. These new public fitness programs should be

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https://doi.org/10.1016/j.heliyon.2024.e29293
Received 30 January 2024; Received in revised form 3 April 2024; Accepted 4 April 2024
Available online 4 April 2024

coordinated between urban and rural areas and be equitably accessible, conveniently serviced, efficiently operated, and strongly guaranteed, as an important cornerstone of accelerated growth towards the development of national sports and as a way of complying with popular expectations of public services for a high quality of life [1]. As an integral part of the national fitness public service system, national fitness resources are the basic materials for people to develop physical fitness activities. However, due to the relatively serious tendency of homogenization of fitness resources for all, multiple problems have become increasingly prominent, including contradictions between supply and demand, insufficient functioning, and irrational spatial layout, resulting in the urgent need to resolve the contradiction between public sports resources and the public's growing demand for sports [2,3].

The "15-min fitness circle" program was introduced to alleviate the shortage of fitness resources, lack of accessibility and other issues. However, there are still problems in planning urban spatial layouts, especially in suburban areas. Moreover, there are few related policy guidance documents, and related academic research has focused on the supply side of the fitness resources themselves, ignoring the demand side of the "population" factor. Therefore, it is necessary to combine the supply and demand of national fitness and explore the spatial allocation of urban national fitness resources from both the supply and demand sides based on the spatial allocation perspective. Based on this, this study combines multisource geographic data with 21,856 data observations of national fitness resources from 181 streets and townships, including 13 districts and counties in Fuzhou City, and matches them with population and transportation data in the region. This study adopts Gini coefficients, the two-step mobile search method, spatial autocorrelation, etc., to explore the spatial layout characteristics and the accessibility and fairness of the national fitness resources in Fuzhou at the municipal, district, and street levels from the supply and demand perspectives. The aim is to gain an in-depth understanding of the construction of national fitness resources in Fuzhou city and the possible deficiencies in the current resource distribution and to provide scientifically-based references for the optimization of urban national fitness resource allocation, the promotion of national fitness resource parity, and the enhancement of people's participation in physical fitness.

The remainder of this paper is structured as follows. The first part reviews related studies, mainly those related to the spatial allocation of public resources, such as urban green space, urban parks, medical resources, elderly care facilities, and sports facilities, summarizes their shortcomings and puts forwards the marginal contribution of this study. The second section describes the research data and research methods, presenting the study area, data sources and data processing methods as well as the two-step mobile search method for multiple travel modes, the Gini coefficient and the exploratory spatial data analysis methods involved in this study. The third section describes the research results and analysis regarding the equity, spatial distribution characteristics, accessibility, and supply-demand balance of the national fitness resources in Fuzhou city. The fourth section presents the research conclusions and recommendations.

2. Literature review

With the development of society and the economy, the serious problems of unbalanced and insufficient distribution of public resources, poor accessibility and low fairness have attracted the attention of many scholars. Spatial accessibility is an effective tool for measuring equity in the spatial allocation of public service resources and has been widely used in the study of spatial patterns, accessibility, and fairness in the fields of urban green space, urban parks, health care resources, eldercare facilities, public service facilities, etc. [4–7]. In the field of green parks, as an important part of the urban built environment and ecosystem, it play a key role in improving urban air quality and promoting physical activity. Xiao et al. combined U.S. census data, national park spatial location data and comprehensive survey data of U.S. residents to explore the spatial accessibility of U.S. national parks. The results of the study showed that the accessibility and spatial layout of U.S. national parks differ significantly among different races, between urban and rural areas, and among regions with different economic levels, of which the accessibility of national parks in ethnic minorities and economically disadvantaged areas is relatively poor, and the equity of the spatial layout needs to be improved [4]. Wei used the Gaussian 2SFCA method to assess park accessibility in Hangzhou, China, and found that the greater the scale of green parks is, the greater the accessibility and spatial equity are [8]. In Senol's study on the accessibility of parks in Izmir, Turkey, it was noted that although the per capita coverage is high, it is affected by many factors, such as transportation layout and the built environment, which to a certain extent hinders access to parks for people with different walking abilities and recreational needs [9]. In the field of health care resources, as a livelihood issue of public concern, the spatial equalization of health care resources is not only a key concern of the government but also a long-term research hotspot for scholars, who focus mainly on the differences in access to health care among different groups and factors affecting the accessibility of health care resources. A study on the spatial layout of medical resources in Henan Province, China, noted that the accessibility of medical resources is affected by topography to a certain extent. The accessibility of medical resources in mountainous areas is significantly lower than that in other terrains. Spatial accessibility tends to decrease from east to west across Henan, and the GDP per capita and the density of housing, road networks, population, etc., all impact the spatial accessibility of medical resources [5]. Similar findings abound internationally. As Liu et al. noted in their study of health care resource allocation in several regions of the U.S., the accessibility of health care resources significantly decreases from urban to rural areas, from economically affluent to impoverished areas, and from areas with concentrations of powerful people to areas with concentrations of disadvantaged groups [10]. In the field of eldercare facilities, population ageing is a widespread social phenomenon in all countries, and with the increasing demand for eldercare, the imbalance of the supply of eldercare resources has become increasingly serious. Numerous studies have noted that the current spatial distribution of eldercare facilities is relatively concentrated, mostly characterized by high resource concentration in central city areas and in southern China and low concentration in the suburbs and in northern China [11,12]. On this basis, Liu Bangyu et al. studied the matching degree of the supply of eldercare facilities from the perspective of social class differentiation, and the results showed that the degree of demand significantly differed between social classes. The matching degree of supply and demand ranged from high to low in order from the middle class to the salaried class, the affluent class, and finally

the lower class, and there were areas in which the different types of eldercare facilities available did not match the demand of residents in different classes [13].

National fitness resources are available to meet the public demand for physical exercise and to promote physical exercise to meet public spiritual and cultural needs, improve physical and mental health, and enhance the popular sense of access to resources [14]. Scholars have also explored the problems and relief paths in the deployment of national fitness resources for the development of sports undertakings from different perspectives. Research has focused mainly on supply systems, financial security, and spatial layout optimization for sports and fitness facilities [15,16].Regarding to allocation of national fitness resources, scholars have mostly used different spatial measures to conduct exploratory analyses of the collected data. Salarvandian et al. explored the accessibility of sports facilities in 22 districts of Tehran using a geographic information system (GIS) network and spatial statistical analysis, and the results of the study showed that the greater the population and residential density of the area are, the fewer sports facilities there are, while the greater the space per capita for sports, the lower the accessibility of the sports facilities. Thus, it was concluded that the sports facilities in Tehran are located mostly in sparsely populated areas with low usage rates [17]. Higgs et al. investigated the accessibility of sports facilities in Wales using the floating catchment area (FCA) model, and the results of the analysis showed that the accessibility of sports facilities in deprived areas of Wales was significantly greater than that in other areas; i.e., community deprivation in Wales was positively correlated with the ease of access to sports facilities for people in the community [18]. Kozma et al. noted in their study on the spatial distribution of sports facilities in the northern Great Plains of Hungary that settlement size has a significant effect on the spatial distribution of sports facilities, and the more populous a region is, the stronger its demand and purchasing power for sports facilities, and the more complete and diversified the layout of sports facilities; moreover, the administrative level of the region is positively correlated with the degree of completeness of the layout of sports facilities [19]. Scholars have also explored the spatial accessibility of sports facilities in different regions of China, and compared with different research results in other international regions, the results of related studies in China are somewhat similar. Most of the studies concluded that a spatial imbalance of sports and fitness facilities still exists in different regions of China, the supply of sports facilities fails to match the demand of residents, and the accessibility of sports facilities in central urban areas is significantly better than that in suburban and rural areas [20–22]. In addition, Lee et al. noted that the convenience of accessing and using sports and fitness resources can effectively enhance residents' willingness to participate in physical exercise and thereby enhance their sense of access [23]. Therefore, it is necessary and meaningful to pay attention to issues such as the balance and accessibility of the spatial distribution of national fitness resources.

According to a review of the relevant literature, the existing research on physical fitness resources still has the following deficiencies: (1) the research scale is too macroscopic. Restricted by the accessibility and accuracy of data on sports facilities, existing studies have analysed the spatial layout and accessibility of sports and fitness resources at the provincial, municipal or county scale and have seldom explored the allocation of sports and fitness resources from a more focused perspective, such as at the street and township scales. Moreover, most studies have focused on urban centres and ignored peri-urban areas. (2) Most related research has focused on the supply side, ignoring the demand side. Current mainstream research in this field has focused on the unilateral spatial layout of sports and fitness resources, ignoring the population distribution, transportation network, residents' travel modes and other key factors affecting the convenience and accessibility of sports and fitness resources. (3) Fragmented small-scale fitness resources are ignored. Existing studies focus mostly on the allocation of large-scale public stadiums, ignoring grassroots fitness resources, such as community fitness paths, which are small in scale, widely distributed, and difficult to locate. These paths have limited service capacity but are more closely linked to the daily lives of residents. This oversight makes existing studies inadequate due to the limited amount of available data and low level of precision, making it difficult for them to comprehensively and accurately reflect the real accessibility of sports and fitness resources in the studied areas.

In summary, it is necessary to analyse the spatial distribution, accessibility, equity and other configurations of sports and fitness resources at the street scale from the perspective of resident living circles to better understand how the development of national fitness and a strong sports nation can be promoted. Compared with existing studies, this study makes some contributions. First, this study combines multivariate geographic data to explore the spatial allocation of national fitness resources in Fuzhou city at three spatial scales—the city, district, and street levels—aiming to more comprehensively and meticulously determine the status quo of the spatial allocation of national fitness resources in Fuzhou city and the problems that may exist. Second, considering the differences in the travel characteristics of different people and regions, this study innovatively adopts a two-step mobile search method based on different travel modes, such as walking, nonmotorized vehicles and motorized vehicles, to measure the accessibility of national fitness resources, which is more universal than measurement methods via a single mode of travel and is more in line with the choice of people's travel modes, ensuring the scientific validity of the results of the study. Third, the national fitness resources in this study cover large public stadiums, sports parks, school sports facilities and other types of resources considered in previous studies but also include community fitness paths, rural sports and fitness facilities and other small-scale fitness resources, overcoming the difficulty of locating the small-scale national fitness resources scattered within the scope of the study. The national fitness resources used for the collection of data are more accurate and comprehensive than those used in other studies, which also ensures the accuracy of the results.

3. Research data and methodology

3.1. Study area

Located in eastern Fujian Province, on the lower reaches of the Min River and in the coastal area, Fuzhou is one of the central cities of the economic zone on the west coast of the Taiwan Strait. It is an important metropolis on the southeast coast of China and is the capital city of Fujian Province. Fuzhou city contains six districts, namely, Gulou District, Taijiang District, Cangshan District, Jin'an

District, Mawei District and Changle District, and six counties, namely, Minhou County, Lianjiang County, Luoyuan County, Minqing County, Yongtai County and Pingtan County, with Fuqing City representing a county-level city. Pingtan County has 45 streets, 97 towns and 39 townships. The geographical area is approximately 11,968.53 km2, and the resident population is approximately 8,448,000 [24].

As early as 2015, Fuzhou City proposed the goal of creating a "strong sports city" and building a healthy Fuzhou. In recent years, Fuzhou City has closely focused on this strategic goal while upholding the development concept of "innovation, openness, green, happiness". The city has fully implemented the national strategy for national fitness, adopted "the comprehensive strength and social influence of sports to enter the first national capital city", and strived to create a nationally ranked model city of sports and fitness and a "national sports consumption demonstration city" to position the city's sports development. In 2021, the Fuzhou municipal government stated the aim to build a national fitness public service system with Fuzhou characteristics as a model for the rest of China by 2025. As part of this initiative, it constructed sports venues and facilities within easy reach and made the slogan "Strong City of Sports" a distinctive symbol of the modernization of the new Fuzhou [24]. Therefore, Fuzhou is a representative and typical case for study because its experience of constructing and developing national fitness resources can provide useful information for other cities.

3.2. Data sources and processing

The national fitness resource data come from the 2022 Fujian Provincial Sports Venue and Facility Survey data (provided by the Financial and Audit Office of Fujian Provincial Sports Bureau) and include the area, number of venues, and address of each venue for each type of sports complex, including hiking trails, national fitness paths, community fitness centres, sports parks, gymnasiums, walking and cycling complexes, golf courses, natural swimming pools, and courts for basketball, volleyball, and soccer in Fuzhou City. Geocoding was performed by means of Gaode map, and after the latitude and longitude corresponding to the national fitness resource points were obtained, the data were uniformly converted to the WGS1984 spatial coordinate system (Fig. 1).

Residential neighbourhood point data were derived from commercial residences at the Highlander Map POI points. The WorldPop2022 raster population was used as the source of population data, and the Tyson polygonal delineation method was used to extrapolate the population volume of commercial residential POI points.

3.3. Research methodology

3.3.1. Multimode two-step floating catchment area (M2SFCA) method

The two-step moving search method was first proposed by Radke et al., in 2000 and further improved and named by Luo et al., in

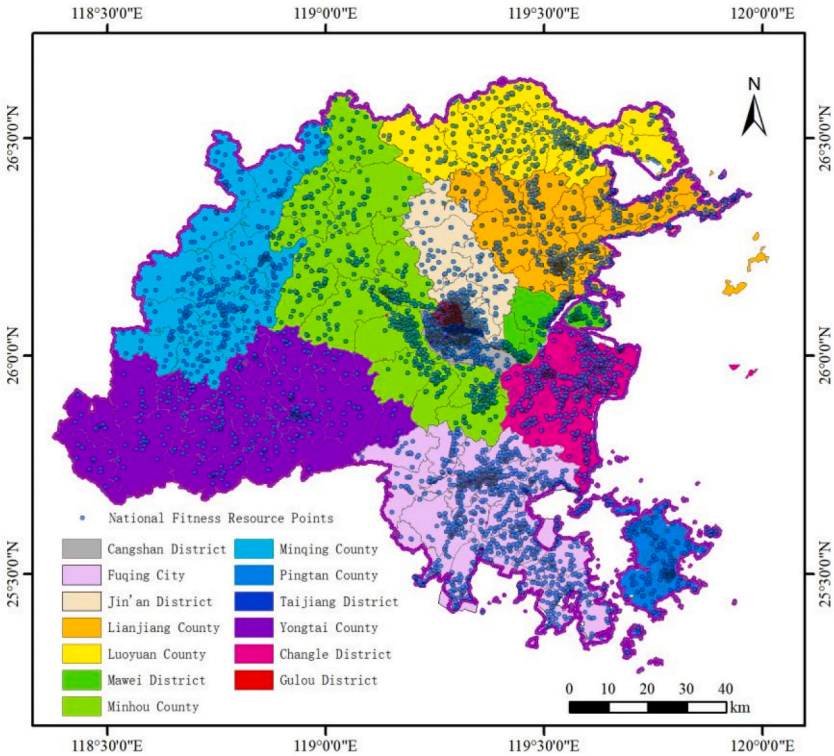

Fig. 1. Distribution of administrative divisions and national fitness resource points in Fuzhou City.

2003. The method performs two searches based on supply and demand points. In the first step, the demand points within the threshold range are searched with the supply point as the centre, and the supply-demand ratio is calculated; in the second step, the supply points within the threshold range are searched with the demand point as the centre, and the supply-demand ratios of all the supply points are summed to obtain the accessibility value [25]. Currently, the two-step mobile search method is regarded by scholars as the most effective measure for calculating reachability[26,27]. The two-step mobile search method is used to evaluate the accessibility of national fitness resources from the perspectives of the supply of national fitness resources and the demand of the population; i.e., the more national fitness resources are available to residents, the greater the level of accessibility to their national fitness resources. The traditional two-step mobile search method does not reflect the accessibility of fitness resources for all under multiple travel modes and does not accurately reflect the real-time and objective road network [28,29]. Therefore, in this study, the multitravel mode two-step floating catchment area (M2SFCA) was constructed on the basis of the traditional two-step floating catchment area combined with the travel characteristics of the residents of Fuzhou City; thus, the accessibility of fitness resources was measured for the whole population under three dominant modes of travel, namely, walking, riding, and driving motorized vehicles. First, using the concept of the 15-min fitness circle proposed in the Fujian National Fitness Implementation Plan (2021–2025), the time threshold to access fitness resources was determined to be 15 min. Second, based on the built environment and road traffic characteristics of Fuzhou city, combined with the relevant literature, the 15-min travel distances for each travel mode of walking, cycling, and motor vehicles were determined to be 1250 m, 3750 m, and 8000 m, respectively [30]. Again, based on the travel preferences of Fuzhou residents, the order of residents' preferred travel modes was set as walking, cycling and motor vehicles; i.e., if the residents of a settlement can reach the national fitness resource points by walking within the 15-min threshold, the travel time and the population with accessibility are counted. If the residents of the settlement cannot reach the resource points by walking 15 min, the travel time and the population that can reach them by cycling 15 min are counted. Finally, if the settlement population cannot reach the resource points using either of the above 2 modes of travel within 15 min, the travel time and the population that can reach them by motor vehicles are counted. The "fitness for all" resource accessibility is calculated as follows:

Step one. The service capacity of national fitness resources is calculated as follows:

$$R_j = \frac{S_j}{\sum_{i\in t_{ij}(N_1)\le t_0} r_{iN_1} \times G\left(t_{ij}(N_1), t_0\right) + \sum_{i\in t_{ij}(N_2)\le t_0} r_{iN_2} \times G\left(t_{ij}(N_2), t_0\right) + \sum_{i\in t_{ij}(N_3)\le t_0} r_{iN_3} \times G\left(t_{ij}(N_3),\right)} \tag{1}$$

In Equation (1), where R_j is the service capacity of the national fitness resource point; S_j is the size of the national fitness resource site; r_{iN_1}, r_{iN_2}, *and* r_{iN_3} are the travel times from an individual's residence to a national fitness resource site by walking, biking, and motor vehicle travel, respectively; and $G(t_{ij}(N_1), t_0)$, $G(t_{ij}(N_2), t_0)$, *and* $G(t_{ij}(N_3), t_0)$ are the time decay coefficients of the Gaussian function. As an example, the walking mode is calculated as in equation (2):

$$\mathrm{G}\left(\mathrm{t_{ij}(N_1)}, \mathrm{t_0}\right) = \begin{cases} \dfrac{\mathrm{e} - (1/2) \times \left(\mathrm{t_{ij}(N_1)}/\mathrm{t_0}\right)^2 - \mathrm{e}^{-(1/2)}}{1 - \mathrm{e}^{-1/2}}, \mathrm{t_{ij}(N_1)} \le \mathrm{t_0} \\ 0, \mathrm{t_{ij}(N_1)} > \mathrm{t_0} \end{cases} \tag{2}$$

Step two. The sum of the supply and demand ratios for the accessibility of national fitness resource points for each settlement within the 15-min time threshold is calculated as the accessibility for the settlement, as follows:

$$Q_i = \sum_{j\in t_{ij}(N_1)\le t_0} R_j \times G\left(t_{ij}(N_1), t_0\right) + \sum_{j\in t_{ij}(N_2)\le t_0} R_j \times G\left(t_{ij}(N_2), t_0\right) + \sum_{j\in t_{ij}(N_3)\le t_0} R_j \times G\left(t_{ij}(N_3), t_0\right) \tag{3}$$

In Equation (3), Q_i is the accessibility of fitness resources for all in the settlement, and the larger its value is, the greater the level of accessibility of fitness resources for all in the settlement [31].

3.3.2. Gini coefficient

The Gini coefficient was first proposed by Lorenz to explore the distributional equity of income among national or regional residents and has subsequently been used for social equity performance and public resource allocation evaluation due to the similarity in nature between public resource allocation and income distribution [32]. To reflect the equity of the distribution of national fitness resources in Fuzhou city, a national fitness equity model was constructed based on the Gini coefficient to measure the differences in the accessibility of national fitness resources in Fuzhou city and the other districts (counties), which were calculated as follows:

$$G = 1 - \sum_{k=1}^{n} (F_k - F_{k-1})(H_k + H_{k-1}) \tag{4}$$

In Equation (4), G is the equity index of fitness resources for all; n is the total number of settlements within the geographic unit; k is the ordinal number of settlements in ascending order of accessibility to fitness resources for all; F_k is the cumulative proportion of the level of demand; and H_k is the cumulative proportion of supply capacity. According to the meaning of the Gini coefficient, when $G \le 0.2$, the spatial distribution of fitness resources for all is in a highly equalized state; when $0.2 < G \le 0.3$, the spatial allocation of national fitness resources is in a relatively average state; when $0.3 < G \le 0.4$, the spatial allocation of national fitness resources is in a relatively reasonable state; when $0.4 < G \le 0.5$, there is a large gap in the spatial allocation of national fitness resources; and if $G > 0.5$, the spatial allocation of national fitness resources has a wide range of disparities and serious inequities, which need to be rectified [28].

3.3.3. Exploratory spatial data analysis (ESDA) methods

The exploratory spatial data analysis method is based on traditional classical statistical methods, including spatial data analysis methods and techniques centred on spatial correlation measurements, which can determine the distribution pattern of the research object from geospatial data and compensate for the defects of classical statistics, ignoring geospatial orientation [33]. The univariate spatial autocorrelation and bivariate spatial autocorrelation used in this study are the basic analysis methods used for exploratory spatial data analysis.

3.3.3.1. Univariate spatial autocorrelation analysis. This study used the global Moran's *I* index to measure the overall spatial correlation of the spatial distribution and accessibility of per capita national fitness resources at the street scale in Fuzhou city. To analyse the possible local spatial characteristics in more detail, the local Moran's *I* index was used to further measure the degree of spatial differences and the significance of the spatial differences between a certain street (town, village or township) and neighbouring districts.

The global Moran's *I* is calculated as follows:

$$I = \frac{\sum_{i=1}^{n}\sum_{j\neq 1}^{n} W_{ij}(x_i - \overline{x})(x_j - \overline{x})}{S^2 \sum_{j=1}^{n}\sum_{j=1}^{n} W_{ij}} \tag{5}$$

In Equation (5), where n is the total number of streets (towns or villages); W_{ij} is the spatial weight; *i* and street (town or village) *j* are adjacent to each other; $W_{ij} = 1$; $W_{ij} = 0$; x_i and x_j are the observed values for street (township) *i* and street (township) *j*, respectively; $\overline{x}$ is the mean of x_i; and S^2 is the variance in x_i. A global Moran's I value that is less than or greater than 0 and passes the significance test indicates that there is a positive or negative spatial aggregation of the spatial layout and accessibility of national fitness resources at the street scale in Fuzhou city. A significant global Moran's I value that is close to 0 indicates that there is no spatial correlation and that the spatial distribution is random [33].

The local Moran's I is calculated as follows:

$$I = \frac{(x_i - \overline{x})}{S^2}\sum_j W_{ij}(x_j - \overline{x}) \tag{6}$$

In Equation (6), where x_i is the per capita space and accessibility level of fitness resources for all in each street (village or township), *W* is the spatial weight matrix, and W_{ij} represents the geographic location of each street (township or village) in relation to other streets (townships or villages). If two streets (townships or villages) are adjacent to each other, the value of W_{ij} is 1; otherwise, W_{ij} is 0. When the value of *I* is positive and passes the significance test, the street (township or village) population has a similar spatial distribution and accessibility level of fitness resources per capita as its neighbouring streets (townships or villages) do ("high - high" or "low - low"); a significant negative value of *I* indicates that the street (township or village) is not similar to neighbouring streets (townships or villages) in terms of the spatial distribution and accessibility level of per capita fitness resources for all ("high - low" or "low - high") [33].

3.3.3.2. Bivariate spatial autocorrelation analysis. To further clarify the degree of match between the supply capacity of national fitness resources and the level of resident demand, with reference to existing relevant studies [12], the accessibility of national fitness resources and the number of residents in the residential area were selected, and bivariate spatial autocorrelation analysis was used to analyse the degree of matching between the supply and demand of national fitness resources. The calculations are as follows:

$$\mathrm{I_i} = \left(\frac{\mathrm{P_i}}{\sum_{\mathrm{i}} \mathrm{P_i^2}}\right)\sum_{\mathrm{j}} \mathrm{W_{ij}Z_j} \tag{7}$$

In Equation (7), I_i is the local autocorrelation value of the settlement; P_i and P_j are the mean deviations of the population size from the accessibility for settlements *i* and *j*, respectively; and W_{ij} is the spatial weight matrix between settlements *i* and *j*.

Table 1
Gini coefficient of national fitness resources in Fuzhou city.

Area	Gini coefficient	Area	Gini coefficient	Area	Gini coefficient
Fuzhou city	0.2679	Lianjiang county	0.9938	Pingtan country	0.9845
Cangshan district	0.9709	Luoyuan county	0.9853	Taijiang district	0.9696
Fuqing city	0.9953	Mawei country	0.8842	Yongtai county	0.9920
Gulou district	0.9846	Minhou county	0.9687	Changle district	0.9931
Jinan district	0.9656	Minqing county	0.9876		

4. Results and analysis

4.1. Equity analysis of "fitness for all" resources

To explore the equity status of the spatial allocation of national fitness resources in Fuzhou city, the Gini coefficient of national fitness resources in Fuzhou city was calculated using streets (townships and towns) as the spatial unit (Table 1), and the Lorenz curve was plotted (Fig. 2、 Fig. 3). Fig. 2 shows the Lorenz curve for the allocation of national fitness resources in Fuzhou city, and Fig. 3 shows the Lorenz curve for the allocation of national fitness resources in all districts (counties), in which a greater degree of curvature indicates that the spatial allocation of national fitness resources is more inequitable [21].

As shown in Table 1, the Gini coefficient of the overall national fitness resources in Fuzhou city is 0.2679, which is relatively average, indicating that the spatial allocation of national fitness resources in Fuzhou city is in a more balanced state overall, and the differences in the allocation between the various districts (counties) are relatively small. According to Figs. 2 and 10% of the residents in Fuzhou city enjoy approximately 10.3% of the national fitness resources, and 30% of the residents enjoy approximately 20% of the national fitness resources.

To further clarify the whether the overall allocation of national fitness resources in Fuzhou city is balanced, the Gini coefficient is calculated for each district (county). The Gini coefficients of all districts (counties) in Table 1 are all greater than 0.8, which indicates a state of serious inequality. This indicates that there is a certain degree of "spatial mismatch" between the allocation of national fitness resources in the various districts (counties) in Fuzhou city and the distribution of the resident population in all districts (counties) of Fuzhou, and the distributions of national fitness resources within each district (county) greatly differ. Combining the Lorenz curves of the districts (counties), 10%, 50%, and 98% of the residents in Changle District (G = 0.9931), for example, enjoy only approximately 4.81%, 20%, and 53.01%, respectively, of the resources available to the whole population. Among residents in Lianjiang County (G = 0.9938), 10%, 47%, and 96.57% enjoy only approximately 3.07%, 20.55%, and 52.32%, respectively, of all fitness resources. Therefore, the overall balanced allocation of fitness resources in Fuzhou is strongly related to the allocation of fitness resources within the districts (counties) and the prevalence of spatial mismatch.

4.2. Characteristics of the spatial distribution of fitness resources

As shown in Fig. 1, Gulou District, Taijiang District, and the two central urban areas have a highly dense distribution of fitness resources, which gradually spread to the surrounding areas in a pattern characterized by concentration in the centre, superficial dispersion, and dense distribution in the south and sparse distribution in the north. The per capita area of national fitness resources on each street (township and village) of Fuzhou city is divided into three levels—less than or equal to 2 m2/person, 2 m2/person–3 m2/person, and more than or equal to 3 m2/person—and corresponds to an insufficient per capita area, a moderate per capita area and a sufficient per capita area. This characterization describes the spatial distribution of the national fitness resources supply in Fuzhou city and is the key aspect of interest in this study.

As shown in Fig. 4, the per capita area of national fitness resources in streets (townships and towns) in Fuzhou city is dominated by insufficient per capita area and sufficient per capita area, accounting for 44.56% and 32.12%, respectively, of the total number of streets (townships and towns). The insufficient per capita area is spatially characterized by a "clustered scattering-type" distribution, and the sufficient per capita area is characterized by a "decentralized patchy" distribution. The number of streets (townships and towns) with insufficient per capita areas is obviously greater than the number of streets (townships and towns) with moderate per capita areas and sufficient per capita areas. The areas with insufficient resources also exhibited more obvious clustering characteristics.

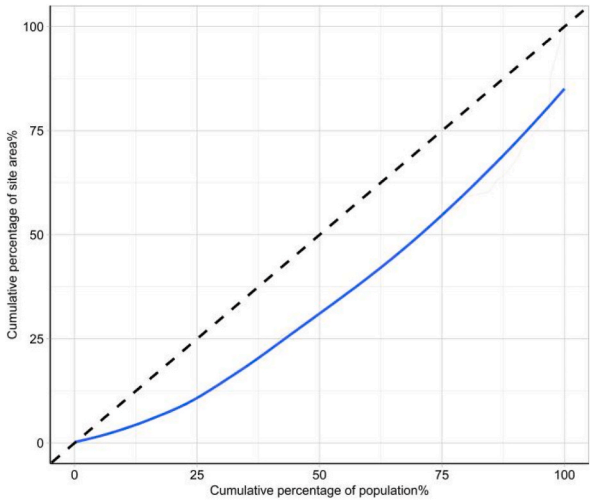

Fig. 2. Lorenz curve of national fitness resources allocation in Fuzhou city.

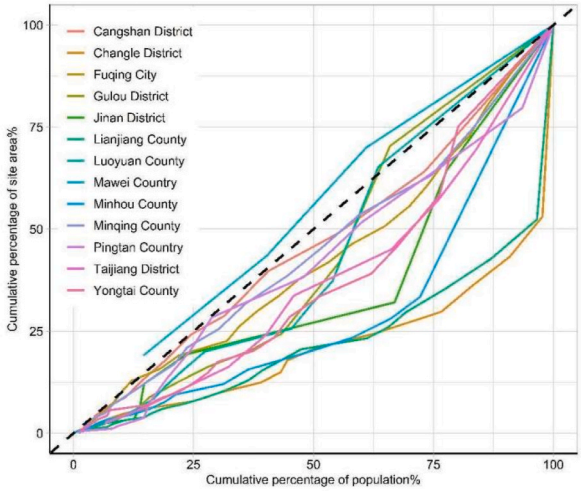

Fig. 3. Lorenz curve of allocation national fitness resources allocation for all districts (counties) in Fuzhou city.

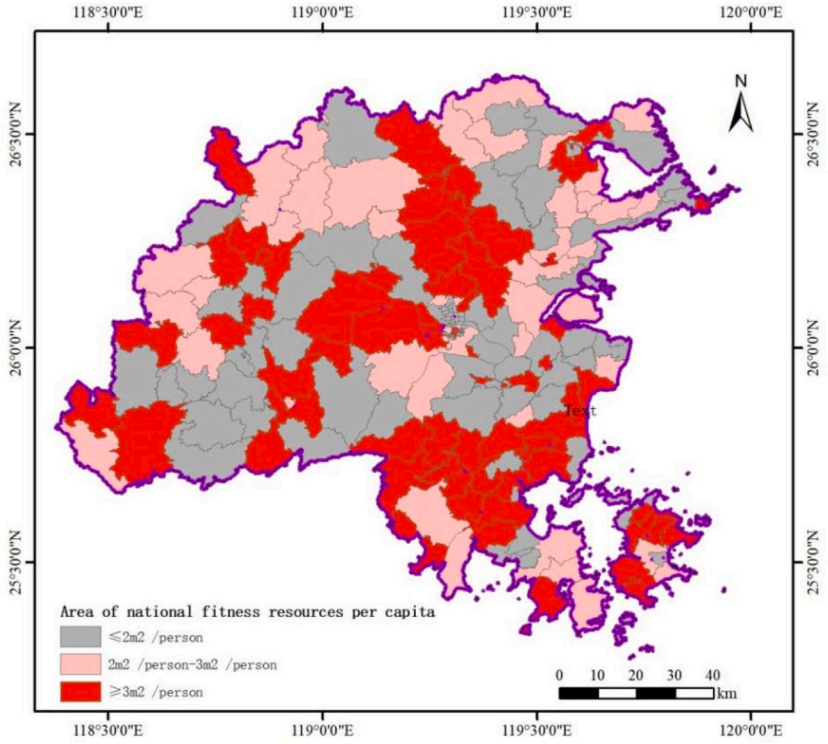

Fig. 4. Spatial distribution of the per capita area of national fitness resources in Fuzhou at the street scale.

In addition, the streets (townships and towns) of Gulou and Taijiang Districts, where the national fitness resource points are densely distributed, are dominated by insufficient per capita areas.

To better reveal the correlation between the spatial distribution of national fitness resources of streets (townships and towns) in Fuzhou city in per capita areas, the global Moran's I was calculated by using ArcGIS 10.2 software. As shown in Fig. 5, the global Moran's I of the per capita area of national fitness resources in Fuzhou city at the street scale is 0.0643, and the Z score is 2.5230, which passes the significance test at the 5% level, indicating the existence of a "high-high" or "low-low" distribution of spatial aggregation. The results of the local spatial autocorrelation analysis in Fig. 4 can effectively reflect the degree of local agglomeration of streets (townships and towns), including four modes, namely, "high-high", "low-low", "low-high" and "high-low". High-high agglomeration indicates that both the region and its neighbours have more than adequate resources per capita; low-low agglomeration indicates that

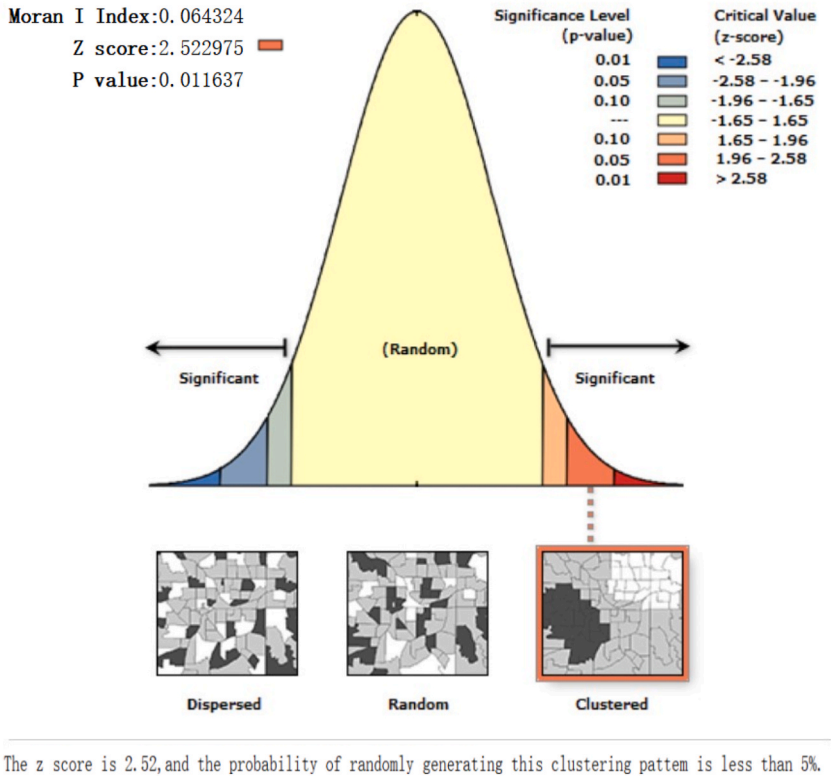

Fig. 5. Spatial autocorrelation report of the per capita area of national fitness resources in Fuzhou at the street scale.

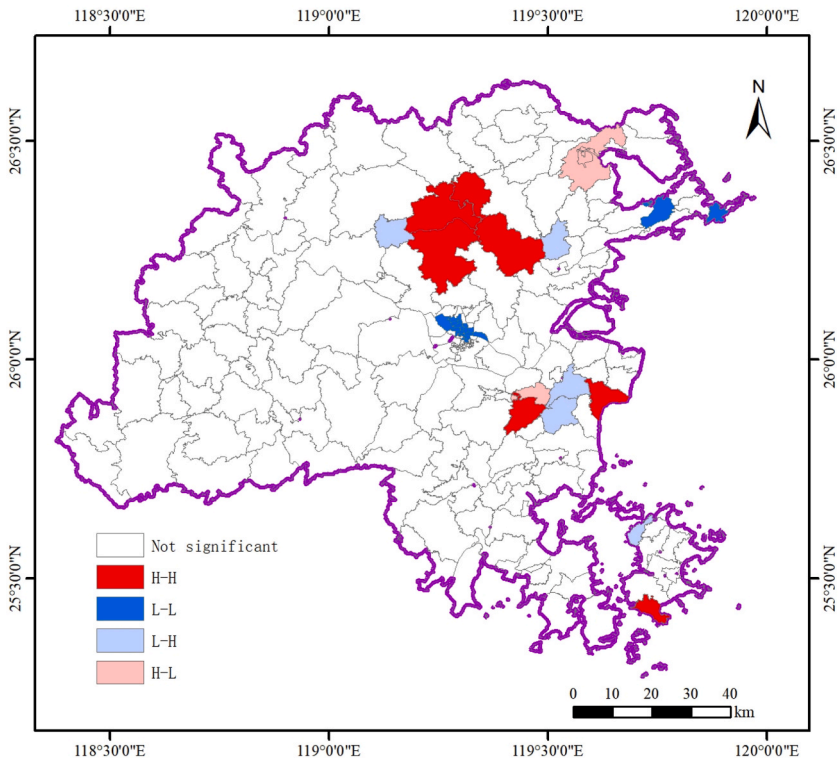

Fig. 6. Spatial autocorrelation of the per capita area of national fitness resources in Fuzhou at the street scale.

both the region and its neighbours have inadequate resources per capita. Similarly, the "low-high" agglomeration pattern indicates that the area has significantly less resources per capita than neighbouring regions, and the "high-low" agglomeration pattern indicates that the area has more adequate resources per capita than neighbouring regions.

As shown in Fig. 6, only 34 streets (townships and villages) passed the significance test, indicating that they play an important role in terms of their level of development, geographic location, spillover effect, and driving effect. In addition, with the exception of the "low-low" agglomeration pattern, which is relatively concentrated in the Gulou and Taijiang Districts, the remaining agglomeration patterns are scattered throughout the districts (counties). In particular, there is a need to further stimulate the spillover and driving effects of "high-high" agglomeration pattern areas and to expand both the agglomeration area and the number of agglomeration areas.

To identify the reasons for the "low-low" agglomeration pattern, Fig. 7 is plotted to more clearly show the geographic location of the regions. As shown in Fig. 7, the "low-low" agglomeration pattern is mainly centred on Chating Street and Antai Street, which expand outwards and occupies 70% of the streets in Gulou District and 80% of the streets in Taijiang District. Moreover, there is a trend towards spillover to neighbouring districts (counties), including Xiangyuan Street in Jinan District, Cangshan District, Cangqian Street, Linjiang Street, and Lake Street, which also exhibit "low-low" agglomeration patterns. Combined with the economic and social development of Fuzhou city, these findings indicate that the area is the political, economic and cultural centre of Fujian Province and the core urban area of Fuzhou city. Additionally, Gulou District and Taijiang District cover areas of only 35.7 square kilometres and 18 square kilometres, respectively, and the population density is as high as 19,000 people/square kilometre. Therefore, against the background of land resources, although the national fitness resources in this area are densely distributed, confined to high-density population agglomerations, and consist mostly of community fitness paths and various types of small-scale sports and fitness venues, phenomena of "hardly finding a game" and "sighing in anticipation of the price" are common. These social issues have become increasingly serious and have led the region to be characterized as having insufficient per capita area for national fitness resources. These regions form a certain amount of agglomeration for important reasons.

4.3. Spatial accessibility analysis of fitness for all resources

The number of people in their area, the transportation time to the fitness point and the degree of difficulty are all important factors affecting the choice to participate in physical activity [34]. Therefore, the two-step mobile search method with multiple travel modes is used to include population size, transportation road network, travel mode and travel time in the analysis to measure the accessibility of national fitness resources in Fuzhou city, aiming to more accurately and scientifically analyse their spatial allocation.

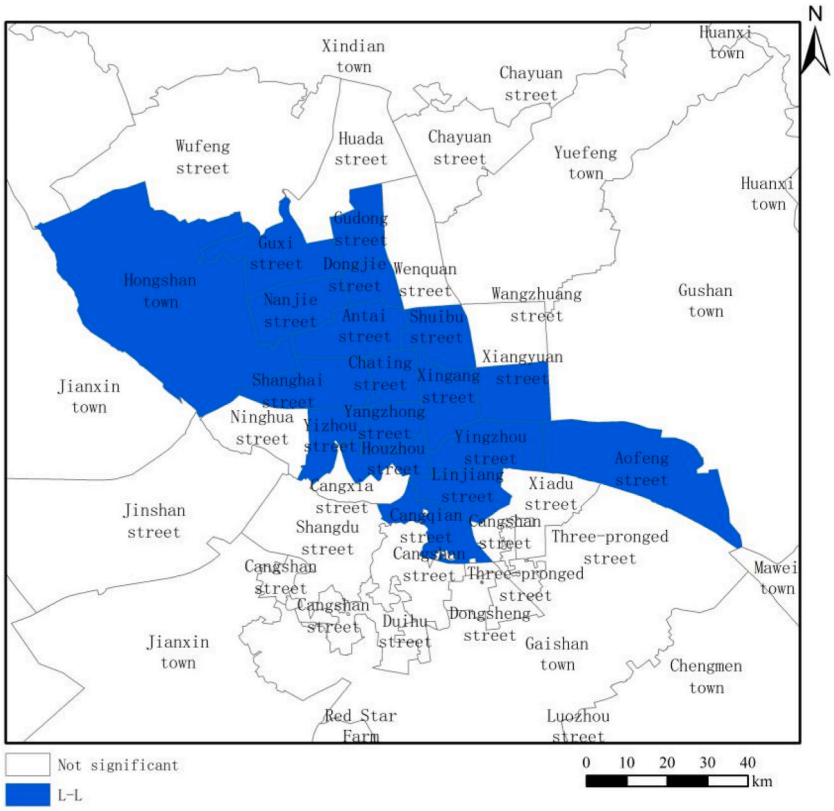

Fig. 7. Local spatial autocorrelation map of the per capita area of national fitness resources in Fuzhou at the street scale (Gulou District and Taijiang District).

The accessibility of national fitness resources on streets (townships and towns) in Fuzhou city was classified into five levels using the natural discontinuity grading method: low accessibility, medium-low accessibility, general accessibility, medium-high accessibility and high accessibility. Fig. 8 shows that the accessibility of national fitness resources in Fuzhou city is mainly dominated by low-accessibility and medium-low-accessibility areas, and a certain scale of agglomeration characteristics has been formed. The other grades are more dispersed and have not yet formed a clear catchment area. Fig. 9 shows that the global Moran's I value of the accessibility of national fitness resources in Fuzhou city at the street scale is 0.0561, and the Z score is 1.9039, which passes the significance test at the 10% level, indicating that there is a spatial aggregation characteristic of "high-high" or "low-low" in the accessibility of national fitness resources in Fuzhou city. In Fig. 10, only 30 streets pass the statistical significance test for accessibility, of which 8, 17, 3, and 2 are in the "high-high", "low-low", "low-high", and "high-low" agglomeration patterns, respectively.

Streets with a "high-high" agglomeration pattern mainly include Shoushan Township, Huanxi Township, Xindian Township, and Rixi Township in Jin'an District; Xiaocang She Township in neighbouring Lianjiang County; Zhuki Township in Minhou County; and Jianxin Township and Jinshan Street in Cangshan District. These areas are all new residential clusters and commercial districts that developed around the central city of Fuzhou in recent years, and as planned urban areas, they are able to strictly implement the provisions of the national land use quota indices for public urban sports facilities by incorporating public urban sports facilities into construction plans and the overall land use plan. Among the above eight streets, there is an area of 119,772 square metres in Fuzhou city, where the Fuzhou Strait Olympic Sports Centre is located; additionally, there is an area of 346,000 square metres in the Fuzhou Jinshan Cultural and Sports Centre combined with the Fuzhou city aerial forest fitness trails, called "Fu Road". In addition, Jin'an District has been listed at the provincial level as a model county for national sports and fitness. As a result, these areas have a rich variety and an abundant area of fitness resources for all, a reasonable spatial distribution, and a high level of accessibility, enabling them to play a better role as examples.

The streets in the "low-low" agglomeration pattern in terms of access are similar to those in the "low-low" agglomeration pattern in terms of the distribution of national fitness resources per capita; these streets are located mainly in Gulou and Taijiang districts, with large sectors of streets in these districts spreading outwards from the centres of the Chating and Antai Streets (as shown in Fig. 11). Influenced by the old city and the urban core city, although the transportation system in this area is more developed and the distribution of national fitness resource points is highly dense, the small administrative area, high population density, and complex spatial operations of the right of way lead more residents of this area to choose to travel by walking, cycling, and other slow-moving modes of transportation when they participate in sports and exercise, which increases the travel time to reach the fitness resource points. In addition, limited by the planning difficulties and urban development functions assigned by administrative areas, urban space should be optimized by using urban corners and vacated space to provide "fitness resources for all" in the formation of "golden corners and silver edges" to meet the increasing demand for fitness. As a result, the level of accessibility to fitness resources in this area is low and should be emphasized in subsequent development.

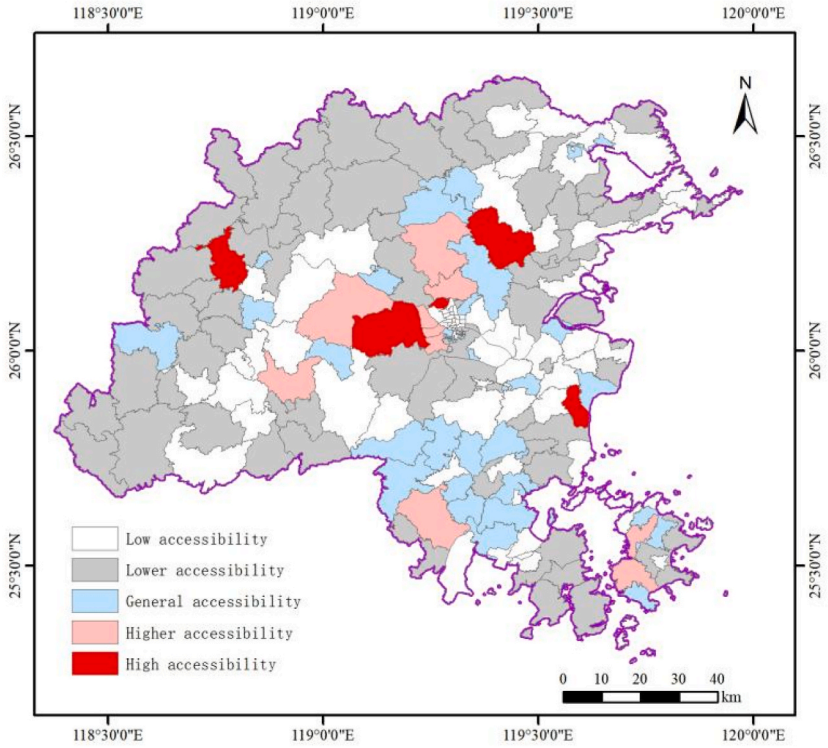

Fig. 8. Spatial accessibility of national fitness resources in Fuzhou at the street scale.

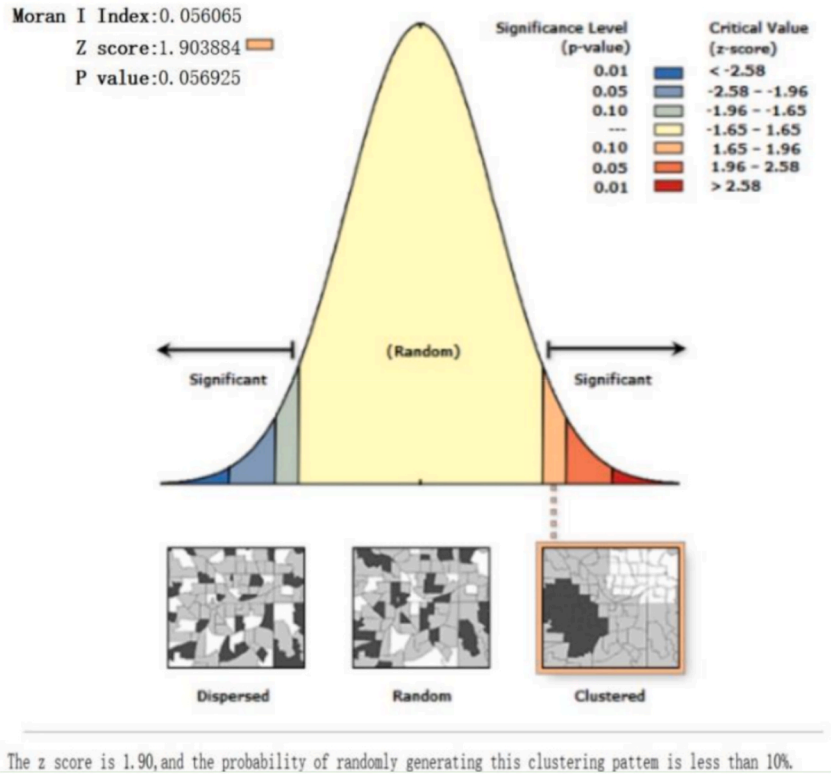

Fig. 9. Spatial autocorrelation report of the accessibility of national fitness resources in Fuzhou at the street scale.

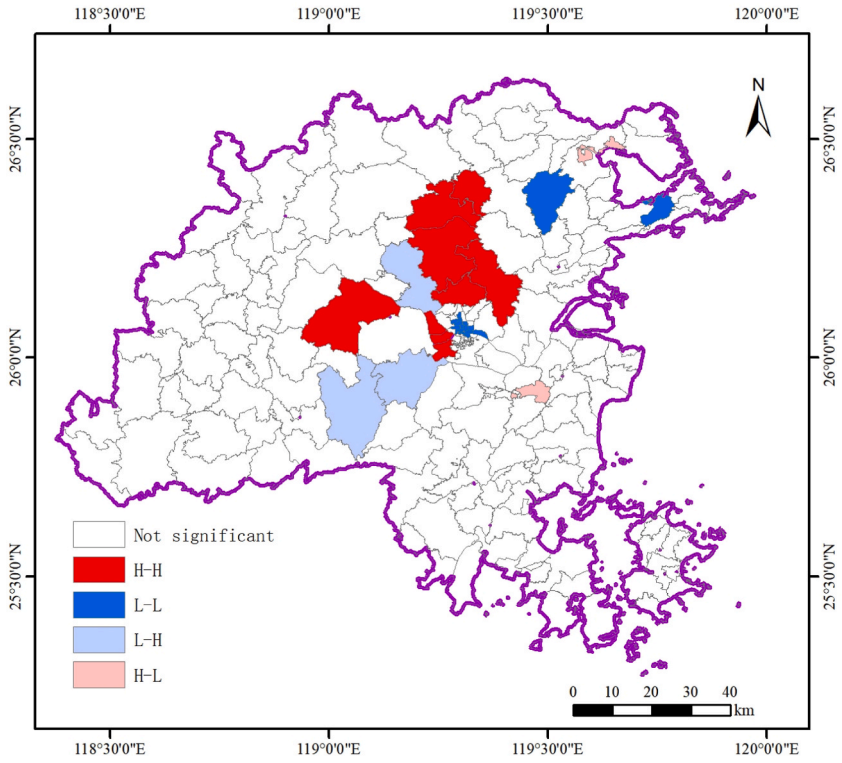

Fig. 10. Spatial autocorrelation of the accessibility of national fitness resources in Fuzhou at the street scale.

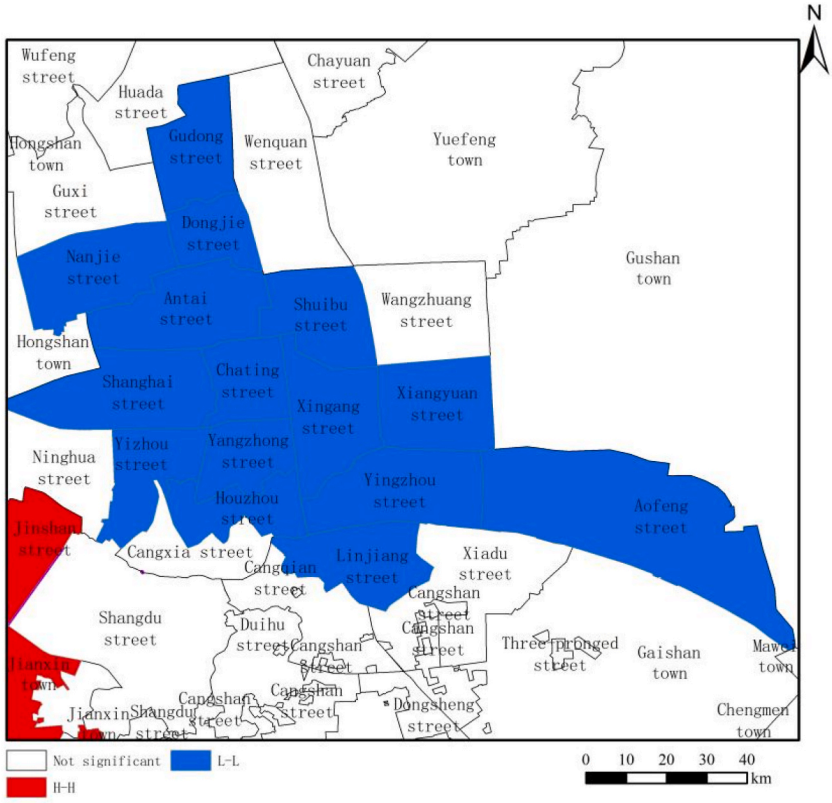

Fig. 11. Local spatial autocorrelation map of the accessibility of national fitness resources in Fuzhou at the street scale (Gulou District and Taijiang District).

4.4. Analysis of the balance of supply and demand for fitness for all resources

To reveal the equilibrium matching characteristics between the supply of national fitness resources and the demand in residential areas at the street scale in Fuzhou city, reference was made to the existing studies [35], and a bivariate local spatial autocorrelation analysis was conducted between the supply capacity of national fitness resources (i.e., accessibility) and resident demand (i.e., population of the residential areas) by using ArcMap 10.2 software. The global bivariate Moran's I was 0.0890, and the Z score was 2.5178, which passed the test of significance at the 5% level. This indicates that the supply and demand relationship of national fitness resources at the street scale in Fuzhou city is characterized by positive spatial agglomeration. In Fig. 12, the "high-high" pattern indicates that the supply capacity of national fitness resources and the demand level of the residential area are both high; the "low-low" pattern indicates that the supply capacity of national fitness resources and the demand level of the residential area are both low. The above two patterns of agglomeration occur in areas with relatively balanced supply and demand. The "high-low" pattern indicates that the area has a good supply of fitness resources and a low level of demand from neighbourhoods, suggesting that the area is ahead of its time in terms of planning allocations. The "low-high" pattern indicates that the supply capacity of national fitness resources in this area is poor and that the demand level of the residential area is high, which means that the allocation of national fitness resources in this area needs to be emphasized in future city development plans.

As shown in Fig. 12, there are seven areas in the "high-high" mode, mainly in Jianxin Town, Luozhou Town and Jinshan Street in Cangshan District, Yuefeng Town and Huanxi Town in Jin'an District, Shangjie Town in Minhou County, and Wufeng Street in Gulou District; most of these areas exhibit the "high-high" pattern in terms of accessibility to national fitness resources. The first five streets (towns and townships) mentioned above are new urban residential areas where the government has focused on development and planning in recent years, with large-scale cultural and sports centres and iconic sports and fitness venues. The newly constructed buildings and residential areas also strictly enforce the provisions of national regulations for the distribution of sports facilities in residential areas, and small and medium-sized national fitness resources are equitably distributed inside and outside residential areas. In addition, although it is a residential area, compared with that of the old city, the administrative area of the region is relatively wide, the road planning is reasonable, the transportation system is perfect and well developed, there are a variety of choices of transportation for residents, and the level of accessibility of fitness resources for the whole population is high. As a result, the model area's capacity to supply fitness is relatively balanced and reasonable for the level of demand in the residential area. Notably, Wufeng Street, which belongs to Gulou District, also presents the "high-high" mode. Wufeng Street is the largest street in Gulou District and has a high population density. To alleviate the demand for sports and fitness of residents in the district, Wufeng Street and Gulou District Culture,

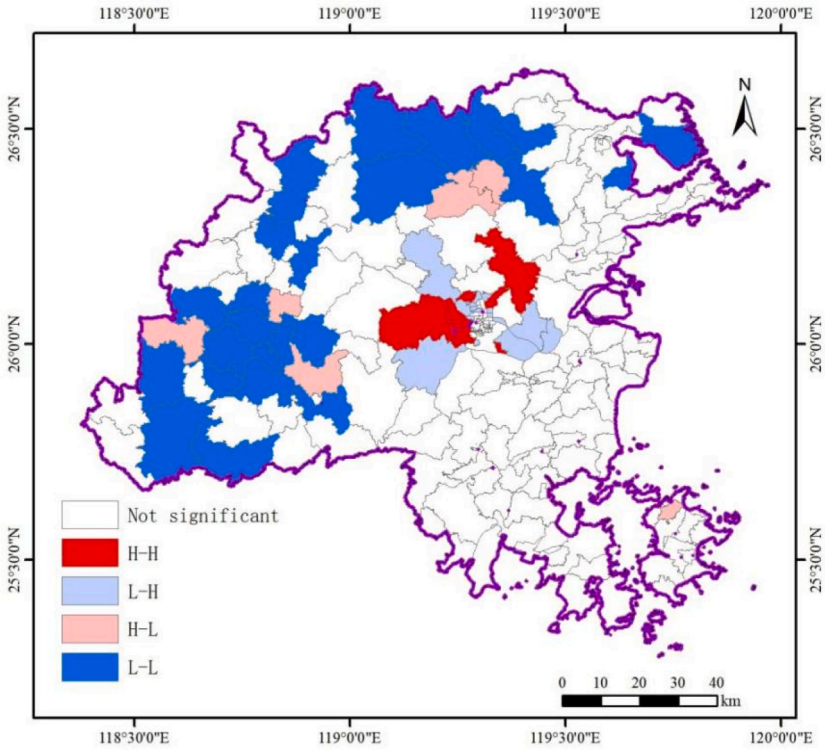

Fig. 12. Model for matching the supply and demand levels of national fitness resources in Fuzhou city at the street scale.

Sports and Tourism Bureau, the State Investment Group, the surrounding town of Hongshan, etc., all planned for the streets within densely populated neighbourhoods to surround parks, green spaces, and corners of vacant land, as the nature of the land permits, as well as additional basketball courts, soccer fields, fitness paths, a Wufeng Outdoor Sports Park, etc. Therefore, Wufeng Street's model of tapping fitness resources for all is effective and worth studying and exploring for application in the old city.

There are 23 districts with "low-low" patterns, mainly in Yongtai County west of Fuzhou and in the northern streets (townships) of Minqing, Minhou and Luoyuan Counties. The model region has a vast land area, but the jurisdiction is characterized by hills and mountains, a small resident population, high population mobility, and a predominantly tourism-driven industry throughout the region. For example, Yongtai County is considered "China's outstanding tourist county" and "Fujian Province's best tourist destination"; Minqing County is considered "China's hot springs hometown". The jurisdictions are mainly in the middle and low mountains, and most of the areas are at altitudes of 500–1000 m. While more than 250,000 people live there, up to 10 million tourists have visited annually in recent years. The new Yongtai Qingliang Sports Town and Huasi Yongtai International Health Sports Town, as well as most of the recreational resort areas, are used for the development of recreational and leisure travel within the jurisdiction. Therefore, due to the characteristics of pillar industries and the population in districts and counties in the "low-low" mode, the current supply of national fitness resources and the demand for fitness are relatively balanced.

The area presenting the "low-high" mode is dominated by the streets of the old city centre of Fuzhou, including five streets in Gulou District, namely, Antai Street, Hongshan Township, Guxi Street, Nanjie Street, and Huada Street, as well as five streets in Taijiang District, namely, Ninghua Street, Aofeng Street, Chayuan Street, Wangzhuang Street, and Xiangyuan Street. The above streets (townships and towns) have limited land resources, great difficulty optimizing the layout of urban space, and serious overload of their traffic-carrying capacity. In addition, the population density is high, and residential areas are concentrated, with strong demand for sports and fitness resources among residents, which makes it difficult for the supply of national fitness resources to meet fitness needs. The "low-high" area also includes Nanyu town and Jingxi town in Minhou County, Luoxing Street and Mawei town in Mawei District, and Chengmen town in Cangshan District. In recent years, as key areas for the industrial transfer of Fuzhou city's "3820″ strategic project, these districts have experienced rapid industrial and economic development, and the resident population has shown a straight rising trend. The Fuzhou High-tech Industrial Development Zone in Nanyu Town is one of the first batch of state-level high-tech zones in China. This zone attracts many high-tech enterprises and effectively drives the explosive growth of the resident population in the district. Chengguan Town in Cangshan District, as the location of the Sanjiangkou Area in Fuzhou New District, is the core of the "3820″ strategic project of Fuzhou city and has been recognized as a key area for industrial transfer in recent years through the strengthening of financing support and talent strategies. It has become a model area for building a better life in Fuzhou and is home to a cluster of emerging industries that constitute a main drivers for the development of Cangshan District and even Fuzhou. The occupancy rate of the residential area within its jurisdiction has also shown rapid growth this year. Although these regions have well-planned and

abundant national fitness resources, the population growth driven by rapid industrial and economic development has caused the construction of relevant national fitness facilities to lag behind the explosive growth in demand for sports and fitness. For emerging urban areas and new industrial agglomerations that are developing at a faster pace, the construction of fitness facilities for all should be accelerated to better meet residents' needs for fitness.

There are six districts with a "high-low" pattern, with a spatially fragmented distribution. The official statistics indicate that these areas have a low population density and are mostly located in suburban areas. Although there are no large-scale sports or fitness venues, the national fitness paths in the jurisdiction are widely distributed and reasonably laid out, with high accessibility to residents. For example, Xiaocang She Township, with a total area of only 58.4 square kilometres, has 60 national fitness resources of various types, such as basketball courts, gyms, table tennis courts and national fitness paths, including a total of 31 walking trails, accounting for 51.67% of fitness resources. Rixi Township, with a total area of only 124.3 square kilometres and a population of less than 7000 people, has walking paths, hiking trails and national fitness paths with a total area of more than 10,000 square metres. Scattered, small-scale and widely distributed community fitness paths, walking trails and other grassroots fitness resources play important roles in meeting the fitness needs of the whole community.

5. Conclusion and recommendations

5.1. Conclusion

With the improvement in living standards, people's need for material goods has gradually changed to a need for a better life, and national fitness is an important part of meeting that need in the new era. The allocation of resources for national fitness is the basic guarantee of national fitness and is the core aspect of improving and building a higher level of public services for national fitness. This study explored the construction of national fitness resources at different scales, such as districts (counties) and streets (townships), in Fuzhou city through a two-step mobile search method involving multiple travel modes, the Gini coefficient, and spatial autocorrelation analysis. The conclusions of the study are as follows: (1) The overall spatial allocation of national fitness resources in Fuzhou is relatively balanced, with small differences among districts (counties); however, the allocation of national fitness resources among different streets (townships and towns) within each district (county) is seriously inequitable, and there is a phenomenon of "spatial mismatch". (2) The spatial distribution of national fitness resources in Fuzhou city presents the characteristics of concentration in the centre, superficial dispersion, and dense distribution in the south and sparse distribution in the north. Gulou District and Taijiang District are areas with a very dense concentration national fitness resources, but most areas have insufficient resources per capita, indicating that the higher the administrative level of an area is, the more abundant its national fitness resources. Areas with insufficient per capita national fitness resources show an agglomeration-type scattered distribution and account for 44.56% of the total number of streets (townships and towns). Areas with sufficient per capita resources have a "decentralized patchy" distribution, accounting for 32.12% of the total number of streets (townships and towns). (3) The per capita area of national fitness resources in each street (township, town) in Fuzhou city shows the spatial aggregation characteristics of a "high-high" or "low-low" distribution, in which the "low-low" aggregation pattern area is relatively concentrated in Gulou and Taijiang Districts, and the areas with the other aggregation pattern are distributed in a fragmented manner. (4) The accessibility of national fitness resources in Fuzhou city is mainly dominated by low-accessibility and lower-accessibility areas, and there are positive aggregation characteristics of "high-high" and "low-low" distribution, in which the "high-high" agglomeration pattern street areas are found mainly in Jin'an District and Minhou County, which have recently developed as new residential agglomeration areas, and the "low-low" agglomeration pattern street area is found mainly in the old urban areas, with the centre at Cha-ting Street and An-tai Street spreading outwards. (5) The relationship between the supply and demand of national fitness resources is characterized by positive spatial agglomeration, with "high-high" mode areas mainly in the new urban areas and new residential areas of Cangshan District, Jin'an District and Minhou County and "low-low" mode areas mainly in Yongtai County and northern areas of Minqing County and Luoyuan County, which are characterized by many hills and mountain ranges. The "low-high" mode area, in addition to including the core streets of the old urban areas in Gulou District and Taijiang District, includes streets (townships) in Nanyu Township, Jingxi Township, Luoxing Street, Mawei Township, and Chengguan Township, which have been the focus of the industrial and economic transformation of Fuzhou city in recent years. Finally, the "high-low" pattern areas are located mostly in suburban areas and show a fragmented distribution pattern. (6) The rational planning and layout of scattered and small-scale grassroots fitness resources, such as national fitness paths and walking trails, play an important role in meeting people's fitness needs and making up for the underallocation of fitness resources for the whole community as a result of land constraints.

5.2. Recommendations

Top-level design must be strengthened, and community-based public services in sports must be promoted. First, to build a higher-level national fitness service system, we should focus on the top-level design. It is recommended that the Fuzhou Municipal People's Government take the lead and jointly construct reasonable, long-term, and land-based policy documents with the Sports Bureau, Natural Resources Planning Bureau, Environmental Protection Bureau, and Housing and Construction Bureau. Under the guidance of the National Fitness Implementation Plan, the planning and configuration standards for urban and community sports facilities in Fuzhou city should be formulated as soon as possible to standardize the development of urban sports public services, to promote the optimization of the planning of national fitness construction in old urban areas and urban centres and to accelerate the supporting construction of fitness resources in new urban areas. Second, synergies and cooperation between the sports public service sector and

other sectors should be strengthened. The current development of sports requires joint management by multiple departments. When formulating policy documents, the scope of management and responsibilities between departments should be refined as much as possible, and the units responsible for project implementation should be identified to prevent unclear responsibilities and powers and misplaced functions at the implementation stage. In addition, a good system of supervisory responsibility should be implemented, and project management and performance evaluation mechanisms should be improved to promote the implementation of the national fitness program and help the project be effective, preventing phenomena such as superficial implementation and formalism. Again, based on the top-level design, the grassroots level should also formulate targeted policy documents, with each district and county's culture and sports bureau regularly following up on the implementation of the National Fitness Implementation Plan, completing the registration of national fitness resource allocation in the area under its jurisdiction and developing a phased work plan. Finally, a diversified capital access mechanism for national fitness resources has been formulated to widely absorb social forces and capital to participate in the work of national fitness. For fitness resources in which social capital has been heavily invested, a flexible fee-charging system can be adopted for time slots, under the principle of meeting the basic physical exercise needs of residents, and local financial departments can set up special funds for sports to support, guide and incentivize more social capital to participate in the cause of national fitness and to promote the communalization of public services in sports.

The service capacity and effectiveness of the use of fitness resources should be enhanced. Promoting the solution of "where to go for fitness" is still an important task in promoting the construction of a strong sports country. First, we should accelerate the implementation of the national requirements for the opening of public stadiums free of charge or at a low cost and promote the opening of school stadiums to the community to enhance the quality of services and the utilization of venues and facilities. National public stadiums and school stadiums open to the community are needed to effectively alleviate people's growing demand for physical fitness and stadium supply, and venue management can be based on the area of the venue to reasonably determine the target population and capacity. Playgrounds, ballparks, and other outdoor venues and facilities may offer free, preferential or paid entry. In addition, the government may explore purchasing services through third parties commissioned by the professional organization of integrated planning. Second, we should address the multichannel revitalization of land resources by systematically determining the conditions for the construction of national fitness venues and facilities on vacant land, corner land, abandoned factories, building roofs and other spatial resources in the city for the relocation of old sports venues. The rational planning of the "golden edge and silver corner" strategy of development can improve the coverage of fitness paths in residential areas to alleviate the demand for national fitness venues and shortages of land for the construction of fitness sites. The construction of sports facilities has been actively integrated into parks, green spaces, slow-moving greenways and other areas to ease the demand for land for the construction of fitness venues for all. For old districts with limited land area, the space on the top floor can be fully utilized to configure simple fitness equipment, table tennis tables, gateball courts, etc. Finally, the sustainable use of venues hosting large-scale sporting events and their proliferation should be fully utilized. The sustainable utilization of venues after the conclusion of large-scale sports events is an important element in popularizing competitive sports among the public and implementing a national strategy for fitness. Large-scale stadiums should give full play to their role as venues for the benefit of the people so that they can be opened as much as possible, according to the principles of classification and orderly opening, to support cultural and sporting events, fitness guidance and other activities. Additionally, the use of business cards with events should promote the integration of sports with tourism and culture with sports. After the game, the diffusion effect of the venue can drive the construction of national fitness resources in the surrounding areas and enhance the atmosphere of fitness for all.

The construction of national fitness resources in new urban areas and new industrial clusters should be accelerated. In new urban areas and new industrial agglomerations, community buildings should be fully utilized to enhance the work of the provincial and municipal Sports Bureau of the People's Project, the Sports Lottery Community Chest and other channels to continuously increase the construction of sports and fitness facilities. Additionally, the "Urban Public Service Facilities Planning Standards" and "Urban Residential Planning and Design Standards" should be strictly implemented to strengthen the sports facilities and project development in a manner that is synchronized with the supply of land, urban planning, and construction efforts. For venues that have been completed, the person responsible for the facility should be clearly identified, and records should be archived so that maintenance and management work can be done during the subsequent period of use. Policies should be completed to effectively address the issue of the last "kilometre".

6. Research limitations and future prospects

This study innovatively adopts a two-step mobile search method based on walking, nonmotorized vehicles and motorized vehicles to analyse the spatial allocation of national fitness resources in Fuzhou city at different spatial scales, such as the municipal, district and street levels, yielding results that are more accurate, scientific and comprehensive than previous research results. In a follow-up study, we can further incorporate data on residents' social and economic attributes to explore the demand characteristics of different populations for physical fitness to quantify the differences in the accessibility of national fitness resources for different populations. Second, in reality, there are some areas with high accessibility to national fitness resources, but residents travel further from their homes to reach other resources. Whether this is due to the homogenization of national fitness resource allocation or other reasons is worth exploring. Again, it is important to consider how differences in the spatial distribution and accessibility of fitness resources affect residents' health and participation in sports, which is a key concern for the future, and understanding this issue will help stimulate people's participation in sports. Finally, due to data availability and limited resources, this study analyses the allocation of national fitness resources in only Fuzhou city in 2022, and in the future, when conditions permit, data from more cities can be collected to conduct more in-depth horizontal and vertical comparative studies over a longer period and a larger space and to determine the

cyclical pattern of change.

Ethical approval and consent to participate

The authors declare that they have no known competing financial interests or personal relationships that seem to affect the work reported in this article. We declare that we have no human participants, human data, or human tissues.

Additional information

No additional information is available for this paper.

Data availability statement

The datasets generated and analysed during the current study are available in the 2022 Fujian Provincial Sports Venue and Facility Survey data database.

The publicly available repository can be found below: https://tyj.fujian.gov.cn/zwgk/.

Funding

This work was supported by the Fujian Social Science Planning Project (FJ2022C018) and the Fujian Jiangxia College National Fund Cultivation Project (JXS2022008).

CRediT authorship contribution statement

Shan Jiang: Writing – original draft, Methodology. **Laibing Lu:** Visualization, Supervision, Data curation. **Haixia Wang:** Software, Data curation. **Jinru Liu:** Resources, Data curation. **Jinfu Xu:** Data curation, Conceptualization. **Qiuying Li:** Writing – review & editing, Software, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Xu Jinfu reports financial support was provided by Fujian Provincial philosophy and social Science planning leading group. Xu Jinfu reports financial support was provided by Fujian Jiangxia College. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] General Office of the Central Committee of the Communist Party of China and General Office of the State Council, in: Opinions on Building a Higher and Higher Level Public Service System for National Fitness, 2022. https://www.gov.cn/zhengce/2022-03/23/content_5680908.htm.2022.
[2] H. Lin, L. Shi, Research on spatial optimization and integration of urban public sports facilities based on GIS spatial analysis: taking Shenyang as an example, Journal of Shenyang Sports Institute 5 (2019) 41–43, 76.
[3] R.C. Liu, J.K. Zheng, H.Y. Han, Spatial expansion of urban fitness for all: extraterritorial experience and Chinese path, Sport Sci. 5 (2023) 28–35.
[4] X. Xiao, Aultman Hall, R. Manning, et al., The impact of spatial accessibility and perceived barriers on visitation to the US national park system, J. Transport Geogr. 68 (2018) 205–214.
[5] S.R. Liu, Y.C. Qin, Y.N. Xu, Inequality and influencing factors of spatial accessibility of medical facilities in rural areas of China: a case study of henan Province, Int. J. Environ. Res. Publ. Health 10 (2019) 1833.
[6] M. Cheng, W.W. Huang, Spatial accessibility evaluation of elderly facilities in Shanghai based on Gaussian two-step moving search method, Journal of Fudan (Natural Science Edition) 2 (2020) 129–136.
[7] F. Chang, L.K. Wang, Y. Ma, et al., Do urban public service facilities match the population? : an assessment based on community living circles, Adv. Geosci. 4 (2021) 607–619.
[8] F. Wei, Greener urbanization? Changing accessibility to parks in China, Landsc. Urban Plann. 157 (2017) 542–552.
[9] F. Senol, I.A. Kaya, GIS-based mappings of park accessibility at multiple spatial scales: a research framework with the case of Izmir (Turkey), Local Environ. (2021) 1379–1397.
[10] L.B. Liu, T. Alford, T. Onega, et al., Refining 2SVCA method for measuring telehealth accessibility of primary care physicians in Baton Rouge, Louisiana, Cities 138 (2023) 104364.
[11] D.N. Wang, C.J. Qiao, S.J. Liu, et al., Assessment of spatial accessibility to residential care facilities in 2020 in Guangzhou by small-scale residential community data, Sustainability 8 (2020) 3169.
[12] C. Guida, G. Carpentieri, Quality of life in the urban environment and primary health services for the elderly during the Covid-19 pandemic:An application to the city of Milan(Italy), Cities 110 (2021) 103038.
[13] B.Y.Liu,N.Qiu,T.J.Zhang,Research on the matching degree of supply and demand of elderly facilities under the perspective of social class differentiation: a case study of the central city of Tianjin.Southern Architecture, https://kns.cnki.net/kcms2/detail/44.1263.TU.20230706.1620.002.html.
[14] J.E. Ruseski, B.R. Humphreys, K. Hallman, et al., Sport participation and subjective well-being: instrumental variable results from German survey data, J. Phys. Activ. Health 2 (2014) 396–403.
[15] E.B. Iversen, G. Cuskelly, Effects of different policy approaches on sport facility utilization strategies, Sport Manag. Rev. 4 (2015) 529–541.
[16] Y.J. Chen, N. Lin, Y.Y. Wu, et al., Spatial equity in the layout of urban public sports facilities in Hangzhou, PLoS One 9 (2021) e0256174.
[17] F. Salarvandian, S.A. Hosseini, A. Moradi, et al., Assessing the spatial distribution of sports spaces within walkong distance in Tehran, Int. J. Unity Sci. 4 (2020) 557–577.
[18] H. Gary, L. Mitch, N. Paul, Accessibility to sport facilities in Wales: a GIS-based analysis of socioeconomic variations in provision, Geoforum 62 (2015) 105–120.

[19] G. Kozma, K. Teperics, K. Czimre, et al., Characteristics of the Spatial Location of Sports Facilities in the Northern Great Plain Region of Hungary.Sports10, 2020, p. 157.
[20] S.A. Lee, J.Y.J. u, J.E. Lee, et al., The relationship between sports facility accessibility and physical activity among Korean adults, BMC Publ. Health 16 (2016) 893.
[21] B. Zhang, Y.F. Dong, K. Kelobonye, et al., Delineating walking catchment of the existing and proposed public sports facilities with open-source data: a case study of nanjing, Applied Spatial Analysis and Policy 2 (2023) 729–749.
[22] Y. Liu, H. Wang, C. Sun, et al., Equity measurement of public sports space in central UrbanAreas based on residential scale data, Int. J. Environ. Res. Publ. Health 19 (2022) 104.
[23] Y. Chen, B. Zhang, M.K. Li, et al., Concatenating daily exercise routes with public sports facilities, bicycle lanes, and green spaces: a feasibility analysis in Nanjing, China, Land 11 (2022) 2251.
[24] Introduction to Fuzhou city [2021-11-12], http://www.fuzhou.gov.cn/zgfzzt/zjrc/zrdl/202111/t20211112_4239329.htm.
[25] J. Radke, L. Mu, Spatial decomposition,Modelling and mapping service regions to predict access to social programs, Geographic Information Science 2 (2000) 105–112.
[26] M.S. Alam, N.J. Tabassum, A.I. Tokey, Evaluation of accessibility and equity to hospitals by public transport: evidence from six largest cities of Ohio, BMC Health Serv. Res. (2023) 598.
[27] Y. Shao, W. Luo, Supply-demand adjusted two-steps floating catchment area (SDA-2SFCA) model for measuring spatial access to health care, Soc. Sci. Med. 296 (2022) 114727.
[28] W.Y. Yang, X. Li, H.L. Chen, et al., A study on the accessibility and equity of multiscale green spaces in Guangzhou based on the two-step moving search method with multiple row patterns, J. Ecol. 5 (2021) 6064–6074.
[29] W.Y. Yang, B.Y. Chen, X.S. Cao, et al., The spatial characteristics and factors influencing modal accessibility gaps: a case study for Guangzhou,China, J. Transport Geogr. 60 (2017) 21–32.
[30] Z.Q. Zhu, C.Z. Huang, L. Liu, et al., Influence of built environment on the use of urban greenways from the perspective of "greenway-neighbourhood": a case study of Guangzhou, Trop. Geogr. 2 (2019) 247–253.
[31] L. Liu, Y. Zhao, H. Lyu, et al., Spatial accessibility and equity evaluation of medical facilities based on improved 2SFCA: a case study in Xi'an, China, Int. J. Environ. Res. Publ. Health 20 (2023) 2076.
[32] M.O. Lorenz, Methods of Measuring the Concentration of Wealth, vol. 70, Publications of the American Statistical Association, 1905, pp. 209–219.
[33] S.X. Yang, J.F. Xu, R.Y. Yang, Research on coordination and driving factors of sports industry and regional sustainable development—empirical research based on panel data of provinces and cities in eastern China, Sustainability 3 (2020) 813.
[34] J.F. Xu, S.X. Yang, The impact and mechanism of public sports services on residents' happiness: an empirical study based on CGSS (2017) microsurvey data, J. Wuhan Inst. Phys. Educ. 8 (2021) 26–32.
[35] Y. Zhao, F. Xu, Y.L. Wan, A method for analysing spatial accessibility and supply/demand balance of park green space based on improved gravity model, Earth Information Science 10 (2022) 1993–2003.