Original Article

Spatial accessibility to midwifery institutions in Wuhan city

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Background: As one of the major medical resources, midwifery facilities provide important healthcare for maternal and newborn health. The research on the spatial distribution of midwifery facilities can help to improve the convenience of seeking midwifery service. The study explored the spatial distribution of midwifery institutions and residents in Wuhan, the capital city of Hubei Province in China, with the aim to further optimize the planning and allocation of obstetric resources.

Methods: We located all the midwifery institutions in Wuhan and analyzed the spatial accessibility to midwifery institutions by using the Generalized 2-Step Floating Catchment Area (G2SFCA) method.

Results: The central districts of Wuhan were densely populated, with densely-distributed midwifery institutions; in contrast, the peripheral districts had low population densities, with diversely-scattered midwifery institutions. Thus, the spatial accessibility to midwifery institutions was good in the central districts of Wuhan but poor in the peripheral districts.

Conclusions: The spatial accessibility to midwifery institutions in Wuhan, as calculated by using the G2SFCA method, can reflect the convenience of Wuhan residents in seeking health care services and thus offer useful information for the planning and allocation of urban midwifery institutions and other medical resources.

Keywords: Spatial accessibility; midwifery institutions; G2SFCA

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Introduction

Medical institutions are key providers of basic public health services in districts and directly affect the levels of urban medical services and the quality of life of residents. The rational allocation and utilization of medical institutions is the key to equal access to health care. In China, nearly two-thirds of the population are women and children. As one of the major public health and medical services, midwifery facilities are especially important for maternal and newborn health (1,2). Previous studies have shown that the travel distance to a hospital is a major cause of maternal mortality (3). Data from research on the spatial distribution of midwifery facilities can improve the access of urban residents to midwifery services and thus increase the overall health level of pregnant women and newborns.

Spatial accessibility refers to the distance to healthcare providers, which has been recognized as a significant barrier to healthcare access. It can be used to describe the convenience of seeking medical service. Many methods can be used to measure spatial accessibility, mainly based on two factors: (I) distance barrier between supply and demand; and (II) a supply/demand ratio, which reflects the scarcity of medical resources (4). Spatial accessibility of midwifery facilities reflects whether pregnant women can conveniently access to medical services. Before the implementation of the "Universal Two-child" policy in China, the imbalanced allocation of obstetric resources and the overload of tertiary midwifery institutions had already become challenging issues in large and medium-sized cities (5). With the

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implementation of the new policy, the demand for children dramatically increases, bringing more pressure and challenges to the already overwhelmed midwifery facilities in large and medium-sized cities (6,7). Studies on the spatial accessibility to midwifery facilities can help to identify the unreasonable and unbalanced allocation and distribution of obstetric resources and provide a strong scientific basis for re-allocating the obstetric facilities and improving the efficiency of obstetric resources utilization.

In our current study, we investigated the spatial distribution differences between midwifery institutions and urban residents in Wuhan, the capital city of Hubei Province, China, with an attempt to further increase the accessibility to midwifery institutions in Wuhan.

Methods

Research areas

As the capital city of Hubei Province, China, Wuhan city is situated in central China and located between 113°41′–115°05′ E and 29°58′–31°22′ N. It is the only sub-provincial city and mega-city in the central region of China and also one of the core cities of the Yangtze River Economic Belt. The city has 13 municipal districts, with a total area of 8,569.15 square kilometers. It has 90 midwifery institutions. The registered permanent residents in Wuhan was 10.7662 million at the end of 2016 (8). This study uses the administrative map of Wuhan from China Information System for Diseases Control and Prevention and the data of midwifery institutions in Wuhan from monitoring program of "National Project on the Impact of Adjusting and Improving the Reproductive Policy on Maternal and Child Health Services" in 2016.

Locating and measuring

Locating of hospitals

Using the JavaScript API of Baidu Map, we resolved the addresses of 90 midwifery institutions in Wuhan and translated the results into longitude and latitude in Baidu coordinate system, namely the Baidu coordinates. Using the spatial correction toolbar of ArcGIS 10.3, we transformed the offset Baidu coordinates into global positioning system (GPS) coordinates. The spatial correction/transformation method used affine transformation to correct Baidu coordinates based on the position relationship between source control point and target control point. Affine transformation can scale, tilt, rotate and shift data to different degrees. The affine transformation functions are: $x' = Ax + By + C$ and $y' = Dx + Ey + F$, in which x and y are Baidu coordinates and x' and y' are the transformed GPS coordinates. A, B, C, D, E, and F were determined based on the location relationship between source control point and target control point. Affine transformation requires at least three control points. Baidu coordinates of source control points were obtained by using Baidu Map coordinate picker, and GPS coordinates of target control points were obtained on the spot by using GPS equipment.

G2SFCA

The conventional 2-Step Floating Catchment Area (2SFCA) (9) catches a specific area twice based on population demand and health care supply. In our current study, we took the number of obstetricians as the supply and the number of residents as the demand. Also, the population grid of 30″ longitudinal and latitudinal resolution was used as the basic unit of population and the geometric center of the grid as the origin/destination points of residents. First, with the midwifery institution j as the center, all of the population grid k was searched within the threshold range d_0. The ratio (R_j) between obstetricians (S_j) and residents (P_k) within the searched area was calculated, representing the number of obstetricians for every 1,000 residents. The formula is as follows:

$$R_j = \frac{S_j}{\sum_{k\in\{d_{kj}\le d_0\}} P_k / 1000} = \frac{1000 * S_j}{\sum_{k\in\{d_{kj}\le d_0\}} P_k} \quad [1]$$

In which d_{kj} is the linear distance between the midwifery institution j and the population grid k. Second, with the center point (i) of each grid as the center, all the midwifery institutions j within the threshold range d_0 were searched. The results (R_j) were summed, which reflects the convenience of residents in the grid i in seeking obstetric services. The formula is as follows:

$$A_i = \sum_{j\in\{d_{ij}\le d_0\}} R_j = \sum_{j\in\{d_{ij}\le d_0\}} \left(\frac{1000 * S_j}{\sum_{k\in\{d_{kj}\le d_0\}} P_k} \right) \quad [2]$$

In which A_i represents the accessibility of grid i to midwifery institutions. A large A_i value means good accessibility and vice versa.

The Generalized 2SFCA (G2SFCA) (10) was a modification of the conventional 2SFCA. Due to the

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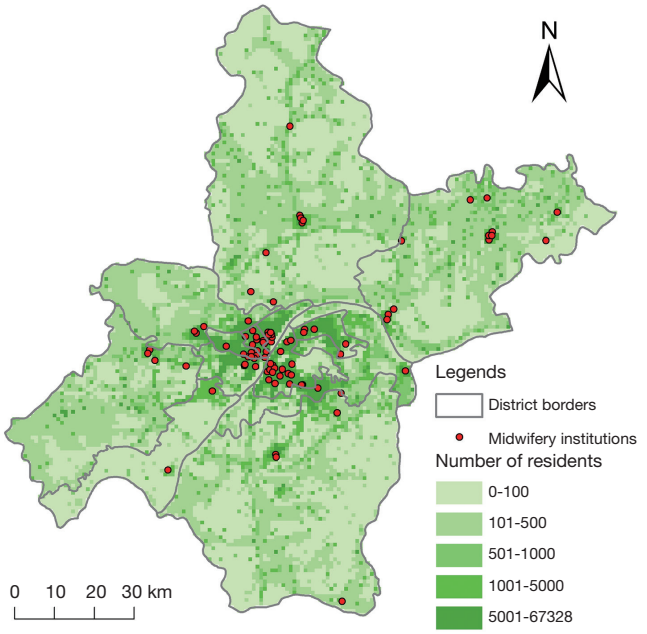

Figure 1 Spatial distribution of population and midwifery institutions in Wuhan.

distance difference within the search radius, a distance attenuation function is added in G2SFCA to accurately describe the characteristics of midwifery accessibility which changes with distance attenuation. The formula is as follows:

$$A_i = \sum_{j\in\{d_{ij}\le d_0\}} \left(\frac{1000 * S_j f(d_{ij})}{\sum_{k\in\{d_{kj}\le d_0\}} P_k f(d_{ij})} \right) \quad [3]$$

In which $f(d)$ is the distance attenuation function. The most common power function was used in this study:

$$f(d) = \begin{cases} d^{-\beta}, & d \le d_0 \\ 0, & d > d_0 \end{cases} \quad [4]$$

When G2SFCA was used to calculate the spatial accessibility, it is critical to choose the right search radius (d_0) and distance attenuation coefficient (β). The values of these two parameters directly affect the calculated accessibility. d_0 reflects the distance threshold of midwifery services, whereas β reflects the attenuation of space with distance. A too small d_0 will lead to inadequate service scope of midwifery institutions, and a too large β will result in the sharp decrease in the utilization rate of midwifery institutions. In our current study, d_0 was set at 20 km (2) and β was set as 1 (11), which were used to calculate the spatial accessibility of grid residents to midwifery institutions. The population-weighted results were summed at the district level, and the accessibility in each district (T_k) was calculated by using the following formula:

$$T_k = \frac{\sum_{i=1\square n_k} P_i * A_i}{\sum_{i=1\square n_k} P_i} \quad [5]$$

in which n_k is the number of grids within the district k.

In our current study, G2SFCA was used to explore the spatial accessibility to midwifery institutions in Wuhan. First, the power function was used as the distance attenuation function to study the spatial accessibility of population grids to midwifery institutions. Then, the spatial accessibility to midwifery institutions in each district was obtained by grid population-weighted overlapping calculation, to explore whether the spatial layout of midwifery institutions was rational. It considered the number of obstetricians, number of residents, and distance attenuation and thus could more effectively reflect the distribution characteristics of midwifery institutions.

Results

Distribution of residents and midwifery institutions in Wuhan

With 30″ grid as a geographical research unit, the population grid of Wuhan in 2016 was processed and calculated. As shown in *Figure 1*, the seven central districts (including Jiang'an District, Jianghan District, Qiaokou District, Hanyang District, Wuchang District, Qingshan District, and Hongshan District) of Wuhan were densely populated, while the six peripheral districts (including Hannan District, Caidian District, Dongxihu District, Huangpi District, Xinzhou District, and Jiangxia Districts) had relatively low population densities, showing a downward trend from the center to the peripheral districts. The distribution of midwifery institutions in Wuhan was consistent with the distribution of population: it was dense in central districts and sparse in peripheral districts.

Distribution of the spatial accessibility to midwifery institutions in Wuhan

ArcGIS 10.3 was used to calculate the spatial accessibility

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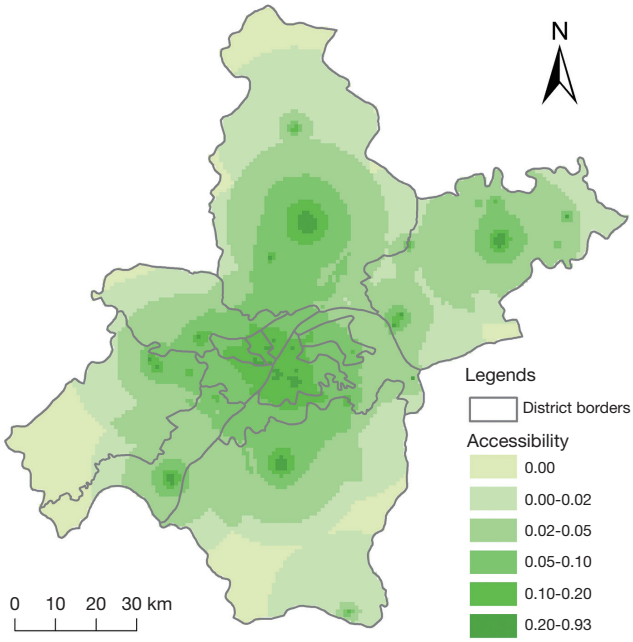

Figure 2 Spatial accessibility of grids to midwifery institutions.

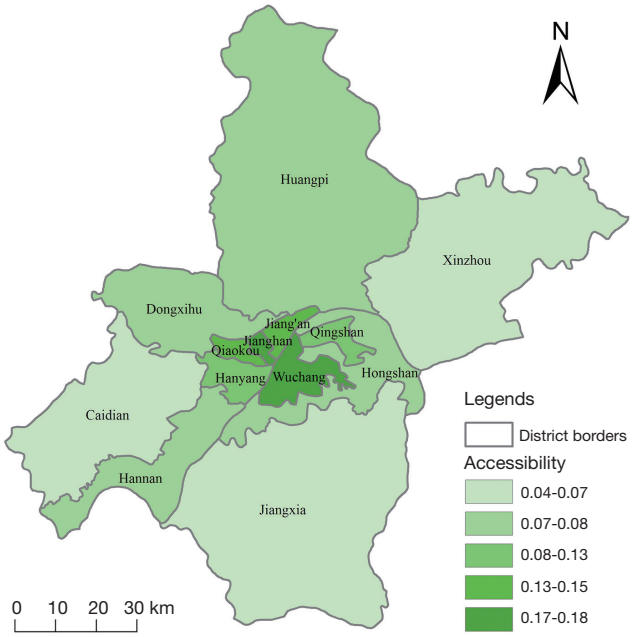

Figure 3 Spatial accessibility to midwifery institutions in different districts.

of midwifery institutions and draw the distribution maps. Firstly, with a midwifery institution as the center, the ratio between the number of obstetricians and the number of grid residents within 20 kilometers was calculated. The distance attenuation coefficient was set as "1", and thus the degree of service shortage of midwifery institution was obtained. Then, with the center point of the grid as the center, the obstetricians/residents ratios within the search area of 20 kilometers were summed to obtain the accessibility of the grid. The distribution of the spatial accessibility from grid population to midwifery institutions is shown in *Figure 2*. A darker color means better accessibility. The central districts had good accessibility; in peripheral districts, only a small number of grids had good accessibility, and most of them had poor accessibility. From the central districts to the surrounding peripheral districts, the accessibility showed a strip-like decline and was zero in a few areas in the peripheral districts. Compared with *Figure 1*, it was found that the accessibility was associated with the layout of midwifery institutions. A shorter distance to a midwifery institution means better accessibility and vice versa.

The accessibility of grids to midwifery institutions was calculated by population-weighted superposition, and the accessibilities of midwifery institutions in different districts of Wuhan were obtained, as shown in *Figure 3*. The accessibility of midwifery institutions was highest in Jianghan District (0.18), followed by Wuchang District (0.17); Jiangxia District (0.06) and Caidian District (0.05) had the lowest accessibilities. Again, the accessibilities were relatively good in the central districts but poor in the peripheral districts. The accessibility to midwifery institutions in each district was remarkably affected by the location of midwifery institutions and the number of obstetricians.

Discussion

By exploring the spatial accessibility to midwifery institutions in Wuhan, we visualized the unbalanced spatial distribution of midwifery institutions, objectively evaluated the convenience of residents in seeking obstetric services, and demonstrated the value of GIS-based G2SFCA in studies on the spatial accessibility to public services.

The 30″ small-scale population data were used in this study to more accurately reflect the population distribution. The searching area moved alongside the 30″ population grids, without being restricted by administrative boundaries. The distance attenuation effect of the interaction between midwifery institutions and residents was also considered. Thus, the differences in the spatial distributions of midwifery institutions and residents' needs in Wuhan were

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analyzed in a more precise way, and the supply-demand relationship and the convenience in seeking obstetric services were evaluated. The accessibility to midwifery institutions showed a decreasing trend from the central areas towards the remote areas: it was good in the central districts and a small number of peripheral districts but was poor in most grids in peripheral districts. In some grids located in the marginal areas, it was even 0.

The spatial accessibilities of population grids to midwifery institutions were summed at the district level to compare the spatial accessibilities of different districts to midwifery institutions. The central districts had densely-located midwifery institutions and had good accessibilities; in contrast, the peripheral districts had sparsely-distributed midwifery institutions and had poor accessibilities. The accessibility to midwifery institutions differed remarkably between central and peripheral districts, suggesting that there is inequity in the allocation of midwifery institutions between central and peripheral districts.

In Wuhan, the occupancy rate of beds is high in central districts but low in peripheral districts (12). Thus, the number of midwifery institutions or obstetricians should be increased in peripheral districts to meet the needs of midwifery services in these areas. Meanwhile, it helps to alleviate the workload of midwifery institutions in central districts, increase the utilization rate of obstetric resources in peripheral districts, and better reflect health equity.

This research provides a scientific basis for the planning and allocation of midwifery institutions in Wuhan and is also valuable for research on the accessibility to other medical resources and social service resources. However, it still had some limitations. First, the number of obstetricians and travel distance were used as factors affecting the selection of midwifery institutions. The distance between supply and demand was based on the linear distance between a midwifery institution and a population grid, which had certain limitations. In the real world, the selection of a midwifery institution by residents is related to many factors such as the size of midwifery institutions, obstetric facilities, and doctor's professional title, which were not considered in our current study. Also, travel time, travel cost, or psychological distance can more accurately reflect travel distance barriers. Therefore, the accessibilities calculated in our current study might have some errors. Furthermore, the effects of social factors such as the proportion of pregnant women in the population, income, and insurance on the demand of midwifery institutions were not taken into account in this study. In our future studies, more accurate demographic and road network information will be added to improve the accuracy of research results.

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Footnote

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at http://dx.doi.org/10.21037/jphe.2019.04.02). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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