Original Research Article

Study on the spatial distribution characteristics and influencing factors of pension service institutions in Shijiazhuang city of China

ABSTRACT

As the capital city of Hebei Province in China, Shijiazhuang faces the problem in the aging of the population that has never been faced before. In order to optimize the allocation of pension service resources in Shijiazhuang city, it is very important to explore the spatial characteristics and influencing factors of the pension service institutions. In this paper, based on data of Shijiazhuang pension service institutions and Shijiazhuang Statistical Yearbook, we used ArcGIS and SPSS software to analyze the spatial characteristics and influencing factors of the pension service institutions in Shijiazhuang. The results showed that: ①The number of pension service institutions in northwest of Shijiazhuang was fewer than that in southeast, but the direction was not obvious. ② The pension service institutions in Shijiazhuang formed a multi-center cluster distribution pattern in the whole city, and the cluster centers were mostly located in urban areas. The high-value agglomerations areas were located in Changan, Zhengding and Gaocheng County of Shijiazhuang under the condition of the significance level α = 0.05. ③ The accessibility of pension service institutions in Shijiazhuang was relatively high in general. Most of pension institutions were located within the 15-minute isochronous circle, and the pension service institutions accessibility presented a spatial pattern of gradually decreasing from the middle to the surrounding areas. ④ Correlation analysis indicated that the number of resident population, elderly population, GDP, public financial expenditure and accessibility were the main factors affecting the distribution characteristics of pension service institutions in Shijiazhuang under the condition of the significance level α = 0.05. It showed that the number of regional pension institutions had great dependence on population and economic development level. This study will provide theoretical support and help for the relevant departments to reasonably plan pension institutions and related service facilities.

Keywords: Pension service institutions; spatial distribution characteristics; influencing factors; Shijiazhuang city

1. INTRODUCTION

With the growing challenge of aging populations around the world,pension issues become the focus of academic attention [1-3]. Recent years, the number of the elderly population in Chinais increasing gradually, and the problem of aging population of China is becoming serious[4-7]. According to the criteria of UNESCO, a country or region is aged when the number of elderly people aged over 60 exceeds 10% of the total population, or the number of elderly people aged over 65 exceeds 7% [8]. Fromthe data of the“China’s seven census”,

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we can see that the population aged over 60 of China accounts for 18.7% of the total population, and the population aged over 65 accounts for 13.50%. The proportion of aged population in China has almost reached twice the United Nations standard. The rapid population aging arouses the enormous demands of elderly people for institutional care services, and the construction of pension service institutions is an effective way to solve the pension problem [9]. However, the supply of elderly care facilities is still short in quantity.And a structural imbalance on the nursing homes has appeared in many Chinese cities [10-12].

In order to reasonable allocation of endowment facilities, many studies on the spatial distribution characteristics and accessibility of pension service institutions had appeared. For example, Jiang et al., [4] usedcrawler technology to obtain the number of nursing homes in 285 Chinese cities and applied a geo-visualization technique to map their spatial distributions. Cheng et al., [12] explored a decision-making approach for measuring spatial equity in Tianjin city. And the distribution of three categories of elderly-care facilities in Tianjin was examined by integrating the analysis of the current situation, accessibility, Lorenz curve and Gini coefficient, and spatial autocorrelation.Tao et al., [13] adopted a two-step floating catchment area method with an additional distance-decay function to measure accessibility to residential care facilities in Beijing.Cai et al., [14] explored the spatial variation in the accessibility of residential aged care facilities (RACFs) and compared the service capacity of public RACFs and private RACFs.

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As the capital city of Hebei Province, Shijiazhuang cityhas a large elderly population, which is increasing year by year. The Shijiazhuang Statistic Yearbook 2020 showed that the population aged over 60 is 2.075 million, accounting for 18.47% of the total population in Shijiazhuang, and the population aged over 65 is 1.445 million, accounting for 12.86%. In recent years, Shijiazhuang has continuously improved its elderly care service system based on home care, supported by community, supplemented by institutions and combined with medical care. In order to increase the old-age service security capacity in Shijiazhuang, it has issued policy documents such as the “13th five year plan for the construction of Shijiazhuang pension service system”, “Opinions on deepening the reform of financial support for the elderly service system”, and “Some measures for Shijiazhuang to fully open the pension service market to improve the quality of pension service”. Although Shijiazhuang has made great progress in the construction of elderly service facilities, there is still a large gap between it and the growing demand for social elderly services. Currently, researches on the issue of elderly care in Shijiazhuang is mainly focused on three aspects: exploration on the feasibility of pension mode [15], a survey on nursing care service capacity[16], and empirical analysis of nursing home location factors[17]. There is a lack of studies on the spatial distribution of elderly care institutions in Shijiazhuang and their influencing factors. For providing a theoretical foundation and basis for the optimal allocation of elderly facilities in Shijiazhuang, this paper used ArcGIS to analyze the spatial characteristics of pension service institutions, and analyzed the reasons for the formation of spatial characteristics with the help of SPSS software.

2. MATERIAL AND METHODS

2.1 Data sources

This study adopted the administrative division of Shijiazhuang in 2020 (includingXinji City). Information about pension service institutions come from the official website of Shijiazhuang Bureau of Internal Affairs, the elderly population data was taken from the Seventh Population Census of the People's Republic of China. Other relevant data such as the level of economic development and public expenditure were taken from the 2020 Shijiazhuang Statistical Yearbook. The names and addresses of the 255 registered elderly institutions were obtained from the List of Information on Elderly Service Institutions in Shijiazhuang released by the Shijiazhuang Civil Affairs Bureau and the 2020 List of Elderly Institutions in Xinji released by

the Xinji Municipal Government. The addresses of the 255 registered elderly institutions were transformed to geographical location using the Baidu Map and ArcGIS software. The traffic network data of Shijiazhuang region was also involved. The traffic network data included railway and road data of Shijiazhuang city, such as subway, highway, national highway, expressways, main road, secondary road and minor road et al. Traffic data was mainly vectorized by ArcGIS software based on Amap.

2.2 Research methodology

2.2.1 Kernel density estimation

Kernel density estimation is an effective index to measure the spatial distribution of regional elements. Its principle is to obtain the continuous density surface of discrete elements through surface interpolation and smoothing processing, so as to intuitively display the spatial distribution and aggregation characteristics of elements [18]. This paper used the kernel density estimation method of ArcGIS software to measure the spatial distribution of elements of pension service institutions. The greater the density value, the more concentrated the spatial distribution of pension service institutions. The formula is as follows :

$$f_n(x) = \frac{1}{nh}\sum_{i=1}^{n} k\left(\frac{x - x_i}{h}\right)$$

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Where: $f_n(x)$ is the kernel density estimate value at point x, h is the band width, n is thenumber of the pension service institutions in Shijiazhuang city, k is the kernel function, and $(x - x_i)$ is the distance from point x to point x_i.

2.2.2 Spatial hotspot analysis

The spatial hotspot analysis tool (Getis-ORD Gi*) in ArcGIS was used to calculate the Z value and P value for each county of Shijiazhuang. If the calculated result Gi*>0, it indicated that the study area presents a high-value aggregation area, namely "hot spot". If Gi*<0, it indicated that the study area presents a low-value aggregation area, namely the "cold spot". Z-score was used to make statistical inference for Gi* results [19]. If the difference was not statistically significant, the observed values were considered to be randomly distributed in the study area.

2.2.3 Accessibility analysis

With the subways, highways, national highways, expressways, major roads, secondary roads and minor roads of Shijiazhuang city, the road network system was constructed, and the isochronous circle method was used to calculate the accessibility of pension service institutions. Then the influence of the Shijiazhuang transportation network on the spatial distribution pattern of pension service institutions was analyzed from a quantitative perspective. Considering the influence of the actual operating speed of different roads on accessibility, the road traffic network was transformed from spatial distance to time cost by assigning different speed criteria to different classes of roads according to Table 1. The accessibility of pension institutions was calculated according to thresholds of 15 min, 30 min, 60 min and 90 min [20].

Table 1. Speed limits for the different grades of road in Shijiazhuang

Roads Type	Subway	High speed	National roads	Expressways	Main roads	Secondary roads	Minor roads
Speed/(km-h^{-1})	80	120	70	80	60	40	30

3. RESULTS AND DISCUSSION

3.1 Spatial distribution patterns

3.1.1Quantity distribution characteristics

The spatial distribution of pension service institutions in Shijiazhuang presented regional imbalance (Figure 1). As can be seen from Figure 1, the distribution pattern of the number of pension institutions in Shijiazhuang presented a directional characteristic of fewer in the northwest and more in the southeast. Counties or districts with a large number of pension institutions were mainly concentrated in the central urban area and their southeast. Among them, Changan, Gaocheng and Zhengding county had the largest number of pension institutions, each more than 20. The second was Zhaoxian county, the number of pension institutions was 16~20; In the third place are Xinhua, Qiaoxi, Yuhua, Xingtang, Xinle, Shenze, Jinzhou and Xinji, the number of these eight counties or districts ranged from 11 to 15; Lingshou, Zanhuang, Wuji, Luquan and Luancheng county ranked fourth. The number of pension institutions in these five counties ranged from 6 to 10. Bottom of the list were Pingshan, Jingxing, Jingxingkuangqu, Yuanshi and Gaoyi county, the number of pension institutions were less than 5. According to the Figure 2, the average number of aged population serving in pension institutions in Wuji, Pingshan, Yuanshi and Jingxing county was higher than other counties or districts, which mean that pension institutions in these areas had more pressure.

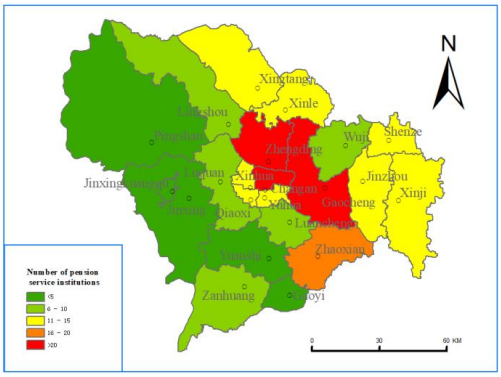

Fig.1.Distribution characteristics of the number of the pension institutions

Fig.2. Average number of aged population serving in pension institutions in different counties

3.1.2 Standard deviation ellipsoids and kernel density analysis

In order to further characterize the spatial distribution of pension service institutions in Shijiazhuang city, standard deviation ellipse and kernel density estimation methods were used to visualize the distribution direction and pattern (Figure 3).

The results of the standard deviation ellipse analysis showed that the spatial distribution of pension service institutions was centered at the junction of Changan, Gaocheng and Zhengding. The spatial distribution direction of pension service institutions in Shijiazhuang was not obvious, showing a slightly "northwest to southeast" direction, which further verified the directional characteristics of the number distribution of pension service institutions mentioned above. This directional distribution characteristic of pension institutions of Shijiazhuang city was mainly subject to the geographical characteristics and regional planning. For example, Pingshan, Jingxing and Jingxingkuangqu were located in Taihang Mountain area of China, and there were only a few pension institutions there.

The natural fracture method was used to spatially display the results of kernel density analysis. The results showed that the pension service institutions in Shijiazhuang formed a multi-center cluster distribution pattern. Among them, Changan, Qiaoxi, Xinhua and Yuhua District in the city center were significant high-value agglomeration areas. In addition to these areas, other gathering centers were mostly located in urban areas of counties or districts, and the number of pension institutions in rural areas was relatively small.It can be seen that the pension institutions of Shijiazhuang were mainly distributed in urban areas, and the balance of their spatial distribution needs to be improved.

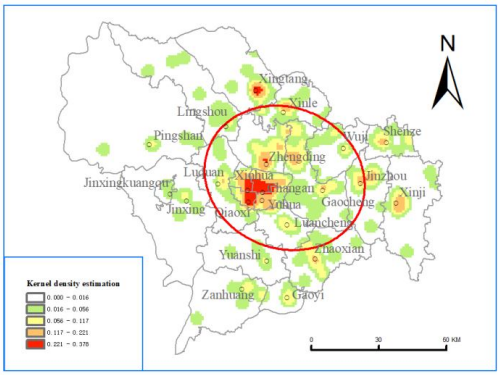

Fig.3. Standard deviation ellipse and kernel density analysis

3.1.3 Spatial hotspot analysis

Spatial hotspot analysis can identify the specific location of spatial aggregation of pension institutions (Figure 4).Bright green, orange and red colors were used to represent high-value gathering areas of pension service institutions, namely hot spots. Light green color was used to represent the low-value gathering area of pension service institutions, namely the cold spot. As can be seen from Figure 4, the high-value area of the number of pension institutions in Shijiazhuang was mainly concentrated in the southeast area, while the low-value area was mainly concentrated in the northwest, which further verifies the directional characteristics of the number distribution of pension service institutions mentioned above. Besides, the Z values of Changan, Xinhua, Zhengding and Gaocheng were greater than 1.96, which indicated that pension service institutions in these regions presented a significant high-value aggregation patternunder the condition of the significance level $\alpha = 0.05$. While Z values of other counties ranged from -1.587 to 1.96. This indicated that the spatial distribution of the number of pension institutions in other districts and counties is relatively balanced.

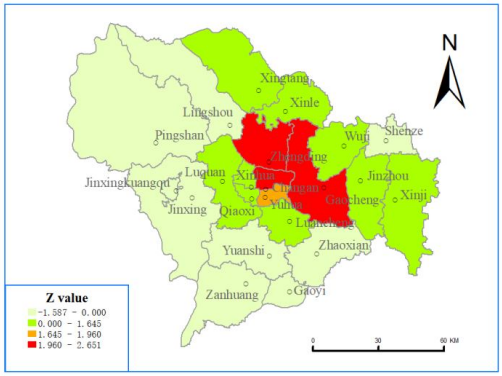

Fig.4. Spatial hotspot analysis

3.2 Accessibility analysis

The Figure 5 showed that the accessibility of pension institutions in Shijiazhuang was relatively high in general. Most of pension institutions were located within the 15-minute isochronous circle, and the pension institutions accessibility presented a spatial pattern of gradually decreasing from the middle to the surrounding areas. Among them, the accessibility of pension service institutions in central urban areas was the highest, such as Changan, Xinhua, Qiaoxi and Yuhua, which were almost all located within the 15-minute isochronous circle and had obvious advantages compared with surrounding areas.The accessibility of pension service institutions in peripheral districts and counties of the main urban area was good. Most of them were located within the 15 min isochronous circle, and only a small part was located within the 15-30 min isochronous circle. Such as Luancheng, Gaocheng, Luquan and Zhengding. Due to the proximity of the main city, dense road network, better road traffic conditions, convenient transportation, these areas of the pension institution accessibility was good. In the peripheral counties and cities of Shijiazhuang, the accessibility of pension service institutions in the east was higher than that in the west. For example, Jinzhou, Wuji, Shenze and Xinji which located in the east, most of the pension institutions in these regions were in the 15 min isochronous circle, and some were in the 15-30 min isochronous circle. Because of the terrain of these counties and cities was flatter and the roads were more dense than those in the west. The worst accessibility was the pension service institutions in Pingshan County in the northwest of Shijiazhuang, and the accessibility was more than 30 minutes in most areas, which was mainly due to the fact that Pingshan County was located in mountainous areas, with sparse road network and inconvenient transportation.

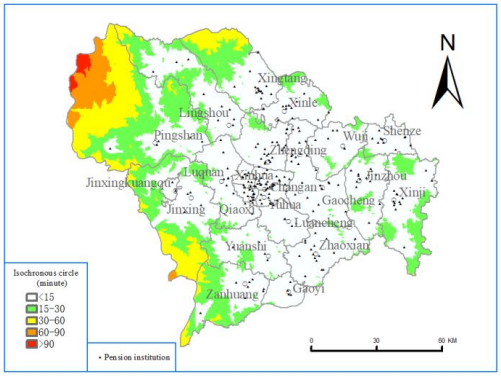

Fig.5. Accessibility analysis

3.3 Analysis of influencing factors

In order to explore the influencing factors of spatial distribution of pension service institutions in Shijiazhuang, this paper selected 10 variables from four dimensions of population, economy, medical care and transportation. The variables included the number of permanent population, number of elderly population, GDP, per capital gross regional product, public financial expenditure, per capital disposable income of urban residents, per capita disposable income of rural residents, number of medical and health institutions, number of medical and health beds and transportation accessibility. The linear regression method was used to analyze the relationship between the number of pension service institutions and 10 independent variables in each county or district (Table 2).

As can be seen from Pearson's correlation coefficient, there was a positive linear correlation between all independent variables and the number of pension service institutions. The order of linear correlation from large to small was: the number of elderly population > the number of permanent population > GDP > public financial expenditure > accessibility > per capital disposable income of urban residents > per capita disposable income of rural residents > the number of medical and health institutions > the number of medical and health beds > per capital gross regional product. The correlation coefficient between the number of permanent residents, the number of elderly population and the number of pension service institutions was greater than 0.6, which was a strong correlation. The correlation coefficient between GDP, public finance expenditure, accessibility and the number of pension service institutions was between 0.4 and 0.6, belonging to the moderate degree of correlation. The correlation coefficients between per capita disposable income of urban residents, per capita disposable income of rural residents, the number of medical and health institutions, the number of medical and health beds and the number of pension institutions ranged from 0.2 to 0.4, belonging to weak correlation. The correlation coefficient between per capital gross regional product and the number of pension institutions was less than 0.2, which was extremely weak.

The significance correlation coefficient values showed that, among the 10 independent variables, the number of permanent resident population, the number of elderly population, GDP, public financial expenditure and accessibility were the main factors affecting the distribution of pension service institutions in Shijiazhuang under the condition of the significance level $\alpha = 0.05$, and the number of permanent resident population, the number of elderly population, GDP, public financial expenditure have a more significant impact on the distribution of pension service institutions under the condition of the significance level $\alpha = 0.01$. It is well known that if the number of elderly population and resident population is large, the elderly care demand is large, and the number of pension institutions is naturally large. The construction of pension institutions usually requires financial support from the

government. When the regional economic development level is high, the financial expenditure for pension development in this region is large, and the number of pension institutions is also large. It can be concluded that the number of pension institutions largely depends on the local economic development level and the public financial expenditure of the local government. Accessibility will also affect the distribution of pension institutions to a certain extent. In areas with high accessibility, due to dense road network and convenient transportation, residents have a short time to reach the pension institutions, and the number of pension institutions was relatively large. Areas with poor accessibility have sparse road network and poor road quality, inconvenient transportation, the number of pension institutions is small.

Table 2. The R^2 and P value between the variables and the number of pension service institution for each county

Independent variable	Resident population	Elderly people	GDP	Per capital gross regional product.	Public finance expenditure	Per capital disposable income of urban residents	Per capital disposable income of rural residents	Medical and health institutions	Medical and health beds	Accessibility
R^2	0.709	0.715	0.595	0.142	0.581	0.380	0.311	0.277	0.225	0.484
P	0.0005	0.004	0.005	0.287	0.006	0.060	0.105	0.133	0.185	0.021*

4 CONCLUSION AND PROSPECT

4.1 Conclusion

With the data of pension institutions in Shijiazhuang and relevant statistical yearbooks, this study applied kernel density estimation, standard deviation ellipse, spatial hotspot analysis, accessibility analysis and linear correlation analysis methods to research the spatial characteristics and influencing factors of elderly institutions in Shijiazhuang. The conclusions as follows:

(1) The spatial distribution of pension service institutions in Shijiazhuang presented the characteristics of less in northwest and more in southeast, but the direction was not obvious, showing a slightly "northwest to southeast" direction. The results of kernel density analysis showed that the elderly care institutions in Shijiazhuang formed a multi-center cluster distribution pattern in the whole city, and the cluster centers were mostly located in urban areas. Spatial hot spot analysis results further indicated that the high-value clusters were located in Changan, Zhengding and Gaocheng of Shijiazhuang cityat the 5 % level of significance.

(2) The accessibility of pension institutions in Shijiazhuang was relatively high in general. Most of pension institutions were located within the 15-minute isochronous circle, and the pension institutions accessibility presented a spatial pattern of gradually decreasing from the middle to the surrounding areas. The central city has the highest accessibility, and the northwest of Pingshan County has the lowest accessibility. The main reason for this

phenomenon was that Pingshan County was located in mountainous areas, where had sparse road network and inconvenient transportation.

（3） The significance correlation coefficient values indicated that the number of permanent resident population, the number of elderly population, GDP, public financial expenditure and accessibility were the main factors affecting the distribution of pension service institutions in Shijiazhuang under the condition of the significance level $\alpha = 0.05$, and the first four variables had more effect on the distribution of pension service institutions under the condition of the significance level $\alpha = 0.01$. The number of pension institutions depends on the population and the level of economic development in the region.

4.2 Prospect

Improving the efficiency of the allocation of elderly service resources by optimizing the spatial layout of pension service facilities is a hot topic issues for the government and scholars. In order to actively respond to the problem of ageing, 14th Five-Year Plan of Shijiazhuang explicitly proposed to build a "15-minute" service circle for elderly care services in urbanized areas. This study found that the spatial accessibility of elderly care institutions in Shijiazhuang was high. The time circle of "15 minutes" basically covered the whole urban area of Shijiazhuang city, but the uneven spatial distribution of pension service institutions in Shijiazhuang was prominent. The high-value clusters were located in Changan, Zhengding and Gaocheng of Shijiazhuang city at the 5 % level of significance. As the number of permanent resident population, the number of elderly population, GDP, public financial expenditure and accessibility were the main factors affecting the distribution of pension service institutions in Shijiazhuang, it was difficult to realize the spatial equilibrium allocation of pension service institutions by simply using market mechanism. The government needed to play a guiding role for leading the spatial distribution of elderly service facilities reasonably. The balanced development of pension service institutions will be realized through scientifically determining the proportion of elderly institutions in each region, supporting land, finance, taxation and personnel policies by government.

Although in this paper we achieved some research results, there are still some shortcomings. For example: ① It was impossible to classify the size of pension service institutions according to the number of beds of pension service institutions for the lack of beds in pension service institutions. and then the distribution characteristics of pension service institutions of different sizes, and whether the number of beds can meet the needs of the elderly population in a certain area failed to be analyzed; ② The spatial analysis of different types of pension institutions could not be conducted separately due to the lack of the attributes of each pension service institutions such as the combination of medical and nursing care, ordinary apartments for the elderly, welfare homes. In future, we will explore these issues further and in depth so as to provide more detailed support and help for relevant departments to rationally plan pension institutions.

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